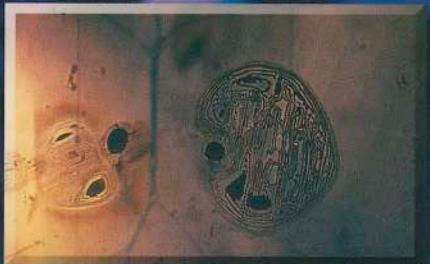
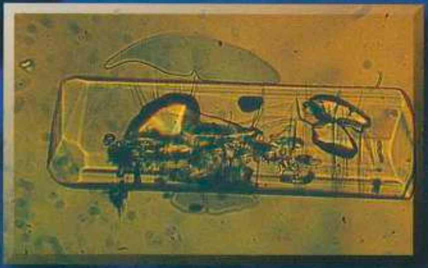
The Journal of Gemmology

Volume 25 No. 6

April 1997





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Vol 25, No. 6, Feb 1997 ISSN: 1355-4565

The identity of reddish-brown inclusions in a new type of Russian hydrothermal synthetic emerald

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ABSTRACT: Transparent reddish-brown platelets in recently produced Russian hydrothermal synthetic emerald were determined as iron oxides with distinct contents of chromium, titanium and nickel.

A new type of Russian hydrothermal synthetic emerald was recently described by Koivula *et al.* (1996). The main difference between the growth methods previously used to grow emeralds (see Schmetzer, 1988) and the most recent type of Russian hydrothermal synthetic emerald is the orientation of the seed (Schmetzer, 1996); chemical and spectroscopic properties of both types of synthetic emerald were found to be more or less identical.

In addition to opaque hexagonal platelets, which were already known as inclusions in the older type of Russian hydrothermal synthetic emerald (Schmetzer, 1988; Sosso and Piacenza, 1995) and thought to be hematite, tiny reddish-brown platelets were mentioned as typical in the new synthetic emerald. These characteristic inclusions were present in all eight faceted samples which were examined by Koivula *et al.* (1996). The nature of these inclusions, however, remained undetermined (see also Scarratt, 1994).

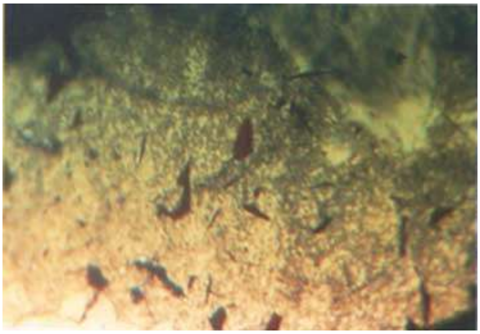

***Figure 1:** Reddish-brown transparent platelets in Russian hydrothermal synthetic emerald. Immersion, 50x.*

One of the rough synthetic emerald crystals of the new type was found to contain transparent reddish-brown inclusions (Schmetzer, 1996). These were developed as thin, more or less irregularly shaped, somewhat corroded platelets *(Figure 1)*. This particular emerald sample was cut and polished in a direction to enable exposure at the surface of several of the reddish-brown inclusions. The examination of these platelets by electron microprobe revealed that they were iron oxides with distinct chromium, nickel and titanium contents and a small amount of manganese *(Figure 2)*. The thickness of the transparent reddish-brown platelets was found to be 2µm or less and, according to their morphology and colour, are also most probably hematite.

The opaque hexagonal platelets in the older type of Russian hydrothermal synthetic emerald display a metallic lustre in reflected light and are composed of iron oxides with

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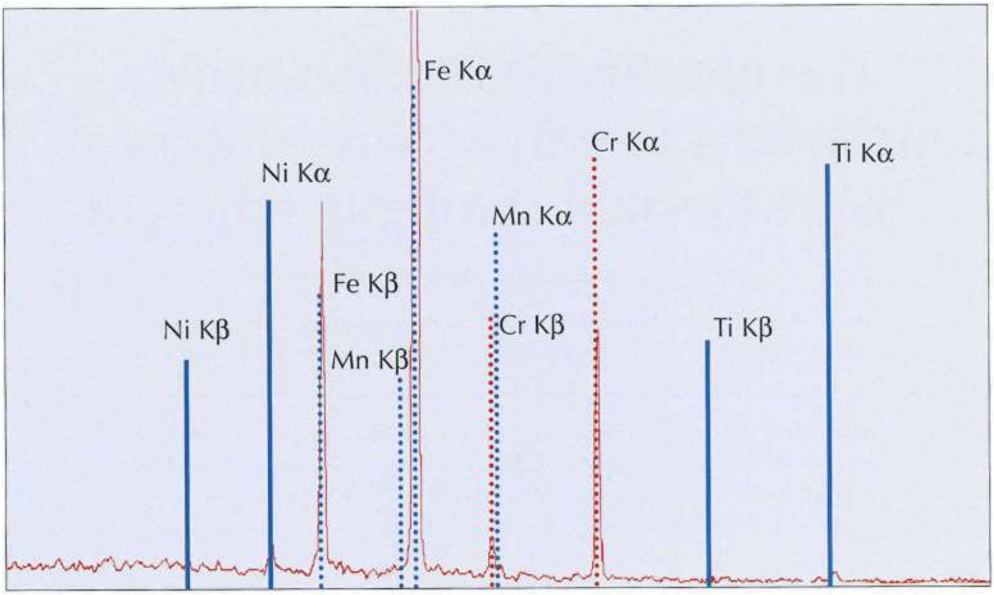

Figure 2: *Wavelength-dispersive spectrum typical of reddish-brown inclusions in Russian hydrothermal synthetic emerald, using LiF as diffracting crystal.*

distinct chromium and titanium contents (Sosso and Piacenza, 1995) or iron oxides with distinct amounts of chromium, titanium and nickel (Hänni, 1996). However, the thickness of the opaque hematite platelets is in the range of 10 to 20μm (Hänni, 1996).

Thus, since they are chemically similar, the only major difference found between the transparent reddish-brown and the opaque iron oxides lies in the thickness of the platelets. Their different appearance under the gemmological microscope is understandable in the light of this result: hematite platelets with a thickness of 2μm or less are transparent reddish-brown and platelets of 10 to 20μm in thickness appear opaque in transmitted light.

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A note on a new occurrence of vanadian grossular garnet from Madagascar

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ABSTRACT: A new occurrence of vanadian grossular garnet from Madagascar is described. Its composition is similar to grossulars from E. Africa and Pakistan and its bright green colour is attributed mainly to vanadium.

Vanadian grossular garnet of gem-quality (tsavorite) is known from East Africa (Kenya, Tanzania; Bridges, 1974) and, to a lesser extent, from Pakistan (Jackson, 1992). A new deposit was discovered at the end of 1991 in the Gogogogo area of south-western Madagascar, about 40 km north of Ampanihy *(Figure 1)* and is being mined by the Delorme Mining Company.

The Malagasy deposit lies in graphitic gneisses associated with marbles within the Precambrian granulitic Vohibory Group. The grossular occurs as porphyroblasts, sometimes idiomorphic, up to several centimetres across, usually fractured, and displays hues ranging from a pale yellowish-green to a dark green. It is surrounded by an assemblage including plagioclase (anorthite), diopside, quartz, graphite and sphene, minerals which may be partially or totally enclosed in the garnet along its borders. This assemblage is more or less replaced by serpentine in the most retrogressively metamorphosed gneiss samples.

Figure 1: *The Gogogogo tsavorite occurrence in Madagascar.*

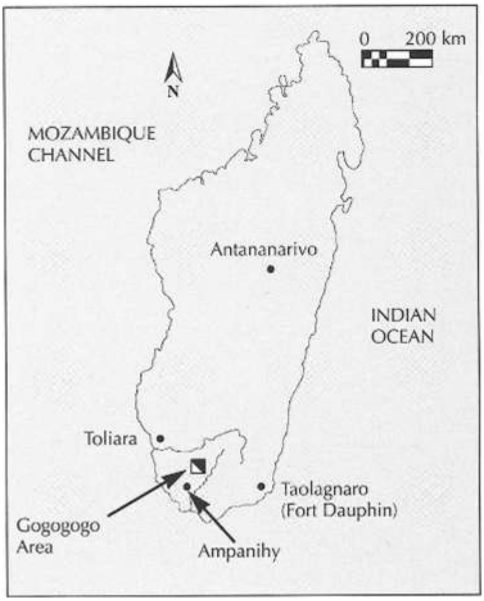

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Figure 2: *Tsavorite rough from Gogogogo, Madagascar; the largest piece is 28 mm long.*

Table I: *Composition of vanadian grossular garnet*

Location	*Madagascar (Gogogogo)*	*Kenya (Lualeni)*[1]	*Kenya (Lualeni)*	*Tanzania (Komolo)*	*Pakistan (Swat)*
RI	1.742	1.743	-	-	1.743
SG	3.62	3.61	-	-	3.64
Wt%	(a)	(b)	(c)	(d)	(e)
SiO_2	39.15	38.70	39.26	42.50	38.17
TiO_2	0.39	0.25	0.43	0.30	0.44
Al_2O_3	20.13	20.90	21.28	20.50	18.51
Cr_2O_3	*	0.19	**	0.12	0.00
V_2O_3	2.50	3.30	1.71	1.20	4.52
FeO	0.07	0.05	0.10†	0.10	0.05†
MnO	0.72	0.75	0.74	0.50	0.30
MgO	0.50	0.50	0.50	0.30	0.10
CaO	36.37	35.10	36.12	34.50	36.62
Total	99.83	99.74	100.14	100.02	98.71
Proportions of garnet group end members					
Grossular	0.91	0.90	0.93	0.95	0.91
Goldmanite	0.05	0.06	0.03	0.02	0.08
Uvarovite	0.01	0.00	0.00	0.00	0.00
Andradite	-	-	0.00	-	0.00
Almandine	0.00	0.00	-	0.00	-
Pyrope	0.02	0.02	0.02	0.01	0.00
Spessartine	0.01	0.02	0.02	0.01	0.01

*Cr_2O_3 ~ 0.3; **Cr_2O_3 < 0.05; †as Fe_2O_3
(a) Average of 6 analyses, (b) From Gübelin and Weibel (1975), (c) Average analysis from Key and Hill (1989), (d) From Muije *et al.* (1979), (e) Average analysis from Jackson (1992)

[1] Which has also occurred in the gemmological literature spelled Lualenyi

Some physical and chemical properties have been determined for a relatively dark green specimen of garnet 28 mm in length (largest piece in *Figure 2*). The results are given in *Table I* with comparable data from the literature. With a refractive index of 1.742 and a specific gravity of 3.62, the garnet examined has physical characteristics similar to those measured for specimens from Kenya, Tanzania (Gübelin and Weibel, 1975; Manson and Stockton, 1982) and Pakistan (Jackson, 1992).

Chemically also it is comparable to the green garnets from East Africa, in particular Kenyan, and Pakistani deposits. The main colouring agent is vanadium. In *Table I* we have not reported the Cr_2O_3 content of our sample because, with the overlap of $VK\beta$ on $CrK\alpha$, it is difficult to determine Cr content accurately. Nevertheless, after correction the Cr_2O_3 concentration is estimated at 0.3%, and it is noteworthy that even with this value the chromium would have a significant effect on the green coloration of the grossular (Manson and Stockton, 1982).

Though still very limited, the first data reported in this note already show that many similarities exist between the tsavorite examined from Gogogogo and samples from the better known deposits of Kenya and Tanzania. This provides yet another geological link between the island of Madagascar and this portion of East Africa, and a fuller study of the green grossular garnets is in progress.

Acknowledgements

We thank F. Fontan, P. Monchoux and L. Roux for their willing and constructive help and Ph. De Parseval for the microprobe facility.

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A Raman microscope in the gemmological laboratory: first experiences of application

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ABSTRACT: Various applications of Raman spectroscopy in a gemmological laboratory are discussed with examples. The major advantage of this system over classical methods of gem testing is the non-destructive identification of inclusions in gemstones and the determination of organic fracture fillings in emeralds. Also, quick and precise identification of gemstones unmounted or in jewellery, as well as the non-destructive analysis of archaeological samples are possible. Due to the high resolution of the instrument, several phases in a gemstone can be identified. Limitations of the Raman microprobe are also listed.

Keywords: Raman spectroscopy, inclusions, gemstone identification, fissure fillings, archeometry

Introduction

The Raman effect was discovered by the Indian physicist Sir C.V. Raman at the beginning of this century. He observed that molecules which were hit by a monochromatic light beam scattered the light and produced spectra which were characteristic for different materials. Although Raman spectroscopy has so far not been widely known in the study of gemstones, it was introduced as an analytical tool for minerals a long time ago. Raman spectroscopy is also well established in other areas of application, such as physical chemistry, materials science, and superconductor and semiconductor physics.

Raman spectrometers have traditionally been large and very expensive instruments, but recent technical developments have revolutionized this technique. The traditional, rather insensitive instruments can be replaced by modern, compact, highly sensitive, easy-to-use and flexible instruments, more suited to the gemmological laboratory (see, for example, Williams *et al.*, 1994). A typical instrument consists of a classical microscope with either transmitted or reflected light, a low-power laser excitation source, the spectrometer for high resolution light analysis and an appropriate computer for data collection and analysis. The total system fits easily on a desk top *(Figure 1)*. For these reasons, Raman microscopes are gradually becoming more widespread in gemmological laboratories around the world, among them the University of Science and Technology in Nantes, AIGS Bangkok, and CISGEM Milan.

The Raman microscope presents the gemmologist with a unique combination of

ISSN: 1355-4565

properties which make it a useful additional technique in tackling gemmological problems. These properties include a high spatial resolution, as low as one micrometre, allowing the highly accurate positioning of the microscope to study inclusions as small as one micrometre. With a high-power objective and spatial light filtering in the spectrometer, the system can be 'confocal', allowing the operator to construct profiles of layered compounds or inclusions inside gemstones, with minimal contribution from the main bulk species. In addition, the analysis is rapid, requires no sample preparation and, most importantly, is non-destructive.

The Raman microscope can thus provide spectra typical of the analysed materials. These spectra can be identified by comparison with known spectra, which means that a large set of reference spectra is an important condition for the successful use of the method.

The following references are generally recommended for understanding the method (McMillan and Hofmeister, 1988; McMillan, 1989); for its mineralogical (Griffin, 1987; Smith, 1987; Malézieux, 1990) and for its gemmological applications (Dhamelincourt and Schubnel, 1977; Delé-Dubois *et al.*, 1980; Delé-Dubois *et al.*, 1981; Delé-Dubois and Merlin, 1986; Pinet *et al.*, 1992; Schubnel, 1992; Lasnier, 1995) should be consulted.

Experimental and technical background

Most gemmologists are familiar with visible spectroscopy, i.e. from an incident broad band white light source, characteristic wavelengths or energies are absorbed by chromophore elements such as chromium in ruby. Fewer are familiar with emission spectroscopy and its application, for example, in X-ray fluorescence. Here the incident energy excites electrons in the substrate, which then decay back to the ground state, *emitting* distinct wavelengths of light, allowing the identification of chemical elements in the substrate (Stern and Hänni, 1982; Hänni, 1993).

The Raman effect is, in contrast, a scattering technique in which a monochromatic light source is used (usually a visible laser). Whilst most of the light is simply scattered and contains no useful information (the so-called Rayleigh or elastic scattering), a small amount, typically one photon in 10^6–10^8, is re-emitted having lost some energy. This shifted or Stokes radiation appears as lines in a spectrum characteristic for the substance under study. Most materials that the gemmologist or mineralogist will encounter have a typical Raman spectrum, serving as a 'fingerprint' for that type of material. The only major subset of materials that cannot be studied are metals and alloys. In addition, subtle changes within one material such as alterations in crystallinity and composition can often be detected.

Figure 1: *A Renishaw Raman microscope installed on a laboratory table at SSEF. The laser source is situated behind the spectrometer body.*

The Raman studies presented here were performed using a Renishaw Raman System 1000 equipped with a Peltier cooled CCD detector, together with a 25 mW air-cooled argon ion laser (Omnichrome) lasing at 514 nm *(Figure 1)*. The laser light was focused on to the sample and the scattering collected with an Olympus BH series microscope equipped with x10, x20 and x50 MSPlan objectives.

Using the 'extended scanning' facility, a complete spectrum from 100 up to 9000 cm^{-1} could be measured with a resolution of

Table I: Section of a Swiss Gemmological Institute search file for minerals with Raman peaks in order of the peak intensities. Line 101 shows the figures related to the mineral bustamite (peaks measured in cm^{-1})

	Colour	*Group*	*Mineral*	*1st Peak*	*2nd Peak*	*3rd Peak*	*4th Peak*	*5th Peak*	*Reference*	*Notes*
95			Brochantite	971.4	1074.5	594.3	480.7	386.5	SSEF	TSUMEB
96			Brookite	149.9					JNBM	USA p.222/514.5 nm 209.4s
97			Brookite	150.0	319.0				Schubnel	
98	Brownish-red		Brookite G	150.0	125.0	244.0	319.0	636.0	Maestrati	
99	Brownish-red		Brookite M	150.0	129.0	321.0	634.0		Maestrati	
100	Brownish-red		Brookite P	150.0	637.0	320.0	500.0	365.0	Maestrati	
101	Pinkish-brown		Bustamite	974.2	644.0	1036.5	315.1	405.4	SSEF	Franklin N.J. NMBS
102		Calcite	Calcite	1083.1	278.2	709.1	151.4	1433.1	JNBM	Mexico p.207/514.5 nm 19.9s
103		Calcite	Calcite	1084.0	279.0	709.0	152.0	1435.0	SSEF	Rough CH-Gonzen
104		Calcite	Calcite	1085.2	279.6				SSEF	3.05 ct

2 cm^{-1}. This allowed not just Raman measurements, but also simultaneous Raman and luminescence studies to be performed between 520 and 1000 nm. A standard PC computer with GRAMS/386™ software was used to collect and store the Raman spectra, as well as allowing data analysis, presentation and the ability to compare the collected data with reference spectra stored in a library in the memory.

Reference spectra

The identification of a mineral by Raman spectroscopy is a comparative method. Only in some rare cases is it possible to calculate and predict the peak positions of a given substance. Therefore the necessity of a collection or data base of reference spectra is extremely important. In the recent past some mineral data aimed at creating a comparison file have been published by the French scientists Maestrati (1989) Pinet *et al.* (1992), and Schubnel (1992). Renishaw is presently compiling a more comprehensive data base consisting of spectra supplied by the various users of their system. Meanwhile, the SSEF has developed its own preliminary data-base system with over 500 spectra from more than 200 different minerals using existing data and adding its own analyses. The reference samples analysed in the SSEF not only came mainly from the gemstone collection of one of the authors (HAH) but also from the Museum of Natural History in Basel (NMBS) and from other reliable collections. *Table I* shows an excerpt from the present SSEF search file. The spectra are not only in alphabetical order but also in order of the peaks, so that an unknown mineral can be identified by comparing the major peaks.

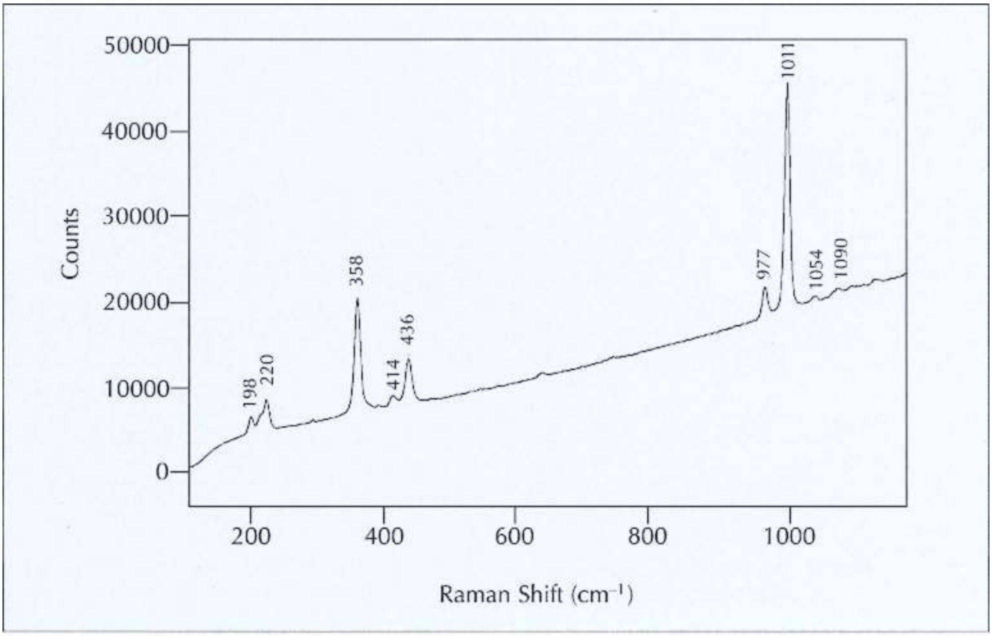
Examples of application

Solid inclusions in gemstones are an important indicator of the nature of a stone and may, additionally, be a characteristic feature of a particular origin. The identification of inclusions has been used frequently, among other methods, to determine the authenticity or origin of a stone. However, until recently the identification could in practical terms only be carried out when the inclusion reached the surface of the stone. Analysis of inclusions not reaching the surface is possible down to a depth of 5 mm, but best results are obtained when the inclusion is close to the surface of the stone. *Figure 2a* shows zircon clusters in a sapphire from Burma; *Figure 2b* shows the Raman spectrum of one of these inclusions, which was easily identified using the search file. An invaluable feature of Raman spectroscopy is that the analysis of solid inclusions can be carried out without damage to the gemstone.

The study of *fluid inclusions* in gemstones is of importance for the determination of the true identity of crystals. The phase transitions of fluids, i.e. the determination of the freezing and melting point of fluid inclusions, can be controlled under a microscope with a cooling/heating stage. This method, commonly applied with thin sections is called microthermometry. Peretti *et al.* (1990) have modelled the pressure oscillation during the formation of Kashmir sapphires using this method. Bruder (1995) has investigated fluid inclusions in sapphires and rubies from different origins. He found that primary and pseudo-secondary fluids in sapphires consist of pure CO_2. During his investigations on ruby samples, Bruder found characteristic differences among the compositions and densities of the fluids. He found indications that fluids in rubies from some marble deposits (e.g. in Pakistan and Afghanistan) contain impure CO_2, the admixture most probably being H_2S. Such a mixture gives a characteristic Raman peak at 2011 cm^{-1} and is of importance for the origin determination of unheated rubies. Dubessy *et al.* (1989) have developed a

Figure 2a: *Zircon clusters in a sapphire from Burma, magnification 50x.*

Figure 2b: *Raman spectrum of zircon in a sapphire from Burma. The major peaks from zircon are at 1011, 358 and 436 cm^{-1}. The peak at 414 cm^{-1} belongs to sapphire.*



method of identification of mixed fluids using a program which quantitatively describes the composition of the fluids.

A *three-phase inclusion* in a sapphire from Andranondambo (south Madagascar) was an excellent candidate to evaluate the analytical possibilities with the Renishaw system (Kiefert *et al.*, 1996). *Figure 3a* shows a flat cavity in a tabular sapphire from Andranondambo. The microscope inspection revealed a gas bubble surrounded by a liquid phase containing bent fibrous crystals. The laser beam was directed on to these inclusions and the system produced the Raman spectra shown in *Figure 3b* which identifies corundum as the host, CO_2 and diaspore as inclusions.

The presence of carbon dioxide in fluids in corundum has been reported earlier (Koivula, 1980; Schmetzer and Medenbach, 1988; Bruder, 1995); its identification by Raman spectroscopy, however, is more straightforward than by microthermometry. The presence of a solid phase in CO_2 such as graphite or diaspore has been published in gemmological literature by Schmetzer and Medenbach (1988). Graphite was also identified by Raman spectroscopy in a three-phase inclusion in a sapphire from Sri Lanka.

Figure 3a: *Three-phase inclusion in sapphire from Madagascar oriented parallel to the basal plane and showing liquid and gaseous* CO_2 *and diaspore needles. View parallel to the c-axis, magnification 50x.*

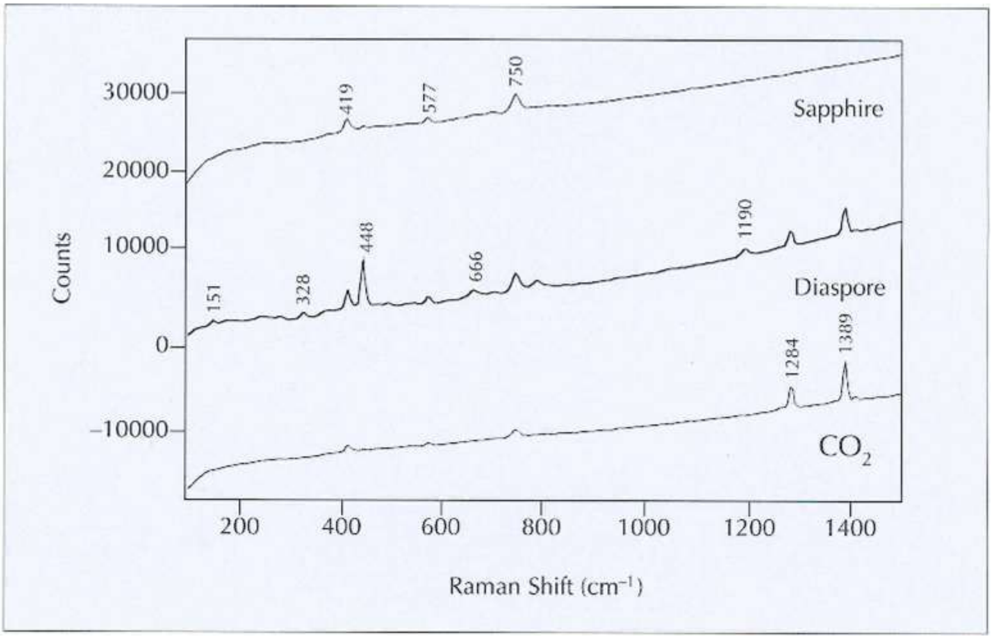


Figure 3b: *Raman spectrum showing the different phases of a three-phase inclusion in sapphire from Madagascar. The labelled peaks are assigned to corundum (top), diaspore (middle) and* CO_2 *(bottom).*

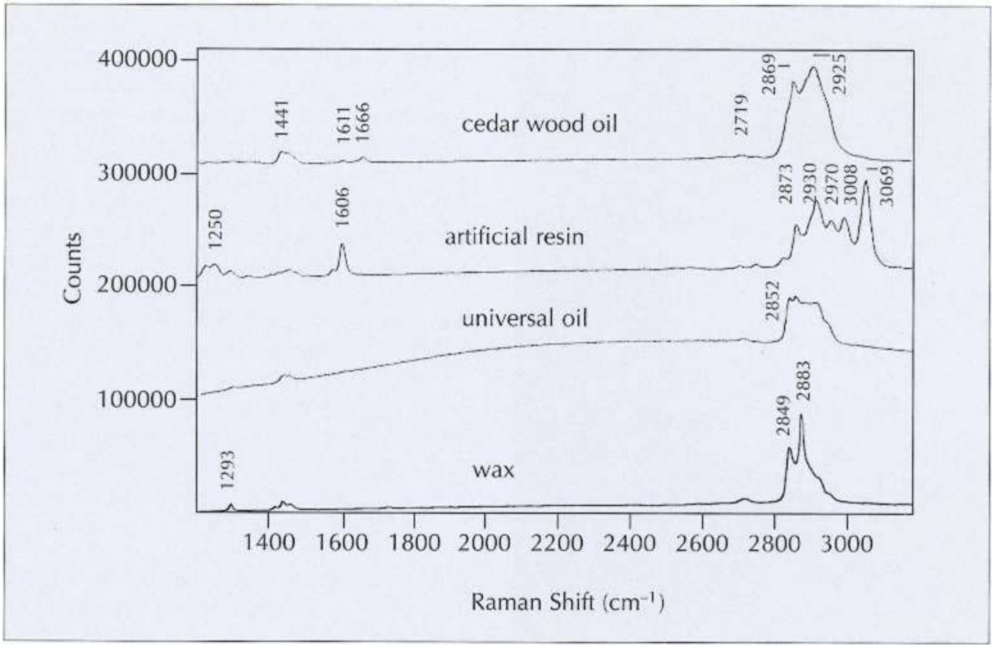
When produced by a flux technique synthetic stones may be identified by Raman spectroscopy by characteristic spectra from their included flux particles. A flux inclusion trapped in Chatham synthetic emerald produces its major Raman peaks at 221 and 570 cm^{-1}, while flux in a Douros synthetic ruby shows Raman peaks at 133, 824 and 850 cm^{-1}.

Organic fracture fillers in emerald frequently need to be identified for test reports. It is quite rare that an emerald is free of fractures and hence free of foreign material in fissures (Hänni, 1992). Organic substances such as oils and natural resins have been used for centuries as fissure fillers to enhance the clarity of emeralds. The organic substances have a refractive index close to that of emeralds and considerably reduce the reflection of fractures filled with air. The range of fillers encompasses numerous substances such as vegetable and mineral oils with volatile components, and more durable fillers like fats and resins (Hänni, 1992).

Nowadays, synthetic resins are used more frequently (Themelis, 1990) because they adhere more permanently to the stone than oils, and may not be released as easily due to their low solubility in detergents and solvents. However, the gem trade is sceptical about these synthetic resins for several reasons. One reason is that the use of artificial resins is relatively new and little is known about how they may alter with time.

The Raman microprobe enables a distinction between natural and artificial resins because of their different molecular structures. The Raman peaks for natural and artificial resin lie in two different parts of the spectrum, the first within the area between 2800 and 3100 cm^{-1}, a second area of characteristic but weaker peaks lies between 1200 and 1700 cm^{-1}. *Figure 4a* shows the Raman spectra of four different substances commonly used for filling fractures in emeralds. Peaks at 1250, 1606, 3008 and 3069 cm^{-1} are strong in artificial resins, but are absent or only very weak in natural resins and oils. Other differences lie within the intensities of certain peaks.

Figure 4a: *Raman spectra of organic substances commonly used to fill fractures in emeralds. The spectrum of the artificial resin, often referred to as 'opticon' in the trade, shows distinct differences from the other substances.*



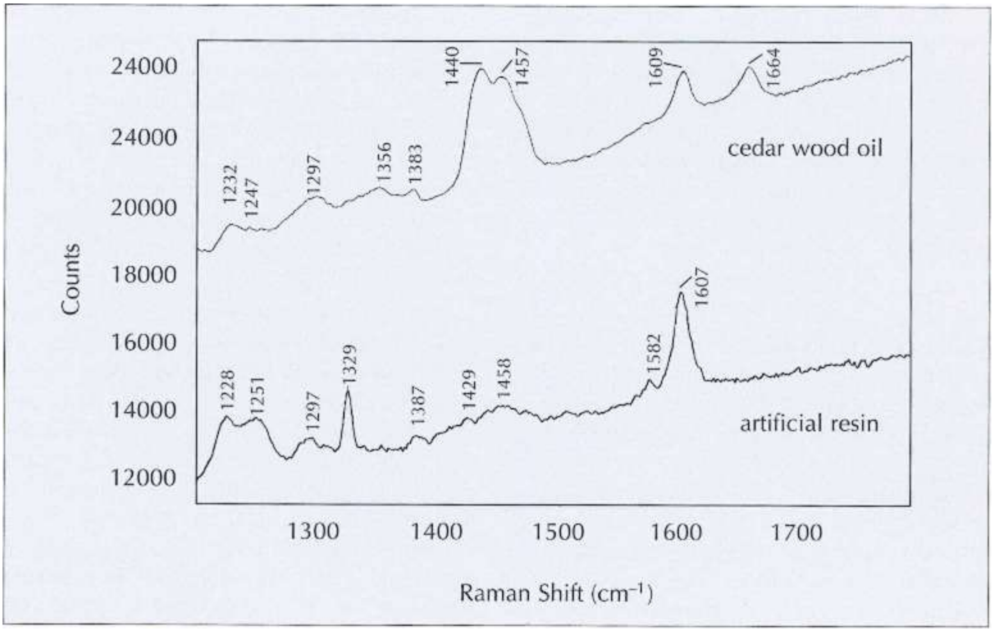


Figure 4b: *Raman spectra of two substances identified in fractures in emeralds.*

Figure 5a: *A watch with moving diamonds under a sapphire cover. By Raman microscopy it is possible to record the Raman line of diamond through the watch glass.*

After such resins have been introduced into emeralds, they may undergo alteration with time. Depending on the degree of alteration, the substance may display an increase in fluorescence which is superimposed on the Raman spectrum of fresh substances, especially in the 2800–3100 cm^{-1} area, so that the peaks in this area may hardly be visible. The 1200–1700 cm^{-1} area is less affected by this fluorescence, so that in some instances the peaks in this area are more useful for identification purposes. *Figure 4b* shows the Raman spectra of two fissure fillers detected in emeralds. The top spectrum shows a natural resin with strong 1440 and 1457 cm^{-1} peaks and an additional peak at 1664 cm^{-1} (*see also Figure 4a*). In comparison, the artificial resin has much higher peak intensities at 1251 cm^{-1} and 1607 cm^{-1}, but much lower intensities in the 1450 cm^{-1} area *(see also Figure 4a)*. Hence, in this and in many other cases, the determination of the type of filler in an emerald fissure is possible.

The identification of diamond is most easily done with a thermal probe (thermotester) where direct contact between the instrument

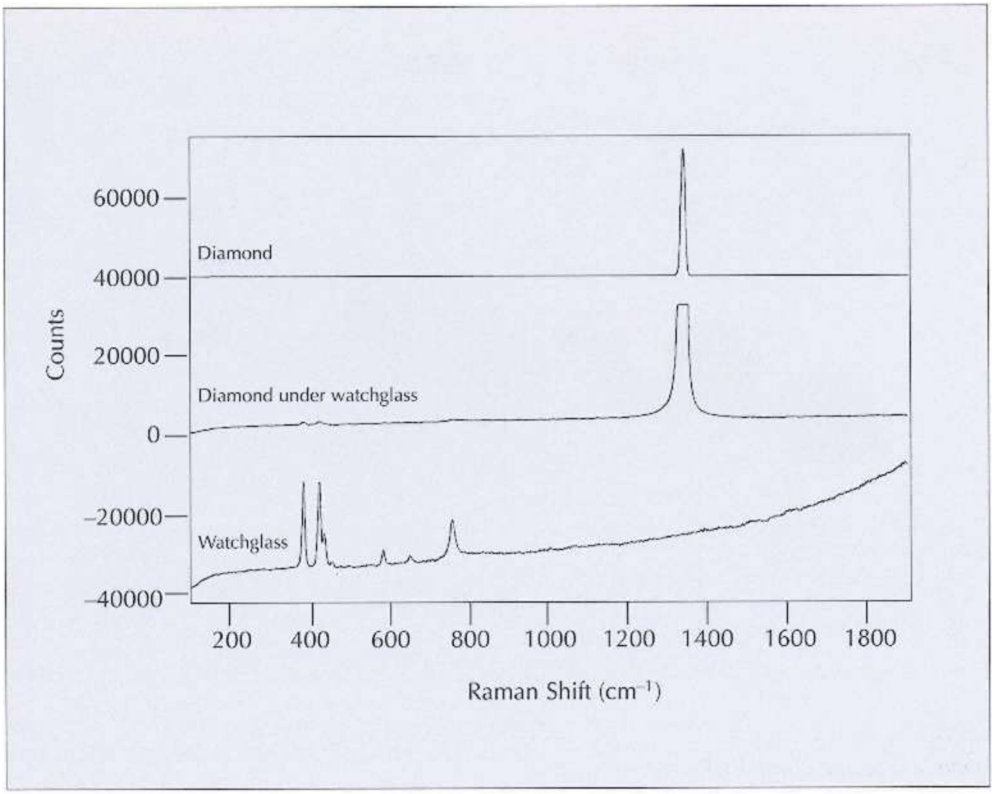


Figure 5b: *Raman spectrum of a diamond under a sapphire watch glass with the comparison spectra of pure diamond and the watch glass.*

and stone can be made. It would seem difficult if not impossible, however, to identify the nature of stones which look like diamond if they are set in a clock face under the watchglass *(Figure 5a).* With a Raman microscope it is sufficient to focus the laser beam down through the 'glass' and on the supposed diamonds. The resulting Raman spectrum recorded is a combined spectrum of the 'glass' material and the diamond. The sample diagram in *Figure 5b* shows the Raman characteristics of diamond with corundum (as 'glass cover').

A mixed lot of Burmese cut gemstones (kindly donated by Professor Dr E. Gübelin) was mounted table-up with Blu-Tack on a slide *(Figure 6a).* The Raman spectra were subsequently recorded and the results compared with reference spectra at first selected as the most likely match. Where this did not lead to a satisfactory match of spectral pattern, i.e. identification, the 'strongest peak' table of our search file was taken as a reference. This way the stones could be identified within a very short time. *Figure 6b* shows spectra of seven identified gemstones. Identification by Raman spectroscopy can also be recommended for rough stones, especially when no characteristic visible absorption spectrum can be obtained or expected.

Identification of mounted gemstones set in jewellery may turn out to be difficult when the setting prevents direct contact of a stone with the refractometer. Pieces of jewellery with historical value, e.g. from museum collections, are in many cases adorned with gemstones. However, it is rather rare that such items have undergone gemmological investigations, mainly because until recently hardness testing was still a recognized gemmological technique

Figure 6a: *Seven Burmese stones fixed with Blu-tack on a glass slide and ready for the microscope sample stage. They are from left to right: peridot, diopside, spinel, amethyst, tourmaline, scapolite and datolite.*

Figure 6b: *Raman spectra of the seven Burmese gemstones.*

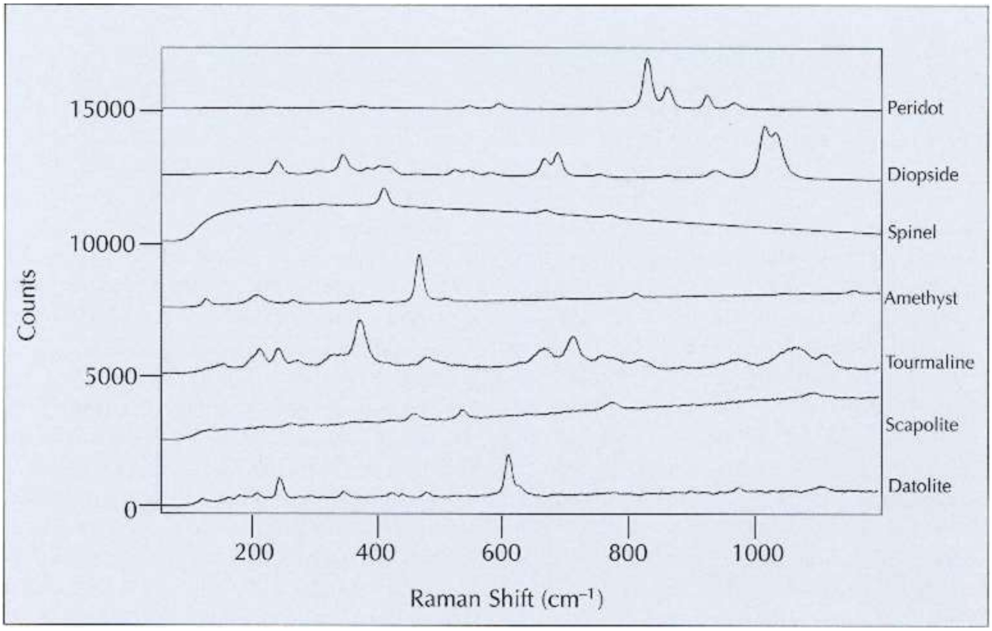


Figure 7: *A bar brooch with a red garnet being analysed on the microscope sample stage.*

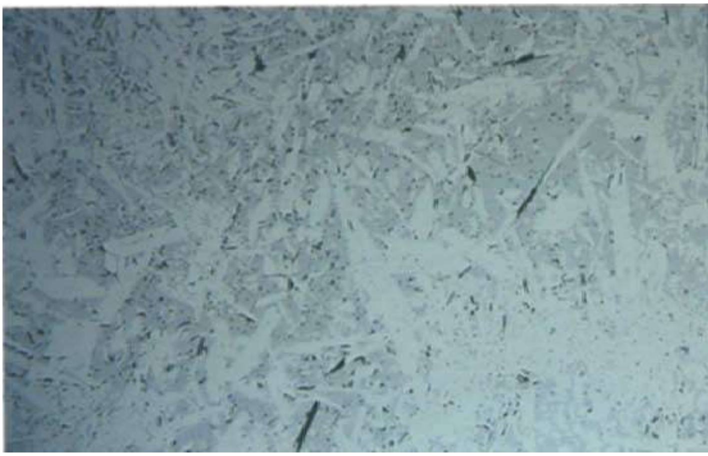


Figure 8a: *A dark violet jade cabochon revealed its complex nature under the Olympus BH microscope used in reflected light mode. The darker mineral groundmass was found to be albite feldspar, the lighter crystals are jadeite, magnification 50x.*

Figure 8b: *Raman spectra of jadeite and albite reference material compared with spectra obtained from the two phases in the violet cabochon.*

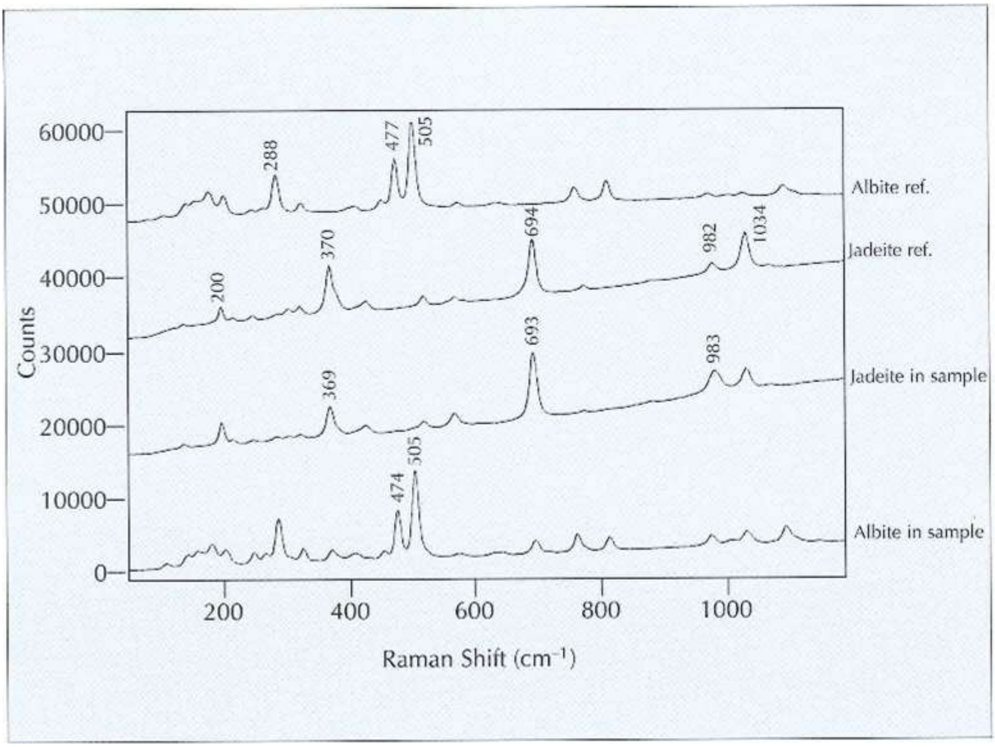


Figure 9: *This prehistoric small axe head (46 mm in length) gave Raman lines of tremolite-actinolite.*

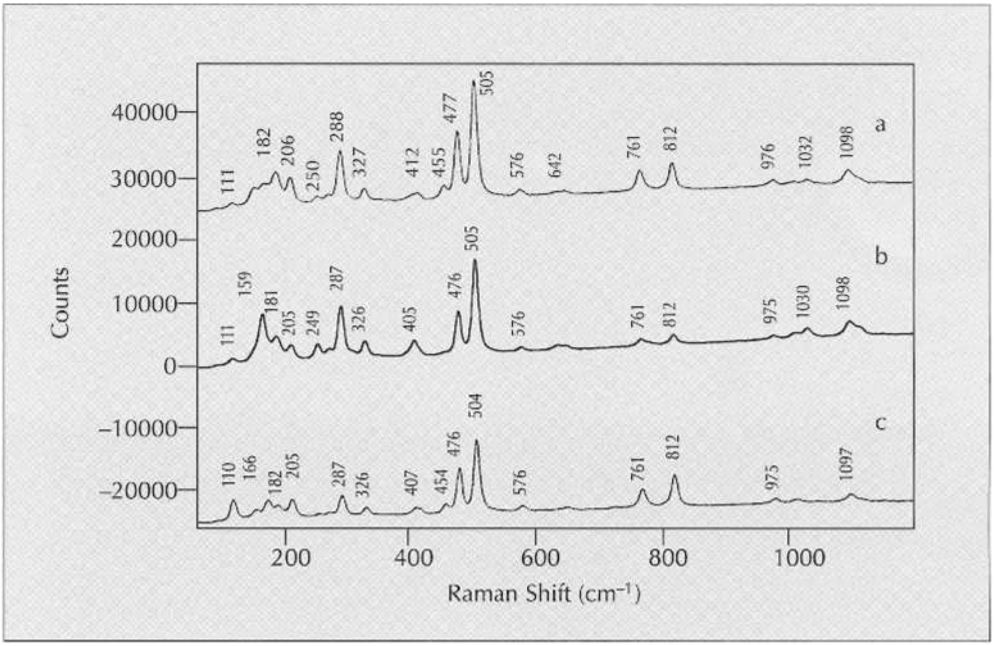
by too many 'identifiers'. Raman spectroscopy now offers an entirely non-destructive means of identification which does not even require mechanical contact between the gem and the analytical tool. This opportunity will hopefully lead to more investigations of museum jewellery (Superchi, 1995).

The brooch shown in *Figure 7* contains a red stone which was easily identified as a garnet from its Raman spectrum, and the optical absorption spectrum confirmed the result.

A violet cabochon was purchased in Mae Sot (Thailand), a market-place for Burmese gemstones. The dark violet colour and the strange structure observed under the microscope first indicated an opaque artificial glass, but a reflected-light image indicated two phases in the material *(Figure 8a).* Needle-like crystals were recognized and quickly identified as jadeite in a groundmass of lower lustre which was found to be plagioclase feldspar. The closest match in our data base of Raman spectra was found to be that of albite. The spectra of the two components of the gemstone are presented in *Figure 8b* together with the two related reference spectra of jadeite and albite.

Bustamite, a rare gem material, is difficult to identify safely with traditional gemmological means, especially when it has a composite polycrystalline nature and is cut as a cabochon. The values of SG (3.43) and RI (1.67 spot reading) are not conclusive. For the identification of this piece we were also considering the possibility of

Figure 10: *Three Raman spectra of an albite crystal, taken in three directions perpendicular to each other. The directional recording of spectra shows anisotropy with respect to the peak heights, but not the peak positions.*



friedelite, another manganese silicate mineral. The Raman spectrum, however, when compared to a bustamite reference (collection of NMBS) allows instant identification. The bustamite reference file, with its major peaks, is shown in line 101 of *Table I*.

A prehistoric axe head (Figure 9) fashioned from an unknown fibrous whitish material was tested for the Laboratory of Prehistoric History of Basel University. Also, for archaeological material, a non-destructive identification technique is a requirement. The spectrum obtained was immediately recognized as a mineral of the amphibole group, the closest fit being with tremolite. In gemmological circles, massive tremolite-actinolite rock is often referred to as nephrite, and is a well known material used to make Stone Age tools. Nephrites are usually greenish due to their iron content (or portion of actinolite in solid solution), but the present sample has a composition close to the iron-free end of the series, i.e. tremolite.

Limitations

Although the cited literature and examples described above prove the importance and usefulness of Raman spectroscopy to gemmology and associated sciences, the method also has some limitations.

The only major subset of materials that do not yield usable Raman spectra are substances such as metals and alloys, characterized by a simple composition and a high symmetry.

Anisotropic minerals produce Raman spectra which can be very different depending on the relative orientation of the laser and the crystal lattice. Fortunately the wave-number position of the peaks is the same in the spectra obtained from every direction. It is only the relative intensity which may vary with the direction. Therefore, when using a data base for spectral comparison which is based on wavelengths of the strongest peaks, one must bear in mind that the sequence from strongest to weakest may change with orientation. An example of small directional differences among Raman spectra in the x-, y- and z-directions of an albite crystal is shown in *Figure 10*. Other minerals, such as phyllosilicates, may show significantly stronger directional differences in their spectra.

We have already remarked upon the general difficulties in getting useful Raman spectra from dense mineral aggregates such as turquoise, howlite, mother-of-pearl, etc. The spectra of such materials suffer from a high contribution of fluorescence radiation, although in some situations the fluorescence can be reduced by reducing the laser power and increasing the measuring time. This could result in a better peak/background ratio.

Although Raman microprobe investigations of gems are generally non-destructive, accidents may still happen with a small number of thermally unstable minerals (e.g. pyrargyrite, hydrated arsenates) or with some organic materials, so care should be exercised in deciding laser intensity and measuring time.

Fluorescent minerals such as ruby and spinel may produce a high amount of non-characteristic fluorescence radiation which might inhibit the analysis of an inclusion. Again, the reduction of the excitation and/or increase of scanning time may help to overcome the problem. In some situations where, for example, organic fillers in emeralds have to be identified, it is also possible to record peaks for an identification in spectral areas where the general fluorescence is small. Luminescence spectra may themselves provide analytical information where the Raman lines are swamped by fluorescence.

When equipped with a standard Olympus microscope the sample stage of the Renishaw Raman Microprobe can be lowered through approximately 15 cm. This free space between the objective and the sample's lower end is a limitation, although it will accommodate most gemstones. For larger pieces, such as a carving or a vase, the fitting of a special microscope objective which reflects the beam through 90° to the side of the microscope, often enables successful collection of data.

Conclusions

Raman spectroscopy offers a wide field of application in which mineralogical and gemmological identifications play a major role. The fact that this spectral technique is usually non-destructive, is of inestimable value not only in gemmology but also in related sciences such as archaeology. Not only the host mineral but also inclusions can frequently be identified. An important application in gemmology for Raman spectroscopy is the detection of the nature of organic fracture fillings in emeralds. Raman spectroscopy can also aid the identification of gemstones set in jewellery when the usual gemmological identification methods such as determination of the density and refractive index or visible spectroscopy cannot be applied.

Acknowledgements

We are grateful to the following institutions and persons for providing reference material to start creating our reference data base: the mineralogical section of the Museum of Natural History in Basel, Switzerland (Professor S. Graeser and Dr J. Arnoth), G. and E. Keller (Bettingen, Switzerland), Mr M. Schuler, Mineralogical Institute of Basel University. We wish to extend our thanks to Professor D.C. Smith for reviewing the original paper, and for his valuable suggestions.

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A study of New Zealand Kauri copal

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ABSTRACT: New Zealand Kauri copal is well known and often appears on the market as a substitute for amber. It can be distinguished from amber by testing with alcohol. Some New Zealand fossil resins associated with coal deposits, however, are similar to non-succinite ambers and are indistinguishable using normal gemmological tests.

Keywords: New Zealand, Kauri, gum, copal, amber.

Introduction

In the early days of New Zealand's history, Kauri gum (as it is popularly known) was one of New Zealand's most important commercial export products *(Figure 1)*. Only ten years after the Colony was formalized by the signing of the Treaty of Waitangi in 1840, records show that 1000 tons were exported to Britain and North America for use in varnishes. Over the succeeding one hundred years, 1850 to 1950, some 450 000 imperial tons were recorded as being exported (McNeill, 1991, pp 18–45). Initially only the finest and most transparent grades were selected for export but in 1865 a 'new' floor covering was invented called linoleum, which led to a market for the poorer grades. Even in the 1980s fifty tons of Kauri gum were exported, mainly for high-quality varnishes for musical instruments. The origin of this gum is the Kauri pine (*Agathis australis*, family Araucariaceae), a conifer which lives for thousands of years. When damaged it may bleed gum or resin for long periods with some masses weighing over 250 kg, even after

Figure 1: *Location of the coal fields from which resin samples were obtained and the southern limit of the Kauri forest in New Zealand.*

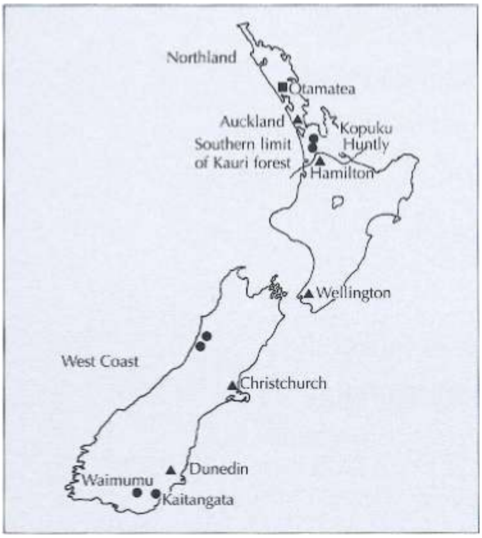


Figure 2: *The main building of the Otamatea Kauri Museum.*

ISSN: 1355–4565

consolidation. Strictly speaking, these conifers exude *resins* as opposed to *gums.* True gums are hygroscopic substances which absorb water, like gum arabic, to form sticky gels; resins, on the other hand, repel water and gradually expel water droplets from their original constitution even when buried in swampy ground. In this respect it is more correctly referred to as Kauri copal.

Figure 3: *One of the specimen display cabinets in the museum.*

Figure 4: *A carved lighthouse, part of the museum collection. Carving 30 cm high.*

Fortunately, the history of Kauri copal in New Zealand has not been lost. The efforts of Merv Stirling, together with a devoted group of residents from the Otamahia and Matakohe area in the north, have resulted in an extensive museum, the Otamatea Kauri Museum at Matakohe *(Figure 2),* devoted to the Kauri pine, the pioneer foresters, the timber and its resins.

This museum consists of five sections:

1. the timber, logs, machinery, the forestry aspects;
2. timber products, carvings, furniture, outsized planks and curios in wood;
3. the resin collection;
4. pioneer exhibits and photograph collection;
5. book and souvenir shop.

Figure 5: *A keepsake manufactured by using Kauri copal to embed two small shells and some maidenhair fern. 30 mm long.*

Figure 6: *Lock of golden 'hair' made by drawing heated copal into strands, subsequently plaited. Specimen 60 cm long.*

The large resin collection, mostly the result of private collectors' donations, is one of the most extensive collections of Kauri copal to be seen anywhere *(Figures 3, 4 and 5)*. It includes innumerable examples in the raw state, polished, compressed, carvings and models, moulded, with embedded curios and insects, drawn into locks of plaited hair *(Figure 6)* and dissolved in solvents as varnish.

The study

A study of Kauri copal was undertaken by members of the Gemmological Association of New Zealand to expand the knowledge published in traditional texts such as Webster (1994), Anderson (1990) and Fraquet (1987), and to establish a sound basis for the distinction of Kauri copal (or natural biological resins of recent origin) from true ambers.

The tests were generally based on:

- smell derived from rubbing or touching the specimen with a hot point;
- inclusions;
- physical properties, density and refractive index;
- shaving or cohesion characteristics when cut with a sharp tool;
- solubility in organic solvents;
- response to ultraviolet radiation.

When a gem or ornamental material is investigated, the quality of the results obtained depends on the quality and range of specimens submitted. The set of 25 specimens assembled for this study were contributed by Auckland members of the Gemmological Association of New Zealand's Study Group *(Figure 7)*. The aim was to study as wide a range of Kauri copal as possible, look for variations, tabulate them and then draw some conclusions. Since Kauri copal was traditionally exported as an industrial raw material the criteria were different from those that might be selected if other gems were being considered. The industrial market demanded that the premium grade had to be as near colourless as possible and to be completely soluble in solvents. The low desirability of specimens with high colour and low solubility led to a great deal of it being discarded until a use was found for it in linoleum. The Association felt that specimens retained from shipments

Figure 7: *A selection of the specimens used in the study.*

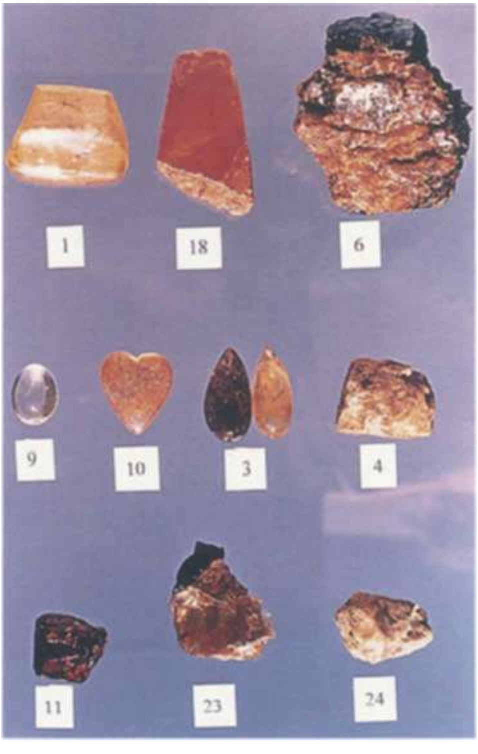
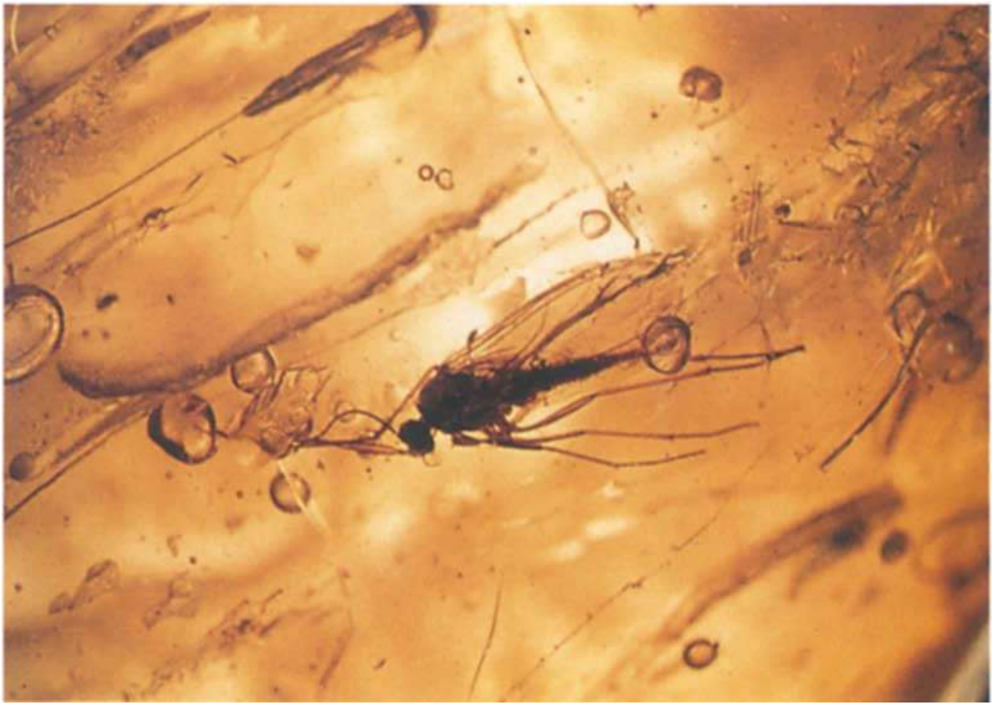


Figure 8a and b: *A pair of images of a visually similar variety of gnat, (a) in a Baltic amber bead and (b) in a fresh piece of Kauri copal. Specimens 1.5 mm long.*



overseas or carved by diggers on the field might not represent all aspects of the product. The methods of recovery also had a strong bearing on the product. As it was generally a low-value material (top quality yielding only 4 pence per pound in 1870 after scrubbing and dressing), recovery was limited to that from areas of relatively easy access. As these were predominantly the soft peat ground, swamps and bog areas, virtually all of the product was less than one million years old, which is very recent in geological terms. Some of the specimens in this study were derived from coal fields; their positions in the stratigraphic sequence helped to establish their ages and to ensure that the study included some local fossil resin specimens.

Appearance

The colour of the resins varied between colourless and the deepest red-brown. Diaphaneity ranged from a high degree of transparency to opaque. Some pieces were obviously relatively fresh with the typical translucency of a mist of included water droplets while others were quite obviously ancient, being attached to coal or lignite of Miocene age (10 to 25 million years old).

Fragrance and age

The composition of Kauri copal is, as with other natural organic resins, very complex and consists of a whole range of molecules with widely different boiling points (Fraquet, 1987, pp 150–1). A simplified differential thermal analysis performed on a fresh specimen indicated that one component started to boil off at 76°C with others vapourizing at various points up to 300°C when a significant residue remained (300°C was the limit of the test conditions). The most volatile components were not present in the older specimens. No great importance was attached to this procedure as a gemmological test because it is destructive. As expected, the older samples were found to have a much lower intensity of fragrance when rubbed on a soft cloth or the heel of the hand.

This loss of volatile components from the surface could also explain the development of fine cracks that commonly mar the surface of copal five to ten years after it has been polished (although this feature does depend on storage conditions). The volatilization causes a small loss of volume in the outer millimetre or so and, as the bulk of the specimen is unchanged, the brittle nature of the material leads to the opening of surface cracks. Minor cracking can be masked and inhibited to a large extent by replacing the loss of volatiles through rubbing the specimen with wheat germ oil, a high boiling point oil of similar refractive index which fills the cracks by partly dissolving a little of the sidewalls.

Inclusions

Most inclusions in the specimens were what one would expect to find in naturally exuded botanical resins, namely: bubbles of gas, air and water, various fragments of organic material, bark, branches, leaves and pollen. But it was the insects and their *disjecta membra* that provided the most interest.

None of the older specimens contained any recognizable fossils. Fossils were only found in the specimens of apparently recent origin but unfortunately it is an imprecise art to date a sample of copal from included insects. Many of our insect varieties have existed for millions of years. One piece of resin, prised from under the bark of a Kauri tree, was polished to reveal a gnat of identical appearance with one previously photographed by the author in a Baltic amber bead *(Figure 8a and b)*. The insect inclusions were essentially those of the forest and included juvenile wetas (a large native grasshopper *(Figure 9)*), spiders, mites, millipedes, native bees, gnats and cockroach egg-cases *(Figures 10–12)*.

Physical properties

Specific gravity

Various values for specific gravities of copal and amber between 1.03 and 1.11 have been given in the literature. A Hanneman SG balance was assembled to measure the Kauri copals and despite its simple appearance it was capable, with careful use, of very accurate results. Not all of the samples were suitable for physical tests of density or

Figure 9: *A juvenile cave weta trapped in recent Kauri copal. Specimen 6 mm long.*

Figure 10: *A Kauri tree leaf trapped in a recent specimen. 40 mm long.*

Figure 11: *New Zealand native honey-bees trapped in Kauri copal. Specimens 20 mm long.*

Figure 12: *Cockroach egg-cases trapped in Kauri copal. Specimens 3 mm long.*

refractive index due to their surface condition or porosity. For the solid non-porous samples our SG results ranged from 1.03 for the youngest specimen to 1.095 for one that was associated with a coal deposit which has been dated at 40 million years old. Three samples of Baltic amber which we tested gave specific gravities of 1.065 to 1.075. The samples could be assigned to two groups with the recent specimens having SGs of 1.03 to 1.055, while the ambers and mature samples ranged from 1.060 to 1.095.

Refractive index

Using a Rayner Dialdex refractometer all the refractive indices of the suitable samples coincided with the published figure of 1.540. There was no detectable variation even in the third decimal place.

Fluorescence

The response to ultraviolet radiation was consistent in some respects but variable in others. Using the GIA GEM LW and SWUV lamp it was found that the strength of fluorescence with exposure to LWUV was greater than to short wave, in every case. Under SWUV, the weathered and exposed surfaces were often more reactive than the body of the piece, usually exhibiting a yellow, mustard to brown fluorescence, and usually strong enough to mask completely the fluorescence colour of the body of the sample. Fresh breaks or polished areas had variable fluorescence ranging from no response through faint blues, medium blues to white. LWUV radiation caused similar but more intense responses. A proportion of the recent samples were inert to SWUV.

Table I. *New Zealand resins, including Kauri copal, and their properties*

Sample	Description	Source	Age	Specific Gravity (SG)	Refractive Index (RI)	Solubility in		Response in		Fragrance
						Ether	Alcohol	SWUV	LWUV	
1	Light honey	Northland	Recent		1.540	Slightly soluble	Soluble	Very-light blue	Light blue body	Very fragrant
2	Honey-coloured slight skin	Northland	Recent	1.04		Slightly soluble	Soluble	Inert	Mustard skin Slight blue body	Strong
3a	Honey coloured	Northland	Recent			Soluble	Soluble	Inert	Light blue	Strong
3b	Dark mottled	Northland	Recent	1.04	1.540	Soluble	Soluble	Inert	Light blue	Strong
4	Light honey opaque	Waimumu lignites	Mid-Miocene			Insoluble	Soluble	Inert	Whitish on skin	Moderate
6	Light brown opaque	Wederburn lignites	Late Miocene			Very slightly soluble surface	Soluble	Inert	White surface	Moderate
7	Honey coloured	Northland	Recent	1.055		Insoluble	Soluble	Inert	Inert	Very strong
8a	Light honey	Northland	Recent		1.540	Slightly soluble	Soluble	Inert	Mustard skin	Very strong
8b	Medium brown	Northland	Recent			Insoluble	Soluble	Inert	Light-blue body	Weak
9	Colourless	Northland	Recent	1.045	1.540	Soluble	Soluble	Very faint blue	Strong blue	Strong
10	Honey colour	Northland	Recent	1.048	1.540	Insoluble	Soluble	Slight mustard skin	Mustard skin	Moderate
11	Dark brown transparent	Kaitangata coals	Ancient	1.060	1.540	Insoluble	Insoluble	Very slight blue	Moderate blue	Slight tarry
12	Burnt surface	Northland	Recent			Soluble	Soluble	Light mustard skin	Mustard skin Blue body	Very strong
13	Dark honey, mottled	Northland	Recent			Soluble	Very soluble	Slight blue/grey	Light blue	Very strong
15	Medium brown transparent	Northland	Recent			Soluble	Soluble	Light blue	Mustard skin/blue body	Very strong
16	Light honey translucent	Auckland	Very recent	1.030	1.540	Soluble	Soluble	Very light blue	Light blue	Strong
17	Heterogeneous medium brown	Northland	Recent			Soluble	Soluble	Whitish with blue in dark areas		Moderate
18	Deep honey	Northland	Recent			Soluble	Soluble	Inert	Light blue	Strong
19	Light honey transparent	Baltic		1.078	1.540	Insoluble	Insoluble	Faint white	White on fresh breaks	Weak
20	Dark brown transparent	West Coast	Ancient	1.075	1.540	Insoluble	Insoluble	Light opaque brown skin	Brown opaque skin	Tarry
21	Honey translucent	Baltic		1.065	1.540	Insoluble	Insoluble	Light mustard skin	Mustard skin/white body	Slight
22	Honey translucent	Baltic		1.070		Insoluble	Insoluble	Opaque mustard	Strong mustard skin	Slight
23	Light honey transparent	Huntly West coal	40 m.y.	1.050	1.540	Insoluble	Insoluble	Very light blue	Medium ligh blue	Slight tarry
24	Light grey brown	Yallourn Victoria Australia	25 m.y.			Insoluble	Slightly soluble	Very light blue	Mustard skin, light blue body	Moderate, piney
25	Dark brown transparent	Kopuku coal	Ancient	1.095	1.540	Insoluble	Insoluble	Slight opaque brown skin	Opaque brown skin	Weak tarry

Solubility

All the specimens were tested for solubility in ether and in alcohol, and some were tested in acetone and in glacial acetic acid. The acetone test was later dropped as it gave unhelpful results.

Ether

Ether, a test liquid that has been extensively recommended in the gemmological literature (e.g. Webster, 1994, p. 575), had a variable effect on the samples. The procedure was to place some ether on the surface of the specimen by eye-dropper and allowed to remain for 30 seconds, the drop being replenished when necessary before the control time elapsed.

Three degrees of solubility were recorded:

Soluble	where the sample became sticky and/or translucent,
Slightly soluble	where only a slight dulling of the surface occurred,
Insoluble	where there was no detectable effect.

Using ether, all of the known older specimens were insoluble but so were three of fourteen recent ones.

Alcohol

The test was carried out in a similar way using alcohol (methylated spirit) with extra drops added when necessary for 30 seconds of exposure. This solvent dissolved all of the recent copals, our three late Miocene specimens (10 to 25 million years old; sample nos 4, 6 and 24) but did not affect any of the three amber specimens, or the four that were associated with the mature coal deposits 40 million years old.

Glacial acetic acid

The glacial acetic acid proved to be an excellent testing reagent with its slow evaporation rate and strong solvent power but was discontinued for the following reasons:

1. the reagent has a pungent odour;
2. great care is needed in handling to avoid acid burns;
3. similar results could be obtained with two or three successive drops of alcohol.

Summary

On the basis of testing a range of copals and ambers it can be concluded that:

- recent copals had lower densities but the differences from older resins were not sufficient to be diagnostic;
- fluorescence in UV radiation is not a reliable guide to the nature of a resin as almost all of the specimens reacted to long wave, while eight of the recent specimens were inert to short-wave UV;
- of the solvents it is clear that ether is not satisfactory but alcohol (in the form of methylated spirits) was very reliable giving a clear differentiation between the recent and the true fossil resins. The fossil copal specimens nos 11, 20, 23 and 25 tested in this series, would not be distinguishable from most other varieties of amber on the market today. Using alcohol only the true ambers and the most mature of the copal specimens were insoluble. This reagent clearly can be used to separate all of the recent copals from the most mature ones, including those associated with the immature coals of mid-to-late Miocene age (and also one from Australia reputed to be of similar age). There is one further aspect.

Baltic amber is considered to be a succinite resin containing 3%–8% succinic acid (Fraquet, 1987). Most of the other ambers – that is from Southern Europe, the Dominican Republic, Burma and Borneo – have very low succinic acid contents and are usually referred to as non-succinite ambers. Chemically Kauri copal and the New Zealand fossil samples have low succinic acid content and are similar to ambers in the second category. With the exception of the Burmese variety, succinite ambers are generally rather tougher than non-succinite varieties when shaved with a jeweller's graver or sharp knife (Anderson, 1990, p. 332). Using standard gemmological tests, the toughness, hardness, density and solubility of the most mature specimens were indistinguishable from non-succinite ambers from other sources.

Conclusion

The traditional Kauri resin is young and is classified as a copal; it can be reliably distinguished from amber by testing its solubility with alcohol. However there are some examples of New Zealand fossil resins (ambers) that appear from time to time that are indistinguishable from other non-succinite ambers. These are usually associated with the coal deposits of the South Island, Kaitanga, Waimumu; the Huntly and Kopuku coal fields. Of these only the Huntly and Kopuku fields would be expected to be derived from the Kauri tree as this was the southern limit for the species. However, coal is mined by organizations with little interest in the small amounts of resin or gum associated with their product so it is highly unlikely that appreciable quantities of New Zealand amber would appear on the commercial market.

Acknowledgements

The author appreciates the assistance of the following Gemmological Association of New Zealand Study Group members: Elizabeth Carroll, Debra Lockie, Arline Broad, Neil Hannah and Charles Cox.

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Identification of B jade by diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy

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ABSTRACT: Diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy has been found to be a useful and non-destructive tool for providing evidence of bleached and wax- or polymer-impregnated jadeites (Grade B jade). Therefore, the natural and untreated jadeites and those which are wax-buffed (Grade A jade) can be reliably discriminated. The strong absorption peaks shown on the DRIFT spectra can be used to test for the presence of polymers and wax. Results of a systematic DRIFT study done on 10 jadeite samples show that some of them have been bleached and wax- or polymer-impregnated. The DRIFT results, which were backed by basic gemmological tests and X-ray photoelectron spectroscopy (XPS), were compared to similar studies by Fourier transform infrared (FTIR) transmission spectroscopy. In comparison, DRIFT spectroscopy has advantages limited to the testing of very thick (greater than 12 mm) jadeite samples and of relatively thin pieces of Grade A jadeite which may not be very transparent to infrared radiation. It also has an advantage for jadeite jewellery with completely closed mountings, which is rare.

Introduction

The international jade business appears to be suffering from a proliferation of treated stones that have appeared on the market since at least 1989 (Hurwit, 1989; Anon, 1991a and b). As the tampering of this translucent green gem, which is prized throughout Asia, is invisible to the naked eye and sometimes even under the optical microscope, more sophisticated detection methods are now required. Fritsch *et al.* (1992) had used infrared absorption (or transmission) spectroscopy to successfully identify bleached and polymer-impregnated jadeite. This technique is of limited use if the jadeite sample is more than 12 mm thick or if it is already a part of a piece of closed-setting jewellery. In the study carried out by Tay *et al.* (1993) using a scanning electron microscope (SEM), photomicrographs of bleached jadeites showed damaged crystal grain structure but failed to identify the chemical composition of the impurities found between grain boundaries. Possible identification of Grade B jadeites by studies of their structure and 'cracked' texture has been done by Ou Yang, 1993.

Although an energy dispersive X-ray fluorescence (EDXRF) spectrometer can be used to detect differences in the major constituents of jadeites, elements lighter than sodium that make up most polymers (carbon, hydrogen, oxygen and nitrogen) cannot be

ISSN: 1355–4565

Table I: *Gemmological and spectroscopic data for natural and impregnated jadeite.*

Sample	*Specific gravity (3.32)*	*Ultraviolet fluorescence*	*XPS C(1s)/Na(1s) ratio*	*Microscopic observations*	*Infrared absorption peaks* (cm^{-1})	*DRIFT absorption peaks* (cm^{-1})
1	sink	none	6	Light green patches. Several brown spots. No fissures.	2920, 2852 (very weak)	2920, 2852 (very weak)
2	sink	none	12	Light, even green. No fissures. Some slight breaks.	2920, 2852 (very weak)	2920, 2852 (very weak)
3	sink	none	8	Very light green showing patches of white mineralization. No fissures.	2920, 2852 (weak)	2920, 2852 (weak)
4	sink	none	10	Very light green with white mineralization. Fine fissures.	2920, 2852 (very strong).	2920, 2852, 746 (very strong) 5792, 5676, 4337, 4260 (weak)
5	sink	none	15	Very light green with white mineralization. Fine fissures.	2920, 2852 (strong)	2920, 2852, 746 (strong) 5792, 5676, 4337, 4260 (weak)
6	sink	none	13	Light green with patches of white mineralization. Some fine fissures.	2920, 2852 (very strong)	2920, 2852, 746 (very strong) 5792, 5676, 4337, 4260 (weak)
7	float	chalky-blue (long wave)	43	Light green. Fine fissures and pit marks throughout surface.	3060, 2966, 2931, 2875 (very strong)	5985, 5800, 4685, 4620 (weak) 4324, 4170, 4054 (strong) 3100-2800 (very strong)
8	sink	none	30	Cabochon with green veins and patches. Fine fissures throughout surface.	3060, 2966, 2931, 2875 (strong)	5998, 4814, 4633 (weak) 4324, 4230, 4067 (strong) 3732, 3060, 2970-2850 (very strong)
9	sink	weak chalky-blue (long wave)	34	Light green cabochon with large pit marks. Fine fissures throughout surface.	3060, 2966, 2931, 2875 (strong)	5998, 4814, 4633 (weak) 4324, 4230, 4067 (strong) 3732, 3060, 2970-2850 (very strong)
10	float	chalky-blue (long wave)	40	Green cabochon. Dark green veins and patches, with pit marks. Fissures throughout surface.	3060, 2966, 2931, 2875 (very strong)	5985, 5800, 4685, 4620 (weak) 4324, 4054 (strong) 3100-2800 (very strong)

□ Wax buffed　▨ Bleached wax impregnated　■ Polymer impregnated

***Figure 1:** The photograph shows 3 samples of wax-buffed jadeite, numbered 1 to 3 (top row, from left to right), 3 samples of bleached wax-impregnated jadeite, numbered 4 to 6 (middle row, from left to right), 4 samples of bleached polymer-impregnated jadeite, numbered 7 to 10 (bottom row, from left to right).*

detected with most EDXRF instruments available to gemmologists (Fritsch, 1992). X-ray photoelectron spectroscopy (XPS), which can be used to detect the high carbon, oxygen and hydrogen content of polymers in jadeite, has been proven to be a reliable technique (Tan *et al.*, 1995). However, its use is severely restricted to research laboratories as the apparatus is expensive and elaborate expertise is required.

In our present investigation, diffuse reflectance infrared Fourier transform (DRIFT) spectroscopy was used for the first time to unambiguously and relatively inexpensively differentiate between Grade A (natural and untreated) and Grade B (bleached wax- or polymer-impregnated) jadeites, and between bleached wax-impregnated jadeite and natural jadeite with wax buffing.

Materials, tests and results

Ten samples of jadeite were used for this study, as shown in *Figure 1*. Three of them were wax-buffed (samples 1–3), another three were bleached wax-impregnated (samples 4–6) and the other four were bleached polymer-impregnated (samples 7–10). Preliminary studies were made on these samples using basic gemmological tests, X-ray photoelectron (XPS) and infrared transmission (FTIR) spectroscopies. The microscopic surface observations and results of preliminary tests are summarized in *Table I*. All the samples originated from Myanmar (Burma).

It can be seen from *Table I* that all of the natural wax-buffed jadeites were inert to ultraviolet irradiation. However, from *Table I*, only some, but not all, of the treated jadeites fluoresced under long-wave ultraviolet light. Also, not all the bleached wax-impregnated jadeites can be differentiated from the ones which are only wax-buffed by ultraviolet fluorescence. This is confirmed by the results of XPS and infrared transmission spectroscopic studies *(Table I)*. The samples were then placed in diiodomethane (specific gravity 3.32) and it can be seen that this test is not a good indication of whether the samples are polymer impregnated or not. This is because only the samples which have a very high level of polymer impregnation float on diiodomethane, showing a specific gravity of less than 3.32 (since polymers have a specific gravity of less than 2.5).

The samples were further tested using a VG ESCALAB MkII X-ray photoelectron (XPS) spectrometer with an MgKα X-ray source (1253.6 eV photons) at a reduced power of 120 W (12 kV and 10 mA) (Tan, 1995). The carbon to sodium peaks ratio, C(1s)/Na(1s), was then found. The results *(Table I)*, when compared with those obtained by Tan *et al.* (1995), confirmed that samples 1–6 contained wax in varying quantities, as this ratio ranged from 6 to 15. Although, as stated in Tan *et al.* (1995), it is difficult to distinguish a wax-buffed jadeite from that which is wax-impregnated using the C(1s)/Na(1s) ratio, samples 7–10 were obviously polymer-impregnated with very high ratios of between 30 and 43.

In the infrared absorption (or transmission) technique, a Bomem DA3.002 Fourier transform infrared (FTIR) spectrophotometer (Tan *et al.*, 1995) was used to determine whether the samples were wax-buffed, wax-impregnated or polymer-impregnated. The resolution of the specrophotometer used was 4 cm^{-1}. For the samples which were only wax-buffed (samples 1–3), weak absorption peaks could be seen at 2920 and 2852 cm^{-1}, which indicate the presence of wax *(Table I)*. In samples 4–6, very strong absorption peaks at 2920 and 2852 cm^{-1} showed a significantly larger amount of wax, indicating that the jadeite had been wax-impregnated. The presence of several strong and distinct peaks in the 2800–3100 cm^{-1} range for samples 7–10 was due to the absorption of the specific functional groups of the polymer material, confirming that the samples were polymer-impregnated. For such samples, the most characteristic absorption peaks were at 3060, 2966, 2931 and 2875 cm^{-1}.

Diffuse reflectance infrared spectroscopy

The technique of diffuse reflectance spectroscopy is successfully and non-destructively used for surface analysis where more well known techniques are difficult to employ. Excellent spectra of coal (Fuller *et al.*, 1982), for instance, can be obtained by diffuse reflectance. Many substances in their natural state (surfaces of solids) exhibit diffuse reflection, i.e. incident light is scattered in all directions. The diffuse reflection spectra can show both absorbance and reflectance features due to contributions from transmission, internal and specular (mirror-like) reflectance components as well as scattering phenomena in the collected radiation (Wendlandt and Hecht, 1966; Kortüm, 1969).

For quantitative reasons, the diffuse reflectance spectra are generally expressed linearly (Kubelka and Munk, 1931) in the Kubelka-Munk function, $f(R_\infty)$:

$$f(R_\infty) = \frac{(1-R_\infty)^2}{2R_\infty} = \frac{k}{s} = \frac{(\ln 10)\,ac}{s}$$

where R_∞ is the reflectance of the sample at 'infinite' depth (i.e. up to 3 mm), relative to the reflectance of a non-absorbing reference (e.g. KBr); k is the absorbing coefficient, s is the scattering coefficient, a is the absorbance, and c is the sample concentration.

The high sensitivity (particularly to surfaces) and non-destructive sample preparation used for experiments are valuable characteristics of the DRIFT technique. The application of DRIFT to study polymer films and coatings is well established (Culler *et al.*, 1984; Sergides *et al.*, 1987). Furthermore, the application of reflectance infrared spectroscopy to gemmology in general has been reported in Fritsch and Stockton, 1981, and Martin *et al.*, 1989. However, the use of this technique to study the surface of jadeite has not yet been explored. All the 10 samples of jadeite were cleaned with highly volatile propanol before they were analysed to ensure that all the contaminants resulting from handling were removed fully. The DRIFT spectra were recorded using a Perkin-Elmer System 2000 FTIR spectrophotometer with a fast recovery deuterated triglycerine sulphate (FR-DTGS) detector. A Harrick Diffuse Reflectance Attachment (HDRA) with two hemispherical mirrors and four plane mirrors collected the diffuse reflectance spectra in the wavenumber

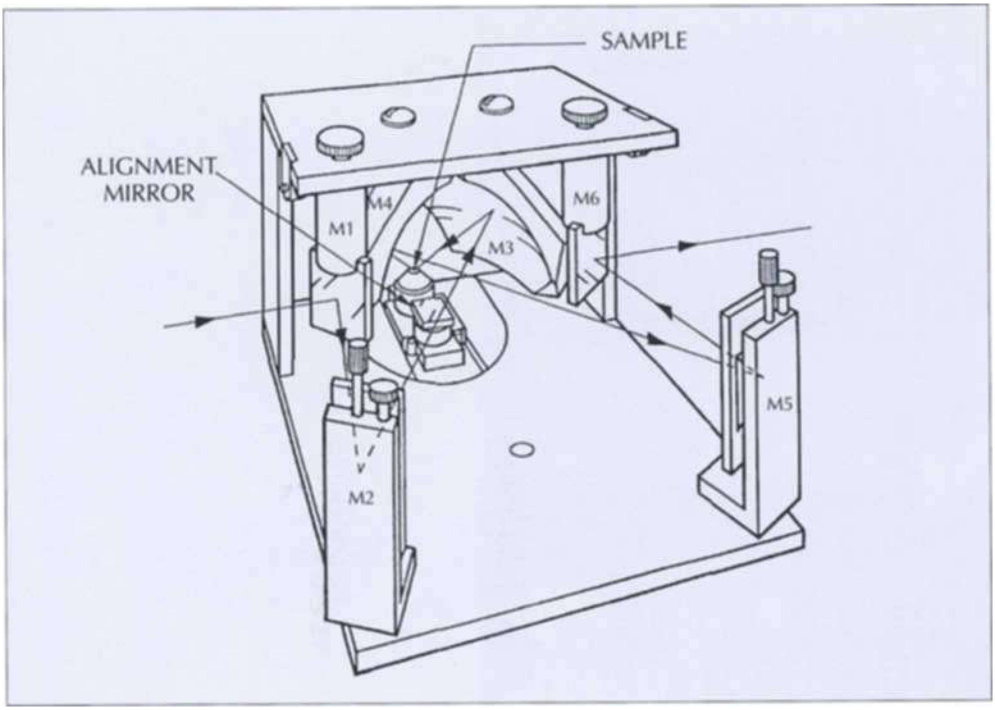

Figure 2: *Schematic drawing of Harrick Diffuse Reflectance Attachment (HDRA) (Harrick Scientific Corporation, 1994). M1, M2, M5, M6: Plane mirrors. M3, M4: Off-axis ellipsoidal mirrors.*

range of 350–6500 cm^{-1}. The schematic drawing of the HDRA, taken from Harrick Scientific Corporation, Document # DOC00008, 1994, is shown in *Figure 2.* The sample holder and the space below mirrors M3 and M4 *(Figure 2)* allowed the testing of jadeite samples up to a few cm thick. Potassium bromide (KBr) powder of less than 74 µm was used as the reference material. At least 100 scans of the sample and the reference material were taken to improve the signal-to-noise ratio of the spectra. The frequency precision of the absorption spectra was expected to be better than 0.5 cm^{-1}. Spectra on both sides of the jadeite sample were recorded to check for consistency of results.

Results and discussion

Figure 3(a) shows a typical infrared (FTIR) transmission spectrum of a natural sample of jadeite with only wax buffing (samples 1–3). Two very weak peaks occurring at 2920 and 2852 cm^{-1} indicate the presence of a small quantity of wax. A typical DRIFT spectrum of these natural samples is shown in *Figure 3(b).* The presence of a small amount of wax used in the wax buffing is similarly confirmed by two weak absorption peaks at 2920 and 2852 cm^{-1}. In contrast to the FTIR transmission spectrum, the DRIFT spectrum shows strong absorption from 1200 to 2200 cm^{-1}, a sharp absorption peak at 700 cm^{-1}, and a weak peak at 5200 cm^{-1}. The reasons for these differences are not yet known. Both DRIFT and FTIR transmission spectra show a typical absorption feature at around 3500 cm^{-1} due to water vapour. A series of lines at around 1600 cm^{-1} in *Figure 3(b)* were actually due to water vapour in the air. It must be added that both sides of each jadeite sample gave almost identical results.

The DRIFT spectrum of a sample of pure paraffin wax illustrated in *Figure 4(a)* shows strong and distinct peaks at 5792, 5676, 4337, 4260, 2920, 2852 and 746 cm^{-1}. *Figure 4(b)*

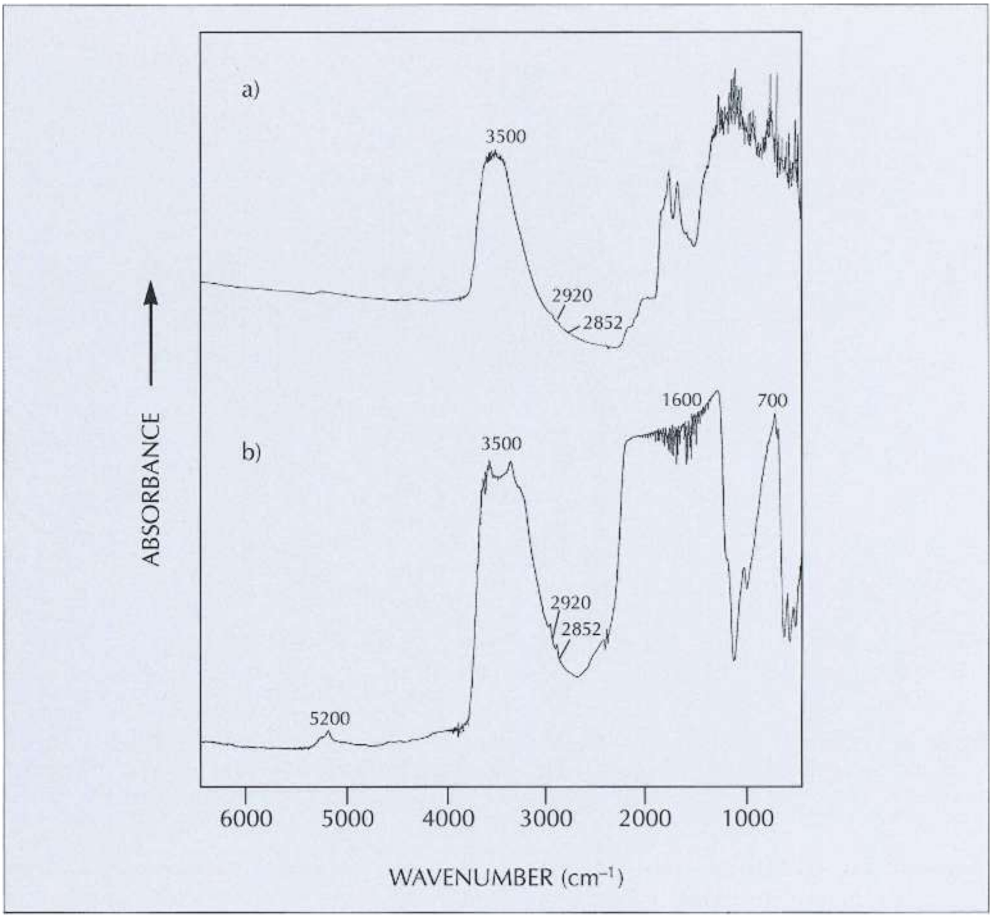

Figure 3: *(a) Infrared transmittance (FTIR) spectrum, and (b) Diffuse reflectance infrared (DRIFT) spectrum, of natural jadeite with wax-buffing (samples 1–3).*

shows a typical DRIFT spectrum of bleached wax-impregnated jadeites (samples 4–6). One can obviously note that these peaks are common to the two spectra. This confirms that wax is definitely present in large quantities in samples 4–6 as compared to the wax peaks in *Figure 3(b)*. The weaker absorption peaks at 5792, 5676, 4337 and 4260 cm^{-1} in the spectrum of paraffin wax, which are not obviously visible in the spectrum of the natural and untreated jadeites with wax buffing *(Figure 3(b))*, are visible in the spectra of the bleached wax-impregnated jadeites *(Figure 4(b))* due to the much higher content of wax. This makes it very easy for us to differentiate between jadeites with wax buffing and jadeites which are wax-impregnated by looking for the presence of significant absorption peaks at these wavenumbers in the DRIFT spectra. The absorption peaks at wavenumbers 2920, 2852 and 746 cm^{-1} are also much stronger in the spectra of the bleached wax-impregnated jadeites than the absorption peaks at these wavenumbers in the spectrum of the natural and untreated jadeites with wax buffing. The absorption peaks of wax in the DRIFT spectra are in good agreement with the infrared transmission spectra of Fritsch *et al.*, 1992.

Figure 5(a) shows the DRIFT spectrum of a polymer commonly used (Fritsch *et al.*, 1992) as a filler in jadeite treatment. The DRIFT spectrum of a highly bleached

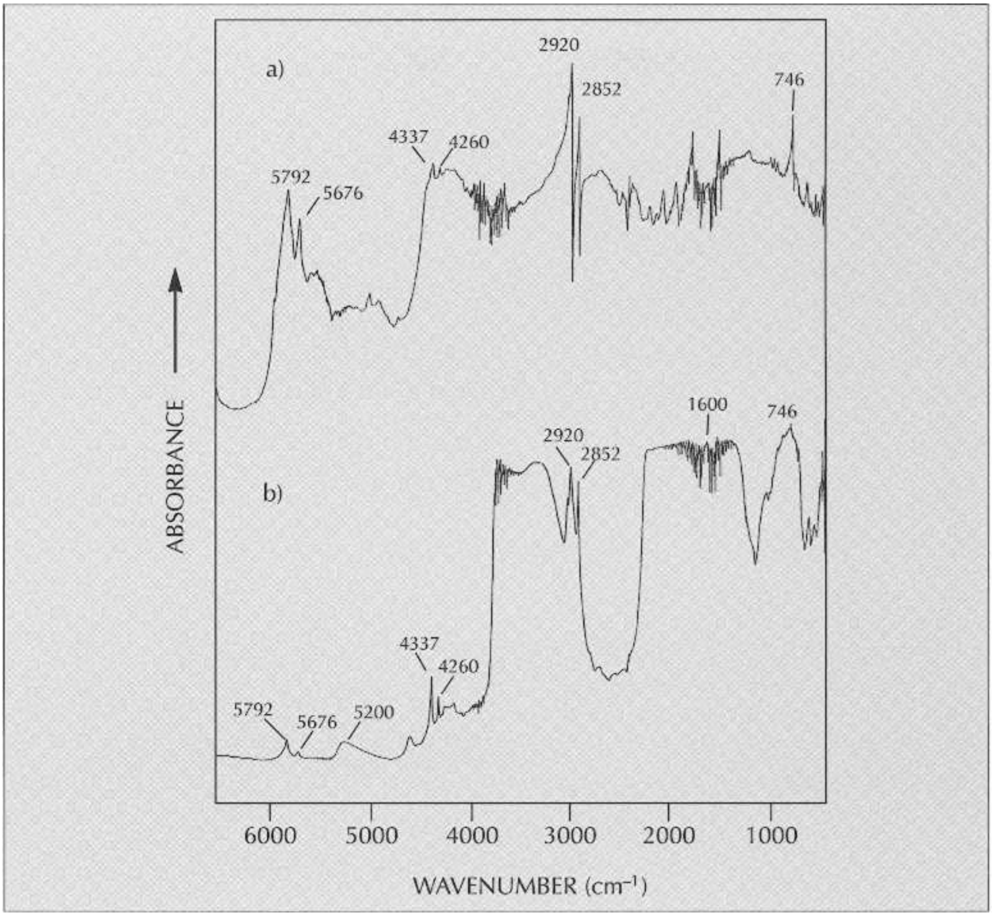

***Figure 4:** Diffuse reflectance infrared (DRIFT) spectra of (a) pure paraffin wax, (b) bleached wax-impregnated jadeite (samples 4–6).*

polymer-impregnated jadeite (sample 7) is illustrated in *Figure 5(b)*. It can be observed that the frequency range below 4600 cm^{-1} in *Figure 5(a)* has been almost completely truncated as there is very high absorption of infrared radiation by the polymer below 4600 cm^{-1}. Therefore, studies can only be made on the part of the spectrum where the absorption is not saturated. However, results were still very satisfactory as absorption peaks at wavenumbers 5985, 5820, 5200 and 4685 cm^{-1} were common in both spectra. The strong absorption between 2800 and 3100 cm^{-1} and peaks at 5985, 5800, 4685, 4620, 4324, 4170 and 4054 cm^{-1} in *Figure 5(b)* indicate the significant presence of polymer on the surface of sample 7. None of these absorption peaks was found in the DRIFT spectra of natural and untreated or bleached wax-impregnated jadeite samples. In fact, the DRIFT spectrum in *Figure 5(b)* is in close agreement with that of *Figure 9(c)* of Fritsch *et al.*, 1992, confirming that the same type of polymer was used in the treatment. The strong features at frequencies above 4000 cm^{-1} of the DRIFT spectrum are found to be very useful determinants of the presence of the polymer used in the treatment. It must be noted that a semi-quantitative method to measure the concentration of polymer or wax in Grade B jadeite was reported in Fritsch, 1994.

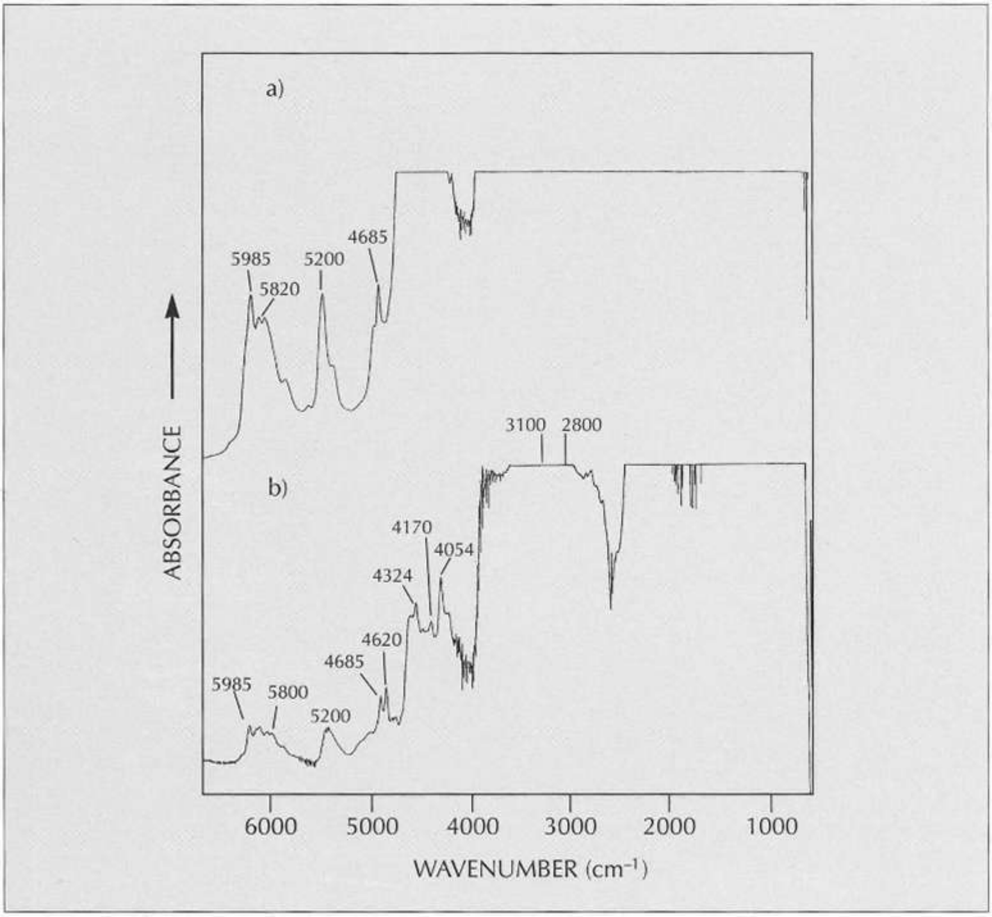

Figure 5: *Diffuse reflectance infrared (DRIFT) spectra of (a) a polymer, (b) highly bleached polymer-impregnated jadeite (sample 7).*

Figure 6 compares the DRIFT spectrum of a jadeite with a low level of polymer-impregnation (*Figure 6(a)*; samples 8–9) and the DRIFT spectrum of a jadeite with a higher level of polymer impregnation (*Figure 6(b)*; sample 10). The high absorption at 2800–3100 cm^{-1} in *Figure 6(b)* shows the high level of polymer impregnation compared to that of *Figure 6(a)*. Although the strong absorption in the region 2800–3100 cm^{-1} clearly indicates the presence of polymer (Fritsch *et al.*, 1992; Tan *et al.*, 1995), the various peaks above 4000 cm^{-1} are in fact more useful indicators of the type of polymer present. The differing peak values above 4000 cm^{-1} in *Figures 5(a)* and *5(b)* show that the polymers were of different types, as polymers of the same type would show similar absorption peak values, e.g. *Figure 5(b)* and *Figure 6(b)*.

The resemblance of *Figures 5(b)* and *6(b)* shows that the same type of polymer was used as a filler for impregnation. The stronger absorption peaks of the polymer may be compared with the weaker peaks of wax in *Figure 3(b)*; their strength indicates that more polymer than wax was used in the filler. These spectra were in excellent agreement with that recorded using infrared absorption (or transmission) by Fritsch *et al.*, 1992). However, the stronger and more distinct peaks detected using DRIFT are an advantage in the

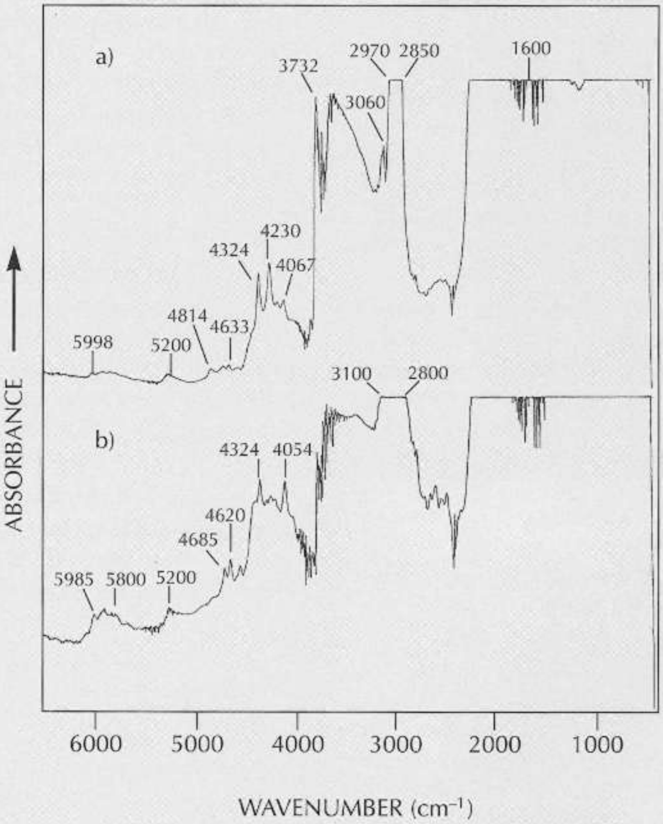

***Figure 6:** Diffuse reflectance infrared (DRIFT) spectra of bleached polymer-impregnated jadeite with (a) low (samples 8–9), (b) high (sample 10), levels of impregnation.*

analysis. When one compares *Figure 6(a)* with *Figures 9(b)* and *9(d)* of Fritsch *et al.* (1992), one can see a startling resemblance in the spectra, indicating that the same type of polymer was used in the treatment of the jade. The useful absorption peaks *(Figure 6(a))* for identification of this polymer were at 5998, 4814, 4633, 4324, 4230, 4067, 3732 and 3060 cm^{-1} and at the 2970–2850 cm^{-1} region.

DRIFT spectra collected in our present study clearly demonstrate the high sensitivity of this technique in the wavenumber region studied, 350 to 6500 cm^{-1}. The various strong and distinct absorption features above 2800 cm^{-1} as shown in the *Figures* were useful indicators in differentiating a natural (wax-buffed) jadeite from one which is treated, and from one which is wax-impregnated from one which is polymer-impregnated. Almost identical results obtained for both sides of the jadeite samples demonstrated that the impregnation treatment was done for the whole jadeite surface. A study (Groves *et al.*, 1981) on the comparison of various Fourier transform infrared (FTIR) techniques for polymer films on metal surfaces shows that the sensitivity of the DRIFT technique gives it a clear advantage over other techniques for studying very thin films on substrates without sample preparation or destruction. This technique can be beneficially applied to the study of polymer in jadeite, as demonstrated in this work.

Conclusion

Basic gemmological tests like the measurement of specific gravity and the observation for fluorescence under ultraviolet light can only be used to indicate very high levels of polymer-impregnation, such as in jadeite samples 7 and 10. For low levels of polymer-impregnation, such as those in samples 8–9, or in samples which are wax-impregnated, as in samples 4–6, these tests fail to produce conclusive results.

Use of infrared absorption (or transmission) spectroscopy produces better results, but it is limited in that it cannot be used non-destructively in testing very thick pieces of jade (more than 12 mm thick) with completely closed mountings. Testing of the jade for polymer-impregnation by X-ray photoelectron spectroscopy is effective in determining wax- and polymer-impregnated jadeites, but this method requires expensive and sophisticated equipment which is rarely available.

DRIFT spectroscopy, in the study of jadeite treatment, however, is not hampered by these limitations. It is a relatively inexpensive and yet accurate way of differentiating natural and untreated jadeites from bleached wax- and polymer-impregnated jadeites. Also, since only the surface of the jadeite sample is tested, the thickness of the jade sample or whether it is part of a piece of jewellery is not of any consequence in the experiments using the Harrick Diffuse Reflectance Attachment (HDRA). In addition, the sensitivity of the DRIFT technique allows the reliable identification of the chemical composition of the surface coating of the jadeite sample.

A summary of the significant DRIFT spectroscopy absorption peaks for the 10 samples is given in *Table I*. From this, one can see that weak absorption peaks at wavenumbers 2920 and 2852 cm^{-1} show that the jadeite has been buffed with wax, but not impregnated with wax or polymer. The additional absorption peaks at 5792, 5676, 4337 and 4260 cm^{-1} and the much stronger absorption peaks at 2920 and 2852 cm^{-1} indicate that the bleached jadeite has been impregnated with wax. Furthermore, absorption peaks at wavenumbers 5998, 4814, 4633, 4324, 4230, 4067, 3732, 3060 and 2970–2850 cm^{-1} show that the sample has been polymer-impregnated. Another polymer-impregnated sample gives the peaks at 5985, 5800, 4685, 4620, 4324, 4054 and 3100–2800 cm^{-1}.

Thus, it has been demonstrated that DRIFT spectroscopy is a useful method of identifying bleached and wax- or polymer-impregnated jadeites.

Acknowledgements

The authors wish to acknowledge the kind provision of the jadeite samples by Fu Yau Yuan Jade Wholesale Company, Singapore. They thank H.Y. Chen for his assistance in the recording of the DRIFT spectra.

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The Stuart Jewel: a new acquisition for the National Museums of Scotland

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ABSTRACT: A rare seventeenth-century trembler-style hat ornament of rose design, set with rubies probably of Burmese origin, has been acquired by the National Museums of Scotland. Relevant historical information on the Stuart family background is included.

The Stuart Jewel

A rare seventeenth-century hat ornament, still in its original velvet-lined leather case, has been acquired from the family of the young woman who first owned it.

The gold, enamel and ruby-set rose is in the style known as a trembler; the flowerhead is joined to the stem by a spring, which allows it to 'tremble', as if nodding in the breeze *(Figure 1)*. An exotic green parrot perches on one of the leaves.

The 19 rubies, mounted with rubover settings, are all table cut with no pavilion facets and are probably of Burmese origin. The large central stone is approximately 8 x 9 mm and weighs about 2 ct *(Figure 2)*; small stones average about 0.25 ct each. Their colour is more 'rabbit's blood' than the classic 'pigeon blood' as there is a noticeable bluish cast giving the stones a very slight purplish hue. They have a treacly appearance and natural crystalline solid inclusions abound *(Figure 3)*. Collectively and characteristic of dolomitic marble host rock, these include dolomite, calcite, phlogopite, spinel and apatite. Adding to the turbid appearance and characteristic of Burmese origin are patches of tightly woven mats of silk (exsolved rutile). Afghanistan is the only other historic source of dolomitic marble ruby, but faceting quality material was rare and exsolved rutile needles

Figure 1: *The Stuart Jewel, a rose in gold and enamel set with rubies.*

Figure 2: *Ruby, 8 x 9 mm, at the centre of the rose.*

have not been observed (Hughes, 1994). The rubies show a strong chromium spectrum (similar to rubies from other localities) and a strong red fluorescence under LWUV; less strong under SWUV.

This jewel, which is still in excellent condition, belonged to Elizabeth Stuart, a descendant of John Stuart of Ochiltree who accompanied Mary Queen of Scots to France in 1558 and served as colonel in the army of the King of France. James VI of Scotland acknowledged him as 'our blood brother'. His two sons, Hans and Anders, settled in Sweden as mercenary officers. Hans was raised to the Swedish nobility in acknowledgement of his background and rose first to command a regiment of Scots in the Swedish King's pay, then in 1609 to command all other foreign troops.

Their heirs followed in these military footsteps. Hans' grandson was the great General Carl Magnus Stuart (Berg and Langercrantz, 1962). Amongst his many European campaigns, he secured the duchy of Holstein against incursions by Danes in 1700 (Sinclair, 1923–4). In 1716 his daughter Elizabeth married General Otto Wilhelm Stael von Holstein. Perhaps it was he who presented her with this fine jewel. Attempts to locate any portraits of the period that depicted this or a similar jewel were unsuccessful and no information relating to the maker is currently available. Jewellery historians may find this a fascinating area for further research.

Figure 3: *Inclusions in the central ruby.*

The National Museums of Scotland has one other example of this type of seventeenth-century trembler jewel – again an enamelled flower arrangement but set with a portrait of King Charles I; a second flower is surrounded with pale emeralds. Surviving seventeenth-century jewels with a Scottish connection are rare and the Stuart jewel will form part of the display in the new Museum of Scotland (opening in 1998) that deals with Scotland's European links.

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Abstracts

Diamonds
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Diamonds

Subduction model for the origin of some diamonds in the Phanerozoic of eastern New South Wales.

G.M. Oakes, B.J. Barron and F.L. Sutherland. *Australian Journal of Earth Sciences*, **43**(3), 1996, pp 257–67.

Eastern New South Wales has produced >500 000 carats of alluvial diamonds, mostly from the Copeton-Bingara area. A local derivation is indicated by their distinct tribal character and lack of surface damage; their ^{13}C values and suite of mineral inclusions are unlike those in diamonds from conventional diamond-producing areas, and their Phanerozoic setting is >1000 km from the nearest craton. A subduction model is developed to explain the origin and geology of these diamonds; this model involves prolonged subduction of mature oceanic crust, resulting in the development of a low-T metamorphic window into the diamond stability field within the downgoing slab at half the depth required by conventional models. The diamonds are preserved at depth by termination of subduction, and brought to the surface by obduction or by entrainment in suitable magmas. The type of diamond formed depends on the original source rock. This model predicts that the New South Wales diamonds are young (Phanerozoic) and that their features, age, associated mineral and geographic distribution relates to the New South Wales tectonic provinces. The subduction diamond model extends the range of indicator minerals to include corundum and Na-bearing garnet, with a new series of carrier magmas (basanite, nephelinite, leucitite). R.A.H.

Diamonds in eclogitic xenoliths from the Udachnaya kimberlite pipe (Yakutia).

A.V. Bobrov, E.O. Bogacheva, V.K. Garanin and G.P Kudryavtseva. *World of Stones*, **11**, 1996, pp 51–3, illus. in colour.

Diamond and other minerals are described from eclogitic nodules in the Udachnaya pipe, Yakutia, Siberia. Out of 155 diamond-bearing nodules found in the Yakutia kimberlites, 130 are eclogites. Crystal forms are illustrated and described. M.O'D.

Chemische Gasphasenabscheidung von Diamant.

P.R. Buerki. *Gemmologie. Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **45**, 1996, pp 159–74, 10 photos, 1 diagram, 1 table, bibl.

For 14 years, the techniques for depositing polycrystalline and single crystal chemical vapour deposition (CVD) diamond layers on various materials have existed, including use of a hot hydrocarbon/hydrogen plasma in vacuum. Much research has been undertaken and some products have appeared on the market. At present CVD on gem diamonds is not profitable, but this may change in connection with weight increase, improvement of proportions and cut, repair of damaged stones, production of coloured stones, and changes or improvement of existing colours. At present coatings of low quality can easily be recognized under the microscope; however, if the material is carefully chosen, the coating carefully applied and the stone carefully polished after deposition, treatment can be difficult to detect. This applies particularly to single crystal diamond layers where sophisticated techniques such as VIS or IR spectroscopy, or scanning electron microscopy are needed for detection. A table summarizes useful identification methods of CVD treated diamonds. E.S.

A new look at the olivine-lamproitic rocks of the Maddur-Narayanpet area, Mahbubnagar district, Andhra Pradesh, India.

N.V. Chalapathi Rao and V. Madhavan. *Journal of the Geological Society of India*, **47**(6), 1996, pp 649–64.

The olivine lamproitic/kimberlitic rocks of this area are re-examined in the light of new petrological and geochemical data. The Ti-poor phlogopites (TiO_2 < 3 wt.%), the presence of primary calcite and the composition of perovskites are comparable to those of kimberlites; kirschsteinite is reported for the first time from Indian kimberlites. Geochemically, these rocks are low in K_2O (< 3 wt.%), are Mg rich (MgO > 30 wt.%; *mg* 73–82) and have incompatible element enrichment levels similar to kimberlites. The *REE* abundances and their chondrite-normalized distribution patterns are remarkably different from those of the olivine lamproites of Western Australia. It is argued that these rocks

Abstractors

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For further information on many of the topics referred to, consult *Mineralogical Abstracts*.

ISSN: 1355–4565

of the Mahbubnagar district are true kimberlites and are genetically related to each other, but differ from the kimberlite of the Chigicherla pipe 2 of the Anantpur district. R.A.H.

Magnesite-bearing inclusion assemblage in natural diamond.

A. Wang, J.D. Pasteris, H.O.A. Meyer and M.L. Dele-duboi. *Earth & Planetary Science Letters*, **141**(1–4), 1996, pp 293–306.

An inclusion in a diamond from the Finsch kimberlite pipe, South Africa, contains a euhedral rhombohedron-shaped crystal (~ 30 μm) coexisting with several idiomorphic olivine (Fo_{93}) grains (~ 80 μm); many tiny anatase particles (~ 2–5 μm) and microcrystallites of diamond (< 1 μm) and disordered graphite are attached to the surface of the magnesite grain. The occurrence of this syngenetic multi-phase inclusion assemblage in a natural diamond provides unambiguous evidence for the existence in the Earth's mantle of magnesite, which has been suggested to be a major carbon reservoir in most of the mantle. R.A.H.

De Beers natural versus synthetic diamond verification instruments.

C.M. Welbourn, M. Cooper and P.M. Spear. *Gems & Gemology*, **32**(3), 1996, pp 156–69, 14 illus. in colour.

With the advent of cuttable synthetic diamonds appearing on the market, especially from Russia, De Beers have developed two new instruments to distinguish synthetic diamonds from natural diamonds. Descriptions are given of how both the instruments operate together with the results of natural and synthetic diamonds tested.

DiamondSure is the cheaper of the two instruments and able to distinguish many stones rapidly either mounted or unmounted. Identification is based on the 415 nm absorption line, which is found only in natural diamonds, except for about 5 per cent of colourless stones, some fancy yellows, pinks and blues of type IIb.

DiamondView is for positive identification of all types of diamonds, based on their far-ultraviolet-excited fluorescence image. Synthetic diamonds show distinctive growth structures compared to natural diamonds which show octahedral or hummocky cuboid growth structures. DiamondView is more complex and less practical for testing large numbers of diamonds, and these two instruments need to be used together. So far they are not on the market but their practical use has been assessed by several gem-testing laboratories. J.J.

Gems and Minerals

Mineralogical Museum of Saint Petersburg University – 210 years.

G.F. Anastasenko and V.G. Krivovichev. *World of Stones*, **11**, 1996, pp 26–35, illus. in colour.

Many gem species can be found in the collections of the Mineralogical Museum of St Petersburg University; their history is outlined together with some illustrations. Beryl and diamond crystals are especially prominent in the collections. M.O'D.

Gems from archaeological excavations at Rome (Crypta Balbi).

G.B. Andreozzi, G. Graziani and L. Sagui. *Gemmologie. Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **45**, 1996, pp 175–88, 8 photos, 3 tables, 2 graphs, bibl.

The Crypta Balbi together with the Pantheon and the Theatre of Marcellus is one of the most important buildings in the Campus Martius built by the Emperor Augustus and Agrippa. The monument was named after General Balbus who financed it and consists of a theatre and a porticoed area behind it: it is here that the excavations took place. Amongst the finds were gemstones and fragments of various quartz varieties (agate, carnelian, jasper, rock crystal), garnet, lapis lazuli, sapphire, emerald, coral, amber, nacre, various rock types and various glasses; some were beautifully engraved. The samples were analyzed by electron microprobe, IR spectrophotometers and gas chromatography to seek their origins. The emerald was found to be from Djebel Zabarach, Egypt, a sapphire came from Sri Lanka and the amber from the Baltic. The materials were buried in the seventh century AD, while styles of the engravings point to a time between the end of the Republican age and the seventh century AD when they were made. E.S.

Tektites: their origins, properties and use.

C.E.S. Arps. *Holland Gem Extra*, **2**(4), 1997, pp 2–3.

Review of the nature, types and occurrence of tektites worldwide with a summary of the three main theories on their origin. At the present time it seems most likely that tektites and impact glasses are ejected products of large meteorite impacts on earth. Notes on identification are also given. M.O'D.

The mineralogical collections of the Ural Geological Museum.

V.N. Avdonin and Y.A. Polenov. *World of Stones*, **10**, 196, pp 46–53.

A number of gem-quality crystals are among the specimens in the collections of the Ural Geological Museum which forms part of the Ural Mining Institute in Ekaterinburg. Major items are described and a history of the enterprise given. M.O'D.

Sapphires from Laos and their inclusions.

G. Bosshart. *Holland Gem Extra*, **2**(4), 1997, pp 4–5.

Gemstone placers of Ban Huai Sai in north-western Laos are producing blue sapphires associated with nearby Quaternary alkali basalt bodies and are usually dark blue. Notes on colour variations are given and on characteristic inclusions, which include frequently-occurring high zircon, U/Th members of the columbite and monazite series, albitic feldspar, rutile, graphite and possibly apatite: other as yet unidentified minerals also occur. Growth structures are prominent but rhombohedral glide planes are absent: negative crystals in basal orientation are surrounded by iridescent fluid rosettes similar to those observed in Thai rubies. A reported source of ruby in Laos is now known to be in a jungle area in the south of the country. M.O'D.

Peruvian opal.

G. Brown. *South African Gemmologist*, **10** (2/3), 1996, pp 16–18, illus. in colour.

A blue opal without play of colour and found at the Acari copper mine in Peru is believed to owe its colour to finely dispersed inclusions of Cu^{2+}. Properties are the same as those shown by other examples of common opal. M.O'D.

Rhodonite of the middle Urals. History and mineralogy.

A.I. Brusnitsyn and A.N. Serkov. *World of Stones*, **10**, 1996, pp 32–40.

Fine ornamental-quality rhodonite is found in the middle Urals of Russia. Details of the material and its occurrence are given with notes on the genesis of the rhodonite rocks. M.O'D.

Crocoite from the Berezovsk gold mines.

A.F. Bushmakin. *World of Stones*, **10**, 1996, pp 28–31.

Some crystals of crocoite recovered from the Berezovsk gold mines near Ekaterinburg, Russia, are of gem quality. Chrome green sphene of similar quality is also found in the area. M.O'D.

Les camées sur malachite.

M. Duchamp. *Revue de Gemmologie*, **129**, 1996, pp 6–9, illus. in colour.

Malachite is not immediately associated with cameo manufacture but this short paper describes several notable examples with details of size, subject and date. M.O'D.

The gem belt of the Urals: an interminable adventure.

E.F. Emlin. *World of Stones*, **10**, 1996, pp 8–22, 6 maps, bibl. in Russian-language section of the issue.

The name Gem Belt is used to denote an area reachable in a day from Ekaterinburg in the Urals. The geology of the area is briefly explained. Details and a chronology of gem mining exploits are given and several of the major gemstone-producing areas are described in some detail. Some celebrated deposits include mines of the Alabashka vein field (blue topaz and beryl), Izumrudnye Kopi (emerald, alexandrite, phenakite), the Lipovskoye mines (pink and polychromatic tourmalines), the Semininskaya mine (greenish-yellow beryl), Shaitanskii Perelivt (agates) and Kornilov Log (rock crystal). Detailed descriptions of emerald, chrysoberyl, alexandrite and phenakite are given. M.O'D.

Jewelry-quality chrome-diopside from the Inagli deposit.

V.G. Gadiyatov. *World of Stones*, **11**, 1996, pp 10–14, illus. in colour, 2 maps.

Probably the world's largest deposit of facet-quality bright green chrome diopside is found at Inagli, eastern Siberia. The geology of the area is described and properties of the diopsides given: colours include a deep emerald-green, grey to greenish-brown and yellowish to brownish-green. Cr content averages 0.5% for the dark green crystals and 0.18% for the light green ones. Trivalent iron is believed to be responsible for the yellow colour. Specimens are reported to be exceptionally transparent. M.O'D.

Fonctions symboliques du quartz dans les sociétés humaines.

E. Gonthier. *Revue de gemmologie*, **129**, 1996, pp 12–17, illus. in colour.

Quartz, especially rock crystal, has played a major part in ornament from the earliest recorded times: several pieces are illustrated and briefly described. M.O'D.

The Dactyliotheca of the Pope Leo XII.

G. Graziani. *Periodico de Minerali (Roma)*, **65**(1–2), 1996, pp 79–204.

A study has been made of a collection of gems and ornamental stones, including 388 items of different cut and shape, given by His Holiness Pope Leo XII to the Mineralogical Laboratory of Rome University 'La Sapienza' in 1824. Hallmarks on a ring and two collets allowed the period and place of manufacture to be put at 1792–1809 in Rome. Most of the specimens appear to consist of small, polished, rounded or octagonal plates of various varieties of silica, but the first section includes 32 jewels mostly set in rings; detailed descriptions of these are given in an appendix, where they are seen to range from topaz, opal, aquamarine, garnet (previously catalogued as zircon or 'ruby spinel'), yellow diamond and yellow sapphire. R.A.H.

Rubini e Zaffiri: inclusioni.

E.J. Gübelin. *Gemmologia Europa*, **V**, 1996, pp 106–36.

Illustrated survey of inclusions in rubies and sapphires with particular reference to specimens obtained from recently discovered and worked deposits. M.O'D.

Hydrogrossular aus Suedafrika – die sogenannte 'Transvaal Jade'.

U. Henn. *Gemmologie. Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **45**, 1996, pp 189–97, 4 photos in colour, 3 photomicrographs, 3 tables, 2 graphs, bibl.

The so-called 'Transvaal Jade' is a translucent to opaque aggregate of hydrogrossular mined near Brits in the Transvaal. Colour is mostly intense green, but there are some pink specimens. Stringers of xenocrysts of pyroxenes, idocrase and chromite are common. Hydrogrossular is a solid solution of the binary series grossular $Ca_3Al_2(SiO_4)_3$ and tricalcium-aluminium-hexahydrate $Ca_3Al_2(OH)_{12}$ where the SiO_4 groups are partly replaced by OH. Water content ranges from 6.2 to 8.0% for the pink samples and 2.2 to 3.5% for the green. RI = 1.725–1.734, SG = 2.54–3.44 for the pink stones; the values for the green varieties are RI = 1.680–1.705, SG = 3.24–3.35. E.S.

Rubini: provenienze e caratteristiche.

E.A. Jobbins. *Gemmologia Europe*. **V**, 1996, pp 12–30.

A survey of some of the more recently-worked ruby deposits (Luc Yen and Khoan Thong in Vietnam, Lin Yaung

Chi and Yadana Kadaykadar in Myanmar and the Pailin area of Kampuchea). Some of the features distinguishing the rough crystals are described, with brief details of mining methods. M.O'D.

Paraíba tourmalines: distribution, mode of occurrence and geologic environment.

J. Karfunkel and R.R. Wegner. *Canadian Gemmologist*, **17**(4), 1996, pp 99–106.

Details are given of the occurrence of copper-bearing blue and green-blue tourmalines from the state of Paraíba, Brazil. Amethyst-violet or emerald green colours are attributed to Mn^{3+} and Mn^{2+}–Ti^{4+} charge-transfer, combined with Cu^{2+} absorptions. The local geology and the mode of occurrence of the tourmalines are described: constants are given in tabular form. Tourmalines of this type occur in two states, Paraíba and Rio Grande do Norte and have been found in at least five different localities. M.O'D.

The radiance of irradiated gemstones.

L.H. Luthjens. *Holland Gem Extra*, **2**(4), 1997, pp 6–11.

Details of the sources, use and results of high energy radiation on gemstones are given with particular reference to diamond and dark blue topaz. The safety of some of the procedures is also discussed. M.O'D.

Mineralientage München 1996.

P. Lyckberg. *Mineralien Welt*, **8**(1), 1997, pp 8–21.

Among specimens exhibited at the 1996 Mineralientage München were tanzanite from Merelani, Tanzania: epidote from Pakistan: citron-yellow tourmaline and intense blue aquamarine from western Nepal: transparent colourless hambergite crystals reaching 7.5 cm in length. From the Pamirs came rose-coloured spinel, orange clinohumite and violet scapolite as well as bicoloured tourmaline, and orange-brown and blue topaz. Corundum and spinel from Vietnam were on display and golden beryl from Orissa, India, crystals of which reached 8 cm in length. M.O'D.

Spektakuläre Quarzneufunde aus Zerrklüften des nepalesischen Himalaya.

G. Niedermayr. *Mineralien Welt*, **8**(1), 1997, pp 24–32, 2 maps.

Particularly large and developed examples of rock crystal have been recovered in the Himalaya of Nepal from alpine cleft-type deposits. The chief producing site is in the Northern Lake area of Dhading district. M.O'D.

Alkali basalts and associated volcaniclastic rocks as a source of sapphire in eastern Australia.

G.M. Oakes, L.M. Barron and S.R. Lishmund. *Australian Journal of Earth Sciences*, **43**(3), 1996, pp 289–98.

Clay-altered volcaniclastic rocks, products of the early explosive stages of Tertiary basaltic episodes, are widespread in the New England region and elsewhere in E. Australia, and are the major source of the alluvial corundum, sapphire and perhaps ruby in the area. Exceptional grades have been recorded during exploration and mining of volcaniclastic sequences in some New England localities, and these rocks therefore constitute prime exploration targets in their own right. Tertiary basaltic lavas are a relatively minor source of corundum and sapphire, although they may be locally significant in the development of derived alluvial orebodies. The contribution by volcaniclastic rocks to detrital accumulations of resistate minerals (e.g. sapphire, zircon and spinel) is strongly and positively disproportionate relative to the abundance of the volcaniclastic rocks themselves. The sapphire-rich provinces are characterized by volcaniclastic rocks that are significantly more fractionated than the surface basalt lavas. R.A.H.

Montana sapphires.

M. O'Donoghue. *Holland Gem Extra*, **2**(4), 1997, pp 3–4.

Summary of the two types of sapphire occurrence in the state of Montana, USA, with notes to accompany an exhibition of specimens from both localities.

[Author's abstract] M.O'D.

On the history of mineralogical studies in the Il'men nature reserve.

V.A. Popov. *World of Stones*, **10**, 1996, pp 42–5.

The Il'men area of the Russian Urals is celebrated for the number and quality of its mineral species. Notes on some of the geological and mineralogical studies carried out on the area are given. M.O'D.

Bernstein der Lausitz.

W. Sauer. *Aufschluss*, **48**, 1997, pp 43–51, illus. in colour.

Details of the occurrence and nature of amber from Lausitz, Saxony, Germany, are given with some notes on the mining history of the area. Some gem-quality material is found in deposits dating from the Tertiary and Quaternary eras. In 1990 approximately 1500 g of amber were found.

M.O'D.

Zaffiri: provenienze e caratteristiche.

K. Scarratt. *Gemmologia Europa*, **V**, 1996, pp 32–54.

Brief overview of the world's main sapphire-bearing areas with particular reference to those in Thailand and Vietnam. Notes on mining techniques are given. M.O'D.

Rubine e zaffiri: storia e leggende.

H-J. Schubnel. *Gemmologia Europa*, **V**, 1996, pp 56–74.

Notes on the occurrence of the corundum gems in pictures and artefacts. M.O'D.

Mineral inclusions in the rock crystal of the subpolar Urals.

L.S. Skobel. *World of Stones*, **10**, 1996, pp 23–7.

Minerals occurring as inclusions in rock crystal from the subpolar Urals, Russia, are listed and described in alphabetical order. M.O'D.

Gemstones in the pegmatites of the eastern Pamirs.

A.M. Skrigitil. *World of Stones*, **11**, 1996, pp 16–25, illus. in colour, 2 maps.

Tourmaline, topaz, scapolite, danburite, beryl, apatite, hambergite and moonstone are described from the eastern Pamirs. These species occur primarily in the pegmatites of the Rangkul' pegmatite field and it is reported that the gem-bearing pegmatites are spatially and genetically related to granites of the Shatput intrusive complex of Alpine age. Properties and varieties of the gem species are given. M.O'D.

Introduction to analyzing internal growth structures: identification of the negative d plane in natural ruby.

C.P. Smith. *Gems & Gemology*, **32**(3), 1996, pp 170–84, 20 illus. in colour, 3 tables.

In the first part of the paper the author introduces the topic of growth structures in stones and how they occur and explains their use in separating synthetic stones from natural stones. He identifies the crystal planes by centring accurately the optic axis, which is then positioned in a vertical or horizontal position and allows the angles of the growth planes to be measured.

The author recommends modifying the stone holder on the microscope so that maximum rotation may be facilitated for positioning the optic axis. Connecting growth planes may also be identified by using a specially designed eye-piece attached to the microscope oculars that acts as a mini-goniometer.

In the past it has been assumed that natural and synthetic corundum, especially flux grown synthetics, could be distinguished on the basis of the negative rhombohedral d $(01\bar{1}2)$ plane, as it had not been observed in natural rubies. The author has found that a small percentage (~1%) of natural corundum from both Vietnam and Myanmar may show the negative d plane. Although very unusual in natural stones, the negative d plane should only be used as a tool for identification in combination with other structural features. J.J.

Alkaline rocks and gemstones, Australia: a review and synthesis.

F.L. Sutherland. *Australian Journal of Earth Sciences*, **43**(3), 1996, pp 323–43.

Valuable gemstones that occur in Australian alkaline rocks include diamonds in lamproites and kimberlites, and sapphires, zircons and rubies in alkali basalts; one gem zircon prospect is carbonatite. In this review, the tectonic settings and origins of Australian gem-bearing alkaline rocks are discussed. There are marked contrasts between diamond and sapphire/zircon associations across the continent. Most western cratonic areas exhibit episodic, sparse, deep alkaline activity from the diamond zone (2000–20 m.y.), while in eastern fold belt areas prolific Mesozoic/Cainozoic basaltic volcanism carried up considerable sapphire and zircon (since 170 m.y.). Some South Australian Mesozoic kimberlitic diamond events (180–170 m.y.) represent ultra-deep material rising through the mantle transition zone. E. Australian diamonds are unusual and at present their origin is contentious. Several different models compete to explain sapphire-zircon formation in E. Australia, and range from eruptive plucking of metamorphosed subducted materials to crystallization from felsic melts or carbonatitic reactions. A unique ruby, sapphire, sapphirine, spinel assemblage from the Barrington basalt shield in New South Wales marks a separate ruby/pastel-coloured sapphire genesis. R.A.H.

Alpine Neuheiten aus dem Karakorum.

A. Weerth, *Lapis*, **22**(1), 1997, pp 13–22.

Fine and sometimes gem-quality crystals of sphene, amethyst, near-colourless to pale yellow and pale lilac apatite, green epidote, greenish calcite and axinite have recently been recovered in the Karakoram Mountains of Pakistan. Some of the calcite is coloured pale green by profuse byssolite inclusions while chlorite gives a similar effect to some of the sphene crystals. M.O'D.

Münchner Mineralientage 1996.

C. Weiss and S. Weiss. *Lapis*, **22**(1), 1997, pp 23–39.

Gem-quality materials on display at the 1996 Munich Mineral Show included fine tanzanite crystals from Merelani, Tanzania (where a crystal weighing 3210 ct has been found): rock crystal from the Urals: ruby crystals in phlogopite from Dhading, Nepal: amethyst crystals from Guerrero, Mexico: fluorite and sphalerite from Chen Zhou, Hunan Province, China: lilac spinel octahedra from south-east of Ratnapura, Sri Lanka. M.O'D.

Amber finds from Table Bay.

B.E.J.S. Werz, J.A. Lee-Thorp and D.E. Miller. *South African Gemmologist*, **10**(2/3), 1996, pp 39–44.

Amber specimens found in Table Bay, South Africa, are not thought to originate either from Europe or America. Specimens were recovered from the wreck of a ship voyaging from the Netherlands to the East Indies and it is possible that the amber came from Europe. Naturally-occurring amber is not recorded from South Africa. M.O'D.

Gemstones of the Timan-North Ural Province.

N.P. Yushkin. *World of Stones*, **10**, 1996, pp 3–7.

Gem species found in the geologically complex Timan-North Ural province of Russia include diamond in kimberlite pipes, silica gemstones, ruby, jadeite, nephrite, spinel, turquoise and a number of other materials. Particular attention is paid to the geology of the diamond deposits and to prospects for future developments in the recovery of many of the other species. M.O'D.

Jewellery

History of development of jewellery in the western world. Part 2.

J. Dykstra. *Canadian Gemmologist*, **17**(4), 1996, pp 112–17.

Covers mainly jewellery of the Byzantine empire and celtic work. M.O'D.

Synthetics and Simulants

Reconstructed rubies of South African origin?

G. Brown. *South African Gemmologist*, **10**(2/3), 1996, pp 32–5, illus. in colour.

Seven cabochons purporting to be reconstructed rubies were found to consist of red and colourless glassy fragments fused together into a solid mass, probably with a glassy matrix or binder. The fragments could be distinguished at 10x magnification. M.O'D.

Man-made substances simulating mainly massive type natural gem minerals.

I.C.C. Campbell. *South African Gemmologist*, **10**(2/3), 1996, pp 20–7, illus. in colour.

Ten specimens imitating turquoise, massive azur-malachite, coral, pink coral, malachite, massive rhodonite of light colour and coral-like colour, lapis lazuli, charoite and chrysoprase were tested and found to be sectile with a knife blade. From this and from other results presented in tabular form it was assumed that the materials were similar to very fine powders bonded with resin or other plastic M.O'D.

Structural analysis of flux grown emerald crystals.

J.-S. Lee, P.-L. Lee and S.-C. Yu. *Journal of the Geological Society of China (Taiwan)*, **38**(3), 1995, pp 273-85.

Crystals of synthetic emerald grown by a V_2O_5–PbO flux process had the composition SiO_2 66.31, BeO 13.70, Al_2O_3 19.42, Cr_2O_3 0.70, V_2O_5 0.04, = 100.17 giving the formula $Al_{2.05}Cr_{0.05}Be_{2.95}Si_{5.95}\ O_{18}$; their structure was refined to R 1.5% (*a* 9.203, *c* 9.172 Å, space group *P6/mcc*, D_{calc} 2.668 g/cm³). The partial substitution of the excess octahedral cations (Al and Cr) for the tetrahedral Be and Si produced a highly distorted BeO_4 tetrahedron, confirmed by bond-angle variance and NMR spectrum. The substitution also involves the incorporation of minor V atoms as impurities in the channels of the beryl structure: difference Fourier analysis showed V to be located at (0,0,0.2091) and (0,0,0.2909). The centre of these two positions is (0,0,$^1/_4$) which is the 2a site for alkali cations in hydrous alkali-rich beryl. The doublet configuration for V in the synthetic emerald is attributable to the high-*T* growth effect of these crystals. R.A.H.

Rubini e zaffiri: trattamenti, sintesi e imitazioni.

M. O'Donoghue. *Gemmologia Europa*, **V**, 1996, pp 76–104.

Survey of the manufacture of the corundum gemstones and of growth methods with notes on the characterization of synthetics and imitations. An overview of work so far carried out on the treatments used to improve colour is given with particular reference to corundum from Montana. M.O'D.

Russian flux-grown synthetic alexandrite.

K. Schmetzer, A. Peretti, O. Medenbach, H.-J. Berhardt. *Gems & Gemology*, **32**(3), 1996, pp 186–201, 23 illus. in colour, 5 tables.

There is difficulty distinguishing natural and synthetic alexandrites, notably the flux-grown synthetics especially if there is a lack of diagnostic mineral inclusions. Synthetic alexandrites are manufactured commercially in the USA and Russia, the latter producing particularly good imitations.

A brief history of flux-grown alexandrites is given, describing the three main processes for the manufacture of alexandrites. A sample of 200 Russian flux-grown synthetic alexandrites, mostly rough, were tested. Most were cyclic twins having one irregular face and some were fully developed single crystals. The results of various tests are given in detail. The main diagnostic properties were identified as a result of examining these samples. Under the microscope it is sometimes possible to detect residual flux or platinum particles in the synthetics. Using an X-ray fluorescence analysis traces of germanium, molybdenum and/or bismuth could be detected in the synthetics, elements which are not found in natural stones. In natural alexandrites there are absorption bands in the 2500 to 3000 cm⁻¹ range due to water and/or hydroxyls, which are absent in the flux synthetics. J.J.

BOOK REVIEWS

Ammolite.

D. Barnson, 1996. Selkirk, Manitoba, Canada R1A 2B2 [Box 179]: The Author. pp [20], illus. in colour, softcover. US$19.95. ISBN 1 55056 421 8.

Very attractively produced guide to ornamental fossil ammonite with a play of colour. Specimens are found in Alberta, Canada, and are marketed under the name ammolite or korite. Details and properties of the material are given and a fine series of photographs illustrate the different types of colour pattern for which, as in opal, various names have been coined. Both solid and composite specimens are sold. Commercial production began in 1981 though the potential of the material had been recognized in the early 1970s. Korite Minerals Ltd is the world's largest producer of ammolite. Some details and illustration of recovery methods are given. The quality of the photographs is first-class: a Japanese version of the text is also available from the publishers under the ISBN 1 55056 420 X. M.O'D.

Beautiful Queensland gems.

H. Bracewell, 1996. Treasure Enterprises of Australia [PO Box 383], Archerfield, Queensland. pp 24, illus. in colour, softcover. AUS$15.00 incl. air mail postage. ISBN 1 86273 101 2.

This most attractive book in larger than A4 format is aimed to give the amateur gem hunter some idea of the gemstone wealth of Queensland. It is also intended to raise the imaginations of many who have never thought of looking for gems and minerals. In both purposes it succeeds admirably. Queensland produces a wide range of gem and ornamental mineral species, from sapphire and topaz to magnificent chrysoprase and, of course, opal. Examples of many species are well illustrated in colour and the brief text succinctly describes the history and present status of some of the more important mines. General information on mines and fossicking concludes a text which certainly ought to attract readers from far outside Australia. M.O'D.

Professional jewellery appraising.

Richard H. Cartier, 1996. Fischer Presses, 1228, Avenue Rousseau, Sillery, Quebec, Canada. pp 178, softcover. CDN$32.00. ISBN 2 921225 23 9.

Books on valuing are not new but most that are available in the UK have originated from the US, and unfortunately, despite a common language, they have not usually travelled well across the pond. Such books have made little impression on the average British jeweller/valuer, who probably still regards American practice to be alien and often indecipherable.

This book, by one of Canada's top gemmologist/appraisers, is a lucid and welcome addition to the literature available for valuers. The style, language and lay-out offers much of value on the theory, ethics and practice of valuing. And it should be remembered that valuing has become more professional in the UK than ever before. While standards here have undoubtedly improved over the last ten years, much more needs to be done before we can truly speak of the science of valuing.

Cartier takes the reader through discussions of the different types of value, including particular emphasis on the principle of fair market value – a concept well understood in North America and applied under specific guidelines, but not so well understood here, to taking in procedures, documentation and presentation, grading gemstones and on to some horror stories.

Along the way, Cartier speaks good common sense on a few issues that have generated an unnecessary amount of hot air in the UK in recent years.

The current debate on computers and which program is the best is an issue covered by a section of less than one page, with the conclusion that this be viewed by the individual as simply another (useful) tool to be made of what you will.

The chapter on diamond grading is fairly straightforward but I am pleased to see that Cartier nails the current fad for a so-called SI 3 grade. This deserves to be discarded.

As far as the chapter on coloured gems is concerned, there is a discussion on the various grading systems in existence, with input from Nelson on the basic science of colour with emphasis on hue, tone and saturation. Cartier favours a simple system of coloured gem grading based on a numerical range of 1–10, with a clarity grading structure analogous to that for diamonds. Such an easy to understand concept, which I strongly favour, lends itself to ready translation to a price guide, such as the Guide Pricing System, to which more UK valuers are likely to subscribe.

Other useful elements in the book include a guide to appropriate mark-ups, which, although I think should not be copied verbatim here, are none the less in sympathy with the principle of flexible and diminishing (as values increase) mark-ups that I constantly preach, tables of useful formulae, chain patterns, a bibliography and, for the masochists amongst us, some algebraic formulae that left me for dead!

Overall I would rate this book excellent, and at a very affordable price, I recommend it to UK valuers. Richard Cartier has produced a readable book full of useful knowledge and sound common sense. Get it on your bookshelf! B.R.D.

Tourmalines, minéralogie, gemmologie, gisements.

J. Cassedanne, J.M. Le Cléac'h, P. Lebrun, 1996. Paris. pp 87, illus. in colour, softcover. Price on application to the journal at 10 rue de Marignan, 75008 Paris. ISSN [of parent serial] 0335-6566 [*Minéraux et fossiles*. Hors série no 3].

Most beautifully illustrated survey of the tourmaline group of minerals in which chemistry, mineralogy, nomenclature, tourmaline as a gemstone, mode of occurrence and prospecting methods, major deposits described by continent and a list of web sites from which further details can be obtained. A good deal of the text deals with Brazilian material and occurrences and each section has its own bibliography. The appearance of specimen details available only via a web site is timely and gemmologists should already be familiar with this unique source of information acquisition and publication. M.O'D.

Pearls, from myth to modern pearl culture.

David Doubilet, 1996. Schoeffel Pearl Culture, Stuttgart. pp 119, illus. in colour, hardcover in presentation sleeve. Price on application. ISBN 3 7701 3932 1.

The book is published to celebrate Schoeffel's 75th anniversary. It contains chapters on the history of pearls, taken from Kunz and Stevenson's *Book of the Pearl*, followed by photographic essays and a short text on some pearl-producing countries.

The colour photographs of both pearls and landscapes are superb, but the accompanying text is rather disappointing, being flowery in style and rather lacking in solid information. The chapters on the history of the pearl including the final pages describing the oyster and the growth of pearls, with clear diagrams, partly make up for this, but the pictures in the photo essay are so good that the book will surely be a hit with anyone interested in pearls or travel. M.C.P.

Glossary of mineral synonyms.

J. De Fourestier, 1994. Sanssouci Verlag, Montreal. pp 61, softcover, ring-bound.

Useful and easily-read guide to many (but not all – this would be impossible!) alternative names used at one time or another for minerals of established species status. Many of the names are attached to gem or ornamental species and when the second edition appears (scheduled for 1998 – the present one is said to be a draft) gemmologists and collectors will find it worth buying. As always, I have lingering doubts about some of the names cited in such books – many, I'm sure, never progressed beyond fanciful literature: this does not invalidate a worthy attempt to round them up, hopefully for the last time! M.O'D.

Ruby and sapphire.

R.W. Hughes, 1997. RWH Publishing, 4946 Clubhouse Circle, Boulder, CO 80301-3725. pp 511, illus. in colour, hardcover. £66.00. ISBN 0 9645097 6 8.

Covering the corundum gemstones, their nature, locations, properties, mode of occurrence and recovery methods, these and other sections accompanied by excellent and extensive bibliographies and by high-quality text diagrams and colour photographs, this major new book has to be on the bench as well as in the private library of serious gemmologists. For the amount of information presented the price is not excessive and my copy at least has survived quite a lot of student use, a good point to look for when the paper is heavy. Readers will find the personality of the author lurking in many places and like the garden robin he makes sure that you are aware of his presence. I found that an attractive feature of the book.

The corundum gems are a large subject to cover and there are many ways in which an author can approach it. The book opens with corundum in history, passes to chemistry and crystallography and thence to many areas which the gemmologist will find most useful. This part of the book includes a section on treatments with up-to-date information and illustrations. Synthetic corundum, composites and fashioning methods precede an interesting study of judging quality; while this aspect of gemstones has been made the subject of several useful small books, it is welcome here in this much larger text.

Preceding the area coverage is a review of corundum geology so that the reader does not come upon unfamiliar geological terms later on and have to search for their meaning. Then gem corundum-bearing areas are treated in alphabetical order of country. The book concludes with sections from Tagore's *Maṉi-Málá (A Treatise on gems)*, first published in 1879 and with notes on ruby and sapphire prices and how to estimate weight. There is an index in which most entries appear to be correct – I have checked only a sample. Major portions of the book are separated by sections of advertising, which are useful for addresses of dealers and which no doubt have helped with the costs of the book.

I found the book quite excellent and found no serious faults. The references are among some of the most comprehensive I have ever seen and the information is profuse and well arranged. Unexpected items such as a list of famous rubies with their descriptions, locations, weights and prices paid (where relevant), present location and references will save a lot of looking through sale catalogues (unaffordable for most private libraries), and other treasures make the book one of the most welcome additions to gemmological literature – improving all the time. All gemmologists should buy a copy. M.O'D.

Stones from heaven: ancient Chinese jade.

Los Angeles County Museum of Natural History, 1996. Los Angeles. pp 24, illus. in colour, softcover. Unpriced.

Short but very useful and well constructed guide to the materials, shapes and history of archaic Chinese jade, acting as a guide to an exhibition of the same name held in Los Angeles and Taipei. The guide selects artefacts from the exhibition to demonstrate major themes and uses; the student of jade could scarcely begin with a simpler or more attractive guide. M.O'D.

Pyrit und Markasit [by various authors].

1996. Christian Weise Verlag, Munich. pp 96, illus. in colour, softcover. DM 39.00. ISBN 3 921656 38 9 [*extraLapis* 11]

Among the papers devoted to a beautifully illustrated celebration of pyrite and marcasite is an examination of pyrite as an inclusion in a number of minerals, including gem species. Pyrite's crystal form and habit are described in other papers and conservation of the iron sulphide minerals, always difficult, is discussed. M.O'D.

Hoseki: Shouchu o kagaku suku. Shuyo hoseki no sekai. [Gems: science in a microcosm. The world of principal gemstones.]

JUNKO SHIDA, 1996. Zenkoku hoseigaku kyokai, Tokyo [National Gemmological Association] 1-24 Chuo-ku, Akashi-cho, Tokyo Bihokaikan, Tokyo T-104, Japan. pp 66, illus. in colour. 19,000 yen.

A superbly illustrated account of the types and significance of inclusions in the major gem species, their synthetic counterparts and treated forms. Notes on other phenomena are included and many photographs show specimen response to cathodoluminescence, to UV radiation and, in the case of treated corundum, to laser tomography. Dimensions of specimens are given in all photographs and, as always, very high magnification is not usually needed. Preliminary matter gives details of some of the photographic techniques used.

This is the only text I know in which the reader is able to detect some of the differences between hydrothermal and flux-grown emeralds and the features to be expected in gem-quality synthetic diamond. Treated stones are given a good deal of prominence.

The quality of the photographs and the general standard of production are the best I have seen in the literature so far, making other texts appear well-worn by comparison. Despite the whole of the text being in Japanese, captions contain at least one line of English so that the non-Japanese reader can be certain of the identity of the stones illustrated. Since the microscope is gradually displacing tests using undesirable chemicals, greater familiarity with the interior of gemstones is vital for the gemmologist. M.O'D.

Gold jewelry from Tibet and Nepal.

J.C. SINGER, 1996. Thames and Hudson, London. pp 142, illus. in colour, hardcover. £19.95. ISBN 0 500 97442 X.

Gold jewellery from this area of Asia has long held a particular fascination for the collector even though most inhabitants of the countries would have seen little of it. The hierarchical nature of Tibetan and Nepalese societies not only allowed a wide variety of jewellery to be made but also made it possible for the wearer's status to be established. Written records are scarce and not always easy to understand, making correct evaluation of artefacts of particular importance.

The book is especially well-illustrated with a set of 100 colour photographs in which the pieces are set against a black background. Preceding chapters deal with ornaments of faith, materials and master craftsmen, the iconography of Himalayan jewellery and the Himalayan amulet. The quickest run-through of the colour plates will show that, as expected, turquoise is by far the most used gemstone. Chapters are well-referenced and there is also a high-quality bibliography. Considering the poor quality of some of the books and articles on this particular area of Asian jewellery, this book represents the level of scholarship that should be aimed at – though there is much more work to do. M.O'D.

Derbyshire black marble.

J.M. TOMLINSON (with geological appendices by T.D. Ford), 1996. Peak District Mines Historical Society, Spec. Publ. No 4. pp 95. £9.95.

This work gives a beautifully illustrated account of the black marble from Ashford-in-the-Water, near Bakewell in Derbyshire, and the inlay work carried out in it, using such materials as Blue John, malachite, baryte and various coloured marbles. The Ashford marble is a very fine-grained, dark, bituminous limestone of Carboniferous age; this was mined from around 1750 until 1905. Such smaller items as brooches, pendants, paperweights and candlesticks, and the larger tabletops and urns, are now collectors' items. There are numerous colour plates and also black-and-white photographs of the workshops; in an appendix photographs are given of some of White Watson's geological tablets showing cross-sections of Derbyshire strata. R.A.H.

Wahroongai news.

Special commemorative issue ... 50th Anniversary, 1946–1996. 1996. East Brisbane: Gemmological Association of Australia, Queensland Division. pp 68 [forms vol. 30 no. 10 of *Wahroongai news*].

Interesting and informative account of the formation of the Queensland Division of the Gemmological Association of Australia, of which the first meeting took place on 29 October 1945. Details of the officials and activities are presented in a way which is an example of how archival material should be published – after it has been retained and subjected to scholarly appraisal. Similar associations should take note! M.O'D.

Opals.

F. WARD, 1996. Gem Book Publishers [7106 Saunders Court, Bethesda, MD 20817 USA]. pp 64, illus. in colour, soft-cover. US$9.95 plus $2.50 s & h. [Fred Ward Gem series.]

An accompanying letter sent to me gave details of how the book was produced and how easy production was compared to earlier volumes in the series. Today the whole text and illustrations fit easily on to a single CD and, apart from the final film made by the prepress house, this was all the material needing to be sent around. The book also contains more photographs than previous ones in the series, an increase of some 50 per cent. Readers might like to note that the drop capitals are each taken from a different opal!

The book itself is of course essential for all with the slightest interest in opal, and to the experienced gemmologist it is particularly valuable in the currency of much of the information provided. The text is divided into history and lore, black opal, boulder opal, light opal, crystals and fossils, Mexican opal, assembled opals, synthetics and simulants, buying and caring for opal and an explanation of the play of colour.

The main opal fields are described and commercial transactions introduced and illustrated – a welcome feature since many gemmologists have no idea of the difficulties, personalities and traditions involved – sometimes a long way from the 'pure' gemmology of the textbook. Also of great interest is the series of pictures illustrating the manufacture of a triplet. But the whole book is superb and another proof of how it is possible to cover a gem species in a single work. M.O'D.

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

OBITUARIES

William Donald Goodger died on 20 November 1996 aged 81. He will be remembered as the Canadian who was instrumental in creating an independent gemmology course that was recognized by the Gemmological Association of Great Britain.

Don was born on 15 March 1915 in Woodstock, Ontario. He received his BA degree from the University of Western Ontario in London in 1937. He went to Emmanuel College at the University of Toronto and was ordained a minister of the United Church of Canada in 1940. During his career as a clergyman he saw a rock collection in the home of a colleague and that led to his second career as a lapidary and gemmologist.

Don completed the correspondence courses leading to his Diploma and FGA in 1972. The following year he helped to found the North York Faceting Guild. He also served on the executive of the Canadian Gemmological Association from 1973 until 1995. During his term as president of the CGA in 1976 the journal *The Canadian Gemmologist* was launched and Don was the managing editor until 1980. That year he retired from his United Church position and he became the Director of Education for the CGA. With time now on his hands he was able to supervise the completion of the Canadian Diploma course which began in 1982.

For many years Don's home was a centre of gemmology where he taught and was involved in gemmology business.

Don's dedication, enthusiasm and generosity will be sorely missed by those of us who knew and worked with him.

Jeannine Dykstra, FGA

Graham Llewellyn. Those in the jewellery trade who knew Graham Llewellyn will need no appreciation to be written of him, least of all by me. But there are many people who did not have the good fortune to meet Graham and I hope my words will bring this delightful man into their life for just an instant.

I do not recall when I first met Graham, but it was not long after I joined Hancocks in 1955. My late father knew him quite well and it was he who introduced me. The first impression gained was Graham's gracious manner – not in any way patronising – simply gracious. As my career progressed in the trade I met him more and more and, eventually, I became responsible for buying jewellery for Hancocks and often attended the auction sales. He was most supportive to me in many ways during my years as Chairman of the Gemmological Association and, all in all, was very kind to me.

Graham joined Sotheby's in 1953 as a jewellery specialist having begun his career in the jewellery department of Harrods. He qualified as an FGA obtaining his Diploma with Distinction in 1948. As a matter of interest another successful candidate that year, also with Distinction, was Robert Crowningshield of the USA. Graham became a Director in 1964 and it was he who set up the very first jewellery sale Sotheby's held in Switzerland. He was chief executive of Sotheby Parke Bernet from 1981 until 1983, a time of great

ISSN: 1355–4565

strain for him personally. Since then he held many other senior appointments inside Sotheby's – but this is only a catalogue of his career and doesn't help you to 'know' Graham.

He was a tall man, slim enough to seem almost slender to those of us of a fuller figure, elegantly dressed, and his walk was almost languid. He was unflustered, unhurried, spreading an atmosphere of calm about him, but above all was his genuine politeness. He had a great sense of fun, his love of the English language led him to enjoy the most wicked of puns, and he had a warm comforting voice. As an auctioneer his style was admirable. He was very decisive, very clear, very observant and precise. In those days he had to know the names of all his regular buyers, not just the 'big' names, for the buyer's name was announced in the room as each lot was sold. It was a much more personal system than that of today where each bidder has a number and a paddle to wave about. Graham had no need of histrionics for he stamped his authority on the room from the very start of the auction. You wanted to buy from him, he had no need to persuade you. To me his gavel was more like the baton of an orchestral conductor, and he took all his sales at a great pace. I suppose attending one of his sales was more like going to the theatre, certainly not the circus!

Graham loved jewellery and particularly gemstones. In the days when he was chief executive and his time was taken up with the 'affairs of state' he was not as involved with jewellery as he had been. From time to time I would telephone him, eventually getting past the rampart of secretaries defending him from unwanted telephone calls, and tell him of a wonderful sapphire or emerald we had just bought suggesting he pop in on his way past Hancocks just to see it. Invariably he would do so just for the pleasure of seeing a beautiful gemstone.

The photograph kindly made available to me by 'Alex' Rhodes of Sotheby's shows Graham as many of us well remember him, smiling during one of his delightful chuckles. He is and will be sadly missed by all of us lucky enough to have known him; for his colleagues there must be a big void in their lives. Although he had retired from the mainstream of the business he was still a great influence. I shall remember him in many ways and always for his kindness, but perhaps above all he represented the very best in manner and manners. He was the Englishman personified, admired, respected by all and, perhaps even better, very well liked – and if you think that is too weak a word spend a moment or two to look it up in the dictionary, you may be surprised!!

Graham Llewellyn

David Callaghan

GIFTS TO THE ASSOCIATION

The Association is most grateful to the following for their gifts for research and teaching purposes, and for contributions towards the gemstone loan collection being set up by the Education Department (see An Urgent Request below):

Mr George Barrell, Kimberley Diamond Ltd (UK EEC office), Windsor, for rough rubies from the John Saul Mine, Tanzania, and rough emeralds from Manyara, Tanzania.

Mr Santpal Singh Chawla, SS Agencies ROP, Bangkok, for 95 sapphires of various colours.

FORTHCOMING MEETINGS

25 April	**Midlands Branch** AGM followed by *Gems from the Law* by John Bugg, LLB, FGA DGA. The Jewellery Quarter Discovery Centre, 77 Vyse Street, Birmingham 18.
27 April	**Midlands Branch.** Gemmology Seminar for Preliminary students. To be held at 3 Denehurst Close, Barnt Green, near Birmingham.
4 May	**Midlands Branch.** Gemmology Seminar for Diploma students. To be held at 3 Denehurst Close, Barnt Green, near Birmingham.
7 May	**London.** Terry Davidson of Cartier Ltd will speak on *150 years of Cartier.* Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU.
9 May	**Annual Trade Luncheon** to be held at the Langham Hilton Hotel, London W1. The guest speaker will be Mr Robin Buchanan-Dunlop, Clerk of the Worshipful Company of Goldsmiths.
18 May	**Midlands Branch.** Gem Club: A diamond grading day with Gwyn Green. 3 Denehurst Close, Barnt Green, near Birmingham.
21 May	**North West Branch.** Doug Garrod, the Education Executive at the GAGTL will give a talk entitled *The ins and outs of gemstones.* Church House, Hanover Street, Liverpool 1.
25 May	**Scottish Branch.** Lapidary Session. 12 noon at the National Museum workshop in Granton, Edinburgh.
18 June	**North West Branch.** Social evening and Bring and Buy. Church House, Hanover Street, Liverpool 1.
15 June	**Scottish Branch.** Field trip. Venue to be arranged.
30 June*	**London.** Annual General Meeting and Reunion of Members followed by a Bring and Buy Sale. Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU.
9 July	**London.** Dr Robert Young will give a talk entitled *Exploring for diamond, emerald and alexandrite in Europe.* Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU.

A date for your diary

GAGTL CONFERENCE
Collectors' Gems

The 1997 Annual Conference is to be held on Sunday 9 November at the Barbican Centre, Silk Street, London EC2Y 8DS. Full details will be announced in the July issue of the *Journal.*

For further information on the above events contact:

London: Mary Burland on 0171 404 3334
Midlands Branch: Gwyn Green on 0121 445 6359
North West Branch: Joe Azzopardi on 01270 628251
Scottish Branch: Joanna Thomson on 01721 722936

**Please note the change of date.*

Mrs Luella Dykhuis, Tucson, Arizona, for assorted stones including emerald, opal, quartz, Montana sapphires, spinel and topaz.

Mr Suresh Ellawala of Ellawala Exports, Colombo, for a contribution towards the stone loan collection.

Mr L.J. Fifield, FGA, Pinner, for three books: *Blue john cavers and blue john mine* by A.E. Ollerenshaw, *The history of blue john stone* by A.E. Ollerenshaw, R.J. Harrison and D. Harrison, and *Stump Cross caverns* by G. Gill.

Mr Dennis Price for garnet with inclusions.

Mr Wu Chao Ming, Taipei, Taiwan, for a cut diffusion-treated ruby.

AN URGENT REQUEST

Please will all members and their acquaintances search into the inner recesses of their 'bit-boxes' and around the darkest corners of desks and workbenches for those unwanted cabochons, doublets, beads, pastes, diamond and any other gem materials that they no longer need. Such gems may still have lots of life in them and if you send these to Ian Mercer at the Education office at the GAGTL they will all be acknowledged and put to work in our many and various student and trade tutorial stone sets and for the new loan collection. We have a great variety of requirements to help with training and demonstrations both in the UK and overseas and your help would be most welcome.

For instance, the Education office is now starting the process of setting up an extensive collection for loan of relevant gem materials especially for Correspondence Course gemmology Diploma students. Initially the collection will be available to UK students but it is hoped that this service will eventually extend overseas. We already provide stone sets for UK Allied Teaching Centres and these sets will be improved to help maintain the standard of practical tuition.

MEMBERS' MEETINGS

London

On 15 January at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU, Christopher M. Welbourn, Principal Scientist at the De Beers DTC Research Centre, Maidenhead, gave an illustrated lecture entitled 'Growth and identification of synthetic diamonds'.

On 19 February at the Gem Tutorial Centre, Mr Geoffrey C. Munn, Managing Director of Wartski, gave a talk entitled 'Sleepers – rediscovery and reattribution in the antique jewellery trade'. As well as illustrating his lecture with a collection of fascinating slides, Geoffrey also displayed several of the pieces he had been discussing.

On 12 March at the Gem Tutorial Centre, Mr Adrian Klein of A. Freeman (Precious Stones) Ltd, and Judy Head of the Hatton Garden Association, gave a talk entitled 'How will our Garden grow?' Adrian looked at the chequered history of Hatton Garden and how it might cope with the demands of the new millennium, and Judy outlined the current initiatives to develop the area.

Midlands Branch

On 7 December 1996 the Annual Dinner of the Branch was held at Barnt Green.

On 31 January 1997 at the Discovery Centre, 77 Vyse Street, Birmingham 18, members enjoyed a Bring and Buy Sale and Quiz.

On 28 February at the Discovery Centre, Mr E. Alan Jobbins gave an illustrated talk entitled 'A gemmological journey from the Alps to Vesuvius'.

At Gem Clubs held at Barnt Green on 23 February and 23 March, Mr Eric Emms spoke on treated stones and Mr Alan Hodgkinson on synthetic gemstones and their identification.

North West Branch

On 19 February members of the Branch visited the Liverpool Museum to view the Power and Gold exhibition. A brief introductory talk was given by Ms Lynne Stumpe, the Exhibition Curator.

On 19 March at Church House, Hanover Street, Liverpool 1, Mr Brian Dunn gave a talk entitled 'Gemstones – a valuer's heaven or hell?'

Scottish Branch

A Lab Night was held on 12 February at Barmulloch College, Glasgow.

On 14 March at the Royal Bristol Hotel, Princes Street, Edinburgh, Mr Ewen Taylor gave a talk on valuation.

GEM DIAMOND EXAMINATIONS

In January 1997, 32 candidates sat the Gem Diamond Examination worldwide of whom 25 qualified, 4 with Distinction. The names of the successful candidates are listed below:

Qualified with Distinction

Kabiotis, George, Athens, Greece
Huali, Yao, Wuhan, P.R. China
Torrent, Denise, Geneva, Switzerland
Tsang Wai Yi, Rita, London

Qualified

Buxani, Reema Haresh, Hong Kong
Chen, Da, Wuhan, P.R. China
Chen, Shiyi, Wuhan, P.R. China
Chih-Chung Yuan, Joe, Wuhan, P.R. China
Chow, Chun Hung William, Hong Kong
Fowle, Michael J., Broughton, Stockbridge
Hun, Lai Chan, Macau
Kepel, Arthur Mvuta, London
Kenny, Sark, Hong Kong
Lawrence, George, Hove
Lemessiou, Maria A., Nicosia, Cyprus
Lodge, Tim, Muswell Hill, London
Mileris, Vladimir C., Bournemouth
Poon, Ka Vai, Hong Kong
Richardson, Cathryn, Silsden, Nr Keighley
Scott, Doreen M., Liverpool
Tse, Stephen Y.Y., Hong Kong
Tsui, Tommy Kin Wah, Hong Kong
Yuan, Jia, Wuhan, P.R. China
Zhang, Yanjun, Wuhan, P.R. China
Zhu, Miao, Wuhan, P.R. China

EXAMINATIONS IN GEMMOLOGY

In the Examinations in Gemmology held worldwide in January 1997 117 candidates sat the Preliminary Examination of whom 89 qualified. In the Diploma Examination 175 sat, of whom 73 qualified, one with Distinction. The names of the successful candidates are as follows:

Diploma

Qualified with Distinction

Li Liping, Wuhan, P.R. China

Qualified

Battiscombe, Brigid, London
Cai Bing, Guilin, P.R. China
Cao Huasong, Beijing, P.R. China
Chang, Morley Sheng-Hong, Seattle, Wash., USA
Chang Yeun Hwa, Taegu, Korea
Chen Liang-Hsuan, Toronto, Ont., Canada
Chen Yingli, Wuhan, P.R. China
Chen Yingying, Wuhan, P.R. China
Choi Su-Ok, Taegu, Korea
Chu Li-Ju, Taipei, Taiwan, R.O. China
Courage, Bruce Crandall, Mahwah, NJ, USA
Dai Fei, Wuhan, P.R. China
Davies, Paul B., Great Missenden
Dong Ping, Wuhan, P.R. China
Duncan, Kenneth Greg, Silver Spring, MD, USA
Dupuy, David John, London
Friedberg, Guy, London
Gao Hongwei, Wuhan, P.R. China
Guastoni, Alessandro, Milan, Italy
Guo Jize, Wuhan, P.R. China
He Xinping, Guilin, P.R. China
Hunter, Rachel Suzanne, Bath
Jackson, Stephen D., Perranporth
Jiang Renyi, Shanghai, P.R. China
Johnston, Dale, Dundonald, Co. Down
Kafetsis, Georgios, Athens, Greece
Kearton, Michael, Eastbourne
Kuang Yonghong, Guilin, P.R. China
Lamb, Maria Tegwen Hotung, Hong Kong
Lau Joyce Pao-Ching, Hong Kong
Lee Yow Hon, Tuen Mun, Hong Kong
Leung Yuen Fan, Hong Kong
Li Dongsheng, Guilin, P.R. China
Li Ki Wing, Kennedy Town, Hong Kong
Li Ruling, Xiang, P.R. China
Lim Seong Jin, Taegu, Korea
Lin Shwun-Jiun, Taipei, Taiwan, R.O. China
Liu Danyang, Wuhan, P.R. China
Liu Yang, Wuhan, P.R. China
McInnes, Catriona O., Edinburgh
McInnes, John L., Edinburgh
Made, Lollo Harriet Annika, Hong Kong
Mao Lingyun, Beijing, P.R. China
Marolla, Marianna, Athens, Greece
Nang Mo Kham, Yangon, Myanmar
Qi Wang, Wuhan, P.R. China
Qiao Li, Wuhan, P.R. China
Schellekens, Ben J., Capelle a/d Yssel, The Netherlands

Seok Jeong-Won, Taegu, Korea
Shao Bing, Shanghai, P.R. China
Shao Zhen-Yu, Shanghai, P.R. China
Starreveld, Francis M.M., Hilversum, The Netherlands
Thant, Tun Min, Yangon, Myanmar
Triantafillos, Spiridon, Athens, Greece
Tsang Shiu King, Kowloon, Hong Kong
Tun, Than, Yangon, Myanmar
Tun Tun, (a) Gant Tal Yang, Yangon, Myanmar
Uriben, Awr, Bellflower, CA, USA
Wang Chunsheng, Beijing, P.R. China
Wang Hsiao-Fei, Taipei, Taiwan, R.O. China
Wang Hongwei, Wuhan, P.R. China
Wang Hua, Wuhan, P.R. China
Wang Qi, Wuhan, P.R. China
Xi Bo, Wuhan, P.R. China
Xia Songyao, Beijing, P.R. China
Xiaoyan Ji, Wuhan, P.R. China
Yang, Eun Kyoung, Daejon, Korea
Yu Man, Wuhan, P.R. China
Yun Hwa Choi, Taegu, Korea
Yung Yung Chong Sylvia, Toronto, Ont., Canada
Zhang Sumei, Guilin, P.R. China
Zhu Yong, Guilin, P.R. China

Preliminary

Qualified

Al-Buflasa, Hanan Mubarak, Manama, Bahrain
Amor, Miranda, Taunton
Anastassopoulou, Angeliki A., London
Bappoo, Reenabai, London
Boccard, Jean-Marie, Geneva, Switzerland
Boddy, Carl S.R., Hong Kong
Brunstrom, Isabella Carin, Stockholm, Sweden
Chen, Hua, Beijing, P.R. China
Chen, Tao, Shanghai, P.R. China
Choi, Uk, Daejon, Korea
Choi, Su-ok, Taegu, Korea
Chong, Yuen-Kwan, Central, Hong Kong
Christou, Angelos G., Islington, London
Clements, Julia Helen, West Hampstead, London
Collins, John Raymond Frank, Swansea
Colombo, Fabrizio, Torino, Italy
Davidge, Elizabeth Anne, Pimlico, London
Davies, Maggie, Oxford
Deutscher, Gilad, London
Fukui, Osamu, Tokyo, Japan
Gevorkian, Vardan, Holmestrand, Norway
Gomez, Jorge E., London
Harding, Rachel Anne, Twickenham
Hill, Emma, Maida Vale, London
Hsieh, Juan Ku-Wei, Taipei, Taiwan, Rep. China
Infuehr, Nicole, London
Irtelli, Pierre Camille, Romford
Isacsson, Eva Johanna, Vilhelmira, Sweden
Jacquat, Stephane, Geneva, Switzerland
Kitazawa, Yoko, Tokyo, Japan
Komninos, Michael, Athens, Greece
Lai, Ho Yan, Kowloon, Hong Kong
Lam, Jill, Rochester
Lau, Bik Lin (Tolisa), Chai Wan, Hong Kong
Lee, Shui Chun, Hong Kong
Leung, Raymond Ying Kit, Aberdeen, Hong Kong
Li, Ling, Shanghai, P.R. China
Li, Wei, Shanghai, P.R. China
Lin, Chief, Kaohsiung, Taiwan, Rep. China
Lin, Zheng, Shanghai, P.R. China
Liu, Hui, Shanghai, P.R. China
Lodge, Tim, Muswell Hill, London
Luo, Xia Ying, Guilin, P.R. China
Ma, Huei Chi, Taipei, Taiwan, Rep. China
Maehara, Tamao, London
Marshall, Ralph Henry, Northwood
Millard, Simon Richard, Corsham
Mo, Yiming, Shanghai, P.R. China
Mutton, Valerie Jean, Langley
Naing, Myo, Yangon, Myanmar
Ng, Melloney Vanessa, Bexleyheath
Nuttall, Suzanne Kathleen, Hong Kong
Pan, Jie, Shanghai, P.R. China
Papadimitriou, Marianthi, Thessaloniki, Greece
Patel, Vishal Praful, Surat, India
Payne, Mark, Westbury-Sub-Mendip
Petersheim, Ragnar, Brumunddal, Norway
Portillo, Irma, Isle of Dogs, London
Qin, Hongyu, Guilin, P.R. China
Rackham, Christina J., Bentley, Nr Farnham
Renard, Joelle M., Ruislip
Sharma, Namita, Panchkula, India
Shen, Beiqi, Shanghai, P.R. China
Stratton, Claire Amanda, Clapham, London
Suh, Sung-Bong, Taegu, Korea
Tang, Tak Chuen, Yeun Long, Hong Kong
Taylor, Alison S.B., Chiswick, London
Teskeredzic, Senada, Sarajevo
Than, Tin Kyaw, Yangon, Myanmar
Tucker, Jonathan William, London
Van der Kuyp, Femke Mariken, Rotterdam, The Netherlands
Van der Vijgh, Caroline E., Diemen, The Netherlands
Vassiliou, Marianna, Nicosia, Cyprus
Vayrynen, Sanna Helena, Farnham
Verny-White, Catherine, Richmond
Wang, Chao, Guilin, P.R. China

GAGTL Gem Tutorial Centre

19 May	**Pearl Course** A new course organized by the *Retail Jeweller* to help retailers distinguish between natural, cultured and imitation pearls and evaluate quality, as well as providing a guide to pricing. For further details call Lynda Bresgall at the RJ on 0171 417 2865.
20 May	**Review of Diploma Theory** A day for Gemmology Diploma students to review their theory work and to prepare for the Diploma theory examinations. Advice on the consolidation and revision of facts, figures, principles, practical techniques and instruments. Let us help you to review your examination technique with the help of past questions. This review would help students who intend to enter the Diploma examination in June 1997. *Price £51.70; GAGTL students £37.00 (including sandwich lunch)*
24 and 25 May or 31 May and 1 June	**Two-Day Diploma Practical Workshop** The long-established intensive practical course to help students prepare for the Diploma practical examination; also highly effective for those in the trade and elsewhere to brush up on technique. This is the course to help you practise the methods required to coax the best results from gem instruments. The course includes a half-length mock exam for you to mark yourself. *Price £170.00 (£122.20 for GAGTL registered students) – includes sandwich lunches*
28 May	**Review of Preliminary Theory** A day for Gemmology Preliminary students to review their theory work and to prepare for the Preliminary examinations. Advice on the consolidation and revision of facts, figures and principles. Let us help you to review your examination technique with the help of past questions. This review would help students who intend to enter the Preliminary examination in June 1997. *Price £51.70; GAGTL students £37.00 (including sandwich lunch)*
14 and 15 June	**Weekend Diamond Grading Revision** This intensive weekend course has been designed for all students about to take the Gem Diamond Diploma. This workshop will include a mock examination to help students gain familiarity and confidence with examination conditions. *Price £141.00. Starts 10.00 a.m. Saturday.*
3 July	**The Natural History of Gems** Where, when and why do gems form? A different look at this planet's geology and dynamic nature. *Price £37.00 (including sandwich lunch)*
5 and 6 July	**FEEG Preparation for FGAs** A session to prepare Fellows for the new European examination in gemmology under the auspices of FEEG.
8 July	**FEEG Examination**
22 July	**A day of Amber, Coral, Pearl and Ivory** A review of the variety and characteristics of these and other organic gems, the best way to identify them and their most common imitations. *Price £123.00 (including sandwich lunch)*

Wang, Yi Fei, Guilin, P.R. China
Warrington, Jennifer Lucy, Auckland, New Zealand
Win, Sandar, Yangon, Myanmar
Wong, Yik Shih, Wimbledon, London
Xu, Lei, Shanghai, P.R. China
Xu, Zhiyi, Shanghai, P.R. China
Yang, Jung-In, Daejon, Korea
Ye, Lei, Guilin, P.R. China
Yumi, Yoshitake, London
Yu, Ping, Guilin, P.R. China
Zhou, Wei Ning, Guilin, P.R. China
Zhu, Ye, Shanghai, P.R. China
Zou, Hon Wah Coral, Kennedy Town, Hong Kong

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8SU, on 11 December 1996 the business transacted included the election of the following:

Diamond Membership (DGA)

Crowder, Michael John, Maidenhead, 1996
Quinn, Samantha Jane, Maidenhead, 1996
Yang, Hui Hsien, Kwai Chung, Hong Kong, 1996
Bilby David, Cheam, 1963
Bonjer, Chantelle, Abbotsford, BC, Canada, 1996
Damianidou, Teresa, Piraeus, Greece, 1996
Fong, Ka Chun John, Hong Kong, 1996
Karatzas, George, Athens, Greece, 1996
Sethia, Pankaj, Mumbai, India, 1996
Snyman, Johanna, E.W., Silverton, Pretoria, Rep. of South Africa, 1996
Wisawayodhin, Kitiya, London, 1996
Xuefang, Lin, Zhunhai City, P.R. China, 1996

Ordinary Membership

Al-rushaid, Yasmeen Abdullah, London
Armati, Alexander Virgilio, Badgemore, Henley-on-Thames
Barsk, Christer, Pello, Sweden
Bashour, Hiyam, London
Boucher, Garry Mark, Leeds
Bruen, Niamh, Dublin
Bruggisser, Christine Edith, Winterthur, Switzerland
Crabtree, Peter F., Harrogate
Ioannou, Alkis, Nicosia, Cyprus
Ioannou, Yiannos C., Nicosia, Cyprus
Karpasitis, Marios A., Larnaca, Cyprus
McKeown, Nicola, Plymouth
McNair, Amelia Kate, Putney, London
Moroz, Inessa, Jerusalem, Israel
Nizam, Zahid Sarwar, Lusaka, Zambia
O'Neill, Gordon Francis, Thornton Hough, Wirral
Plant, Jenifer, Southgate, London
Rayner, David Paul, Gerrards Cross
Romer, Derek Michael, Kilmaley, Co. Clare, Ireland
Savage, Joan Adele, Warley
Tester, Garry Michael, Crowhurst
Tsiropoulos, Aris, Nicosia, Cyprus
Zetter Mag, Christa, Vienna, Austria

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8SU, on 12 February 1997 the business transacted included the election of the following:

Diamond Membership (DGA)

Li, Liping, Wuhan, P.R. China, 1996

Fellowship (FGA)

De Poli, Vesta, London, 1982
Guan, Zichuan, Shenyang, Liaoning, P.R. China, 1996
Li, Li, Wuhan, P.R. China, 1996
Mao Yanying, Zheijiang, P.R. China, 1996
Michallat, Mark, Tadcaster, 1991
Norström, Stig Erik, Skärholmen, Sweden, 1977
Pandya, Manoj Kumar, Mumbai, India, 1983
Wang, Fenglan, Tanghsan, P.R. China, 1996

Ordinary Membership

Bena, Thomas, Thornton Heath
Chookruvong, Kanjana, Rajtawee, Bangkok, Thailand
Clark, Darel James, Farnham
Fujii, Noriyuki, Higashi-Osaka City, Osaka, Japan
Fukai, Hiroshi, Osaka City, Osaka, Japan
Fukumitsu, Keiko, Kawanishi City, Hyogo Pref., Japan
Hashimasa, Mitsuyo, Kanazawa City, Ishikawa, Japan
Hikita, Yoshitsugu, Osaka City, Osaka, Japan
Hirai, Kayoko, Matsubara City, Hyogo Pref., Japan
Hirano, Tomoko, Sapporo City, Hokkaido, Japan
Honda, Minoru, Osaka City, Osaka, Japan
Hotta, Kimiko, Ikoma City, Nara Pref., Japan
Hudson, Sally, Putney, London
Iimuro, Yukiko, Chiba City, Chiba Pref., Japan
Ikeda, Naoko, Kofu City, Yamanashi Pref., Japan

Ishizaki, Kuniko, Tokyo, Japan
Kaneda, Yukari, Toyama City, Toyama Pref., Japan
Kataoka, Hideyuki, Kobe City, Hyogo Pref., Japan
Kawabata, Hiroyuki, Matsubara City, Osaka, Japan
Kepel, Arthur Mvuta, London
Kodera, Yukiko, Aichi, Japan
Koselja, Michal, Turnov, Czech Republic
Koshiba, Shoko, Sagamihara City, Kanagawa Pref., Japan
Lalaounis-Tsoukopoulou, Ionna, Athens, Greece
Leishman, Douglas Alan, Haute Nendaz, Switzerland
Matsumura, Yasunao, Kadoma City, Osaka, Japan
Maxey, Theresa Butterfield, Albuquerque, New Mexico, USA
Misaki, Yumi, Tokyo, Japan
Miwa, Yosuke, Tokyo, Japan
Montgomery Iii, Robert Lee, Glendale, CA, USA
Moore, Rowan Duggan, Stoke, Coventry
Murakoshi, Mitsuko, Nagareyama City, Chiba Pref., Japan
Oka, Chiayu, Mii Gun, Fukuoka Pref., Japan
Okumura, Ayako, Osaka City, Osaka, Japan
Orlicky, Zbynek, Praha, Czech Republic
Otsuka, Yoshimasa, Tokyo, Japan
Phillips, Andrew Hodson, Gorebridge
Pierce, Paul Richard, Mount Bryan, South Australia, Australia
Samejima, Mutsuko, Nara City, Nara Pref., Japan
Schulze, Julia Helen, London
Serjent, Philip Ronald, Riyadh, Saudi Arabia
Shibata, Masakazu, Toyonaka City, Osaka, Japan
Sonoda, Natsumi, Kobe City, Hyogo Pref., Japan
Stanley, Brendan, Mayfair, London
Tanaka, Sakura, Kobe City, Hyogo Pref., Japan
Tanaka, Chieko, Tokyo, Japan
Vaughan, Howard John, Widmer End, High Wycombe
Wachiruksasawakul, Suvilai, Bangruk, Bangkok, Thailand
Wijeyawardena, Tharanga Kanchana, Milton Keynes
Yamamoto, Kanae, Kobe City, Hyogo Pref., Japan
Yamashita, Rie, Fukuoka City, Fukuoka Pref., Japan
Yasuzawa, Yusuke, Osaka City, Osaka, Japan
Yoneda, Chie, Nishinomiya City, Hyogo Pref., Japan
Young, Robert, Ely
Young, Roger, Flitcham, King's Lynn

Laboratory Membership

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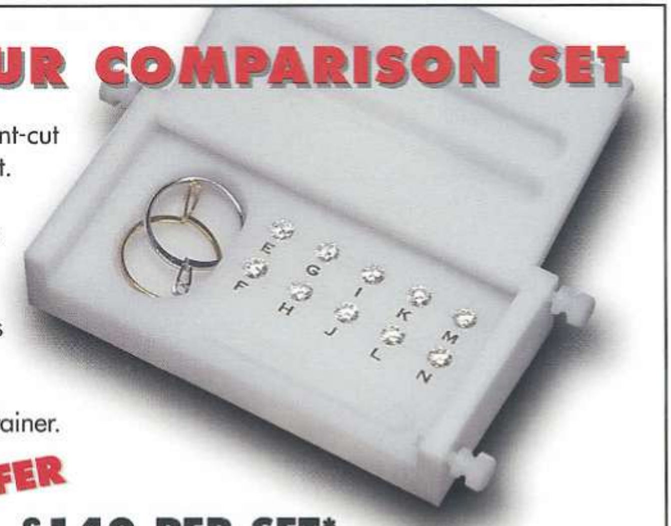
Euro Pearls, London EC1
Robin Finnegan Jeweller, Darlington
Quy Design, Croxley Green

Coat of Arms and Laboratory Logo

Members of the GAGTL having gained their Diploma in Gemmology or the Gem Diamond Diploma (FGA or DGA) may apply for the use of the Coat of Arms on their stationery or within advertisements.
Laboratory members are invited to apply for use of the Laboratory logo.

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

For further information please contact:
Jacqui Holness
Gemmological Association and
Gem Testing Laboratory of Great Britain
◆ 27 Greville Street (Saffron Hill Entrance), London EC1N 8SU ◆
Telephone: 0171-404 3334 Fax: 0171-404 8843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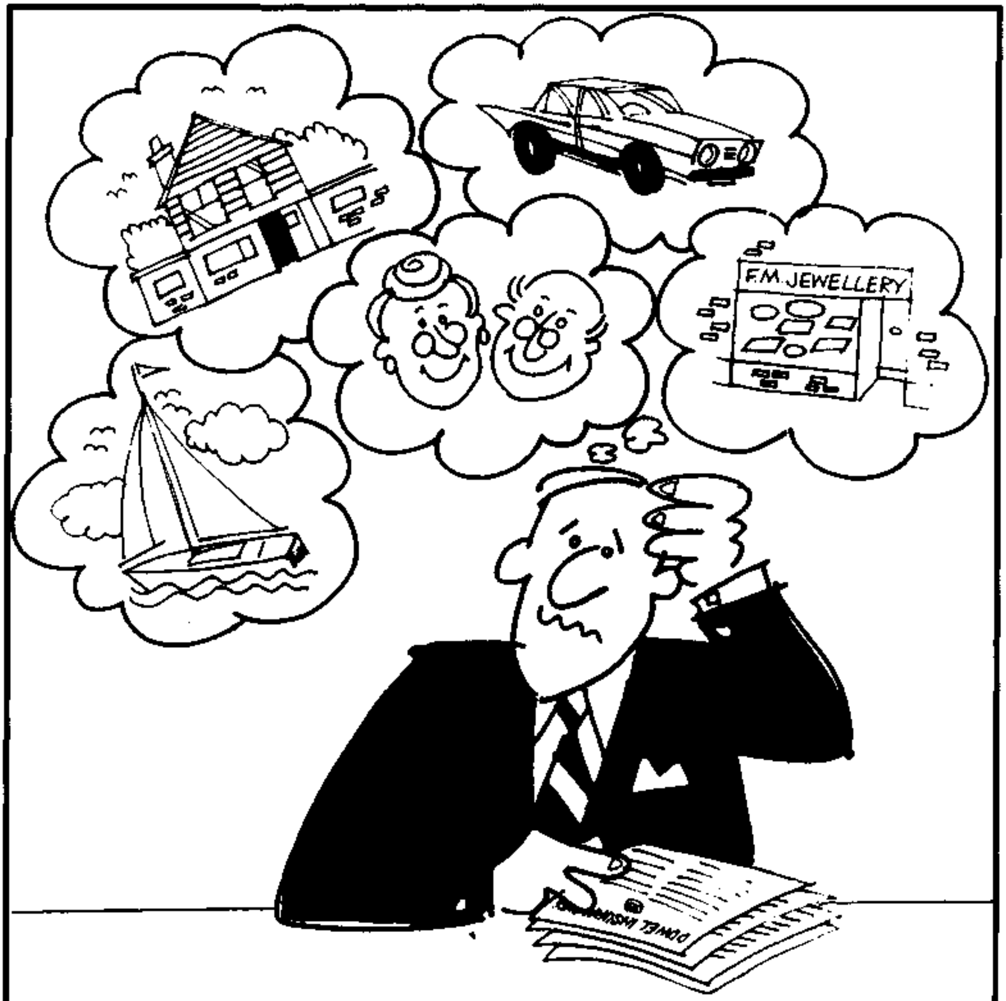
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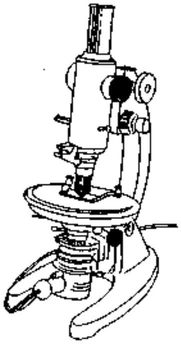

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The Editor is glad to consider original articles shedding new light on subjects of gemmological interest for publication in *The Journal*. Articles are not normally accepted which have already been published elsewhere in English, and an article is accepted only on the understanding that (1) full information as to any previous publication (whether in English or another language) has been given, (2) it is not under consideration for publication elsewhere and (3) it will not be published elsewhere without the consent of the Editor.

Typescripts Two copies of all papers should be submitted on A4 paper (or USA equivalent) to the Editor. Typescripts should be double spaced with margins of at least 25 mm. They should be set out in the manner of recent issues of *The Journal* and in conformity with the information set out below. Papers may be of any length, but long papers of more than 10 000 words (unless capable of division into parts or of exceptional importance) are unlikely to be acceptable, whereas a short paper of 400–500 words may achieve early publication.

The abstract, references, notes, captions and tables should be typed double spaced on separate sheets.

On matters of style and rendering, please consult *The Oxford dictionary for writers and editors* (Oxford University Press, 1981).

Title page The title should be as brief as is consistent with clear indication of the content of the paper. It should be followed by the names (with initials) of the authors and by their addresses.

Abstract A short abstract of 50-100 words is required.

Key Words Up to six key words indicating the subject matter of the article should be supplied.

Headings In all headings only the first letter and proper names are capitalized.

A This is a first level heading

First level headings are in bold and are centred on a separate line. The first text line following is indented.

B *This is a second level heading*

Second level headings are in italics and are flush left on a separate line. The first text line following is indented.

Illustrations Either transparencies or photographs of good quality can be submitted for both coloured and black-and-white illustrations. It is recommended that authors retain copies of all illustrations because of the risk of loss or damage either during the printing process or in transit.

Diagrams must be of a professional quality and prepared in dense black ink on a good quality surface. Original illustrations will not be returned unless specifically requested.

All illustrations (maps, diagrams and pictures) are numbered consecutively with Arabic numerals and labelled Figure 1, Figure 2, etc. All illustrations are referred to as 'Figures'.

Tables Must be typed double spaced, using few horizontal rules and no vertical rules. They are numbered consecutively with Roman numerals (Table IV, etc.). Titles should be concise, but as independently informative as possible. The approximate position of the Table in the text should be marked in the margin of the typescript.

Notes and References Authors may choose one of two systems:

(1) The Harvard system in which authors' names (no initials) and dates (and specific pages, only in the case of quotations) are given in the main body of the text, e.g. (Gübelin and Koivula, 1986, 29). References are listed alphabetically at the end of the paper under the heading References.

(2) The system in which superscript numbers are inserted in the text (e.g. ... to which Gübelin refers.^{3}) and referred to in numerical order at the end of the paper under the heading Notes. Informational notes must be restricted to the minimum; usually the material can be incorporated in the text. If absolutely necessary both systems may be used.

References in both systems should be set out as follows, with *double spacing* for all lines.

Papers Hurwit, K., 1991. Gem Trade Lab notes. *Gems & Gemology*, **27**(2), 110–11

Books Hughes, R.W., 1990. *Corundum*. Butterworth-Heinemann, London. p. 162

Abbreviations for titles of periodicals are those sanctioned by the *World List of scientific periodicals* 4th edn. The place of publication should always be given when books are referred to.

Volume 25 No. 6
April 1997

The Journal of Gemmology

Contents

Cover Picture

Solid and liquid inclusions in sapphire (top), and multiphase inclusions in tourmaline (middle) and emerald (bottom) are highlighted on a background of violet flux-grown synthetic spinel. Identification of such inclusions is now possible with Raman spectroscopy (see pp. 394–406). Photographs of inclusions by Dr Hans Werner Schrader, FGA, and of the spinel by Petri Tuovinen, FGA.

Registered Office: Palladium House, 1–4 Argyll Street, London W1V 2LD

ISSN: 1355–4565

Printed by Quadrant Offset Limited, Hertford, England