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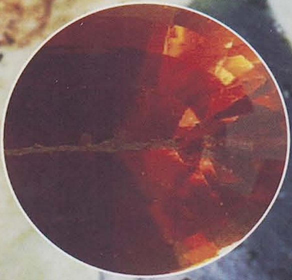
Chrome chalcedony

Sky-blue glass



Brazilian imperial topaz

The Gemmological Association and Gem Testing Laboratory of Great Britain

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Some effects of extreme heat treatment on zircon inclusions in corundum

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ABSTRACT: The mottled appearance and darkening of zircons in heat-treated corundum from Chimwadzulu Hill, Malawi, is due to melting and interaction of zircon with the surrounding corundum. At high temperature the original zircons are partially or completely replaced by monoclinic m-ZrO_2 (baddeleyite), and a glass-like phase. These two phases show regular intergrowths comprising rounded to elongate blebs of m-ZrO_2 distributed within a glassy matrix that may extend into the host corundum via healed microfractures. The glass shows variable compositions within the Al_2O_3-ZrO_2-SiO_2 system and only minor amounts of other components are present. The m-ZrO_2 phase contains up to 4.8% HfO_2 and is readily distinguishable from other Zr-phases by its characteristic Raman bands, notably the doublet at 180 and 192 cm^{-1}. Fluorescence peaks at 1091, 1146, 1169, 1199, 1220 and 1270 cm^{-1} and several others in the range 1390 to 1660 cm^{-1} provide an additional aid to identification. The observed intergrowths are interpreted as quench melt textures in the Al_2O_3-ZrO_2-SiO_2 system in which case heating above the eutectic temperature (*c.* 1750°C) is inferred. Identification of these quench phases and textures in zircon pseudomorphs can provide a useful criterion for recognizing cases of extreme heat treatment in other gem sapphires and rubies.

Keywords: baddeleyite, quench melt, Raman, ruby, sapphire, zircon

Introduction

Heat treatment is commonly used to improve the colour of natural corundums, sapphires and rubies for use as gemstones. Recognition of the extent to which stones have been heat-treated is of increasing importance within the gem trade because of the effect on market value. Various criteria may be used (Hughes, 1997). These include identification of glassy surface features, colour gradations and zoning, the destruction or modification of pre-existing fluid and solid inclusions and the development of planes of new groups of secondary inclusions, especially surrounding older ones.

In a recent paper it was noticed that zircon inclusions in corundum from

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Analytical methods

A JEOL JSM-6310 Scanning Electron Microscope (SEM) equipped for Energy Dispersive X-ray (EDX) analysis was used to analyse 15 zircon inclusions and their thermal decomposition products exposed on the surface of three carbon-coated, polished wafers. SEM Images were recorded at magnifications up to × 10,000. X-ray spectra were recorded on small areas (1 × 1 microns) using an accelerating voltage of 15kV and beam current of 1nA. Quantitative and semi-quantitative analyses, with an accuracy of ± 2 and ± 10 wt.% respectively, were carried out using pure metals, metal oxide and silicate standards and established ZAF correction procedures. Detection limits were of the order of 0.2 wt.% for all the elements analysed.

A Renishaw micro-Raman system equipped with an Ar-ion laser (514.5 nm) and attached to an Olympus microscope was used to record the Raman and related spectra of phases associated with the original zircon inclusions. Magnifications up to 600 × were used and spectra were obtained, in confocal mode, using count times of some 30 seconds. A pure silicon standard was used to calibrate the system at regular intervals. Raman shifts were reproducible to within 1 or 2 cm^{-1}.

Chimwadzulu Hill, Malawi (Rankin, 2002) show distinctive changes in heat-treated samples. The most notable features are mottling, darkening and the development of aureoles of emanating trails of secondary inclusions.

In the present paper we report on the phase changes that accompany this darkening and associated fracture-filling and discuss the temperature controls on their formation with reference to the system ZrO_2-SiO_2-Al_2O_3. The extent to which the identification and recognition of these phase changes may be used to distinguish heat-treated samples from other localities is also discussed.

Description of samples studied

Polished slices (1-2 mm) were prepared from three large crystals (1 cm) of heat-treated, pale blue/green sapphires from the Chimwadzulu Hill deposit of Malawi. Details of the temperatures to which these specimens had been heated were unknown to the authors. However, the gemmological features, geological occurrence and inclusion characteristics of these samples, including the distribution and morphologies of zircon crystals and clusters, have already been summarised and illustrated (Rankin, 2002). The zircons typically occur as well-formed, transparent, stubby or elongate crystals up to 150 microns in size. They commonly occur in clusters or groups of between 5 and 10 crystals. In heat-treated samples the zircons appear turbid, with darkened rims and radiating haloes of secondary inclusions within healed fractures.

Results

SEM/EDAnalysis

Many of the zircon inclusions when viewed under the SEM appeared well-formed, with sharp planar boundaries (*Figure 1*). They have stoichiometric compositions close to the idealized formula for zircon, $ZrSiO_4$, (*Table I*) with HfO_2 contents in the range 1.3 to 3.4 wt.%

Table 1: *Representative analyses of unaltered zircon and m-ZrO_2 associated with thermally decomposed zircons.*

	Zircon	*ZrO_2 phase*
Wt.%	*J1 198*	*J1204*
SiO_2	32.88	1.33
ZrO_2	65.97	98.77
HfO_2	1.34	3.87
Total	100.19	103.97

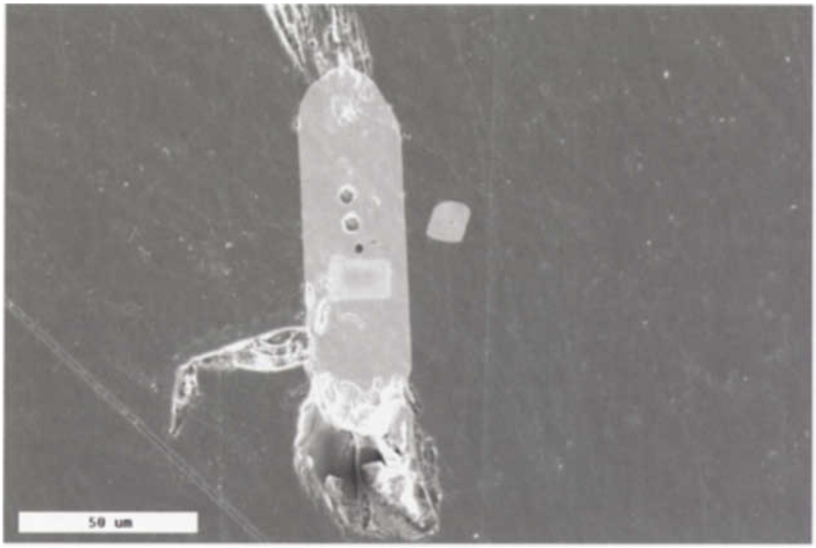

Figure 1: *Back-scattered electron image from a scanning electron microscope (SEM) of a single zircon inclusion exposed on the polished surface of heat-treated corundum. Note the sharp contacts between zircon and the host corundum, the radiating fractures and the three spheroidal inclusions in the centre of the zircon. The lighter rectangular area in the middle of the zircon is due to electron beam damage caused by rastering during analysis. Bar scale in microns.*

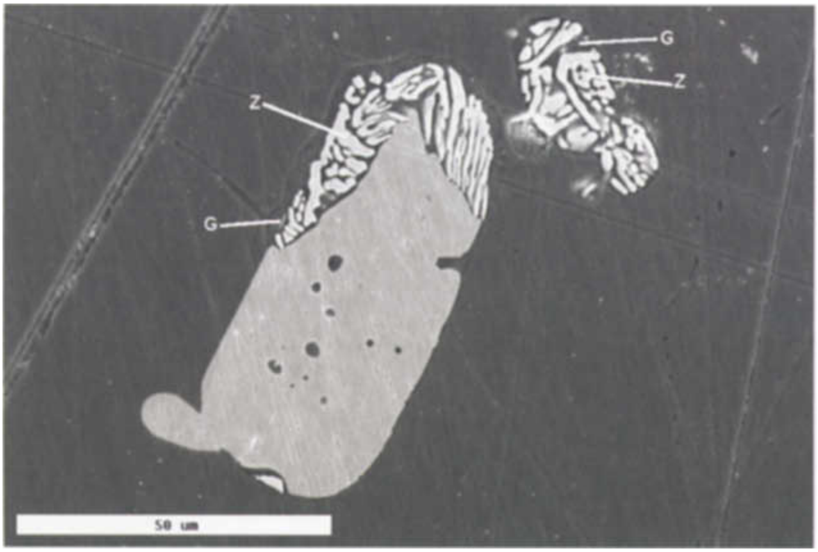

Figure 2: *Back-scattered electron image of two original zircon inclusions showing the extreme effects of thermal decomposition and replacement by a regular intergrowth of a bright ZrO_2 phase (Z) within a grey ZrO_2-SiO_2-Al_2O_3 glass-like phase (G). The larger zircon shows partial, and the smaller inclusion total, replacement. Note the irregular contact between the glass like phase and the host corundum in contrast to the sharp contacts between the unaltered zircon and corundum. Bar scale in microns.*

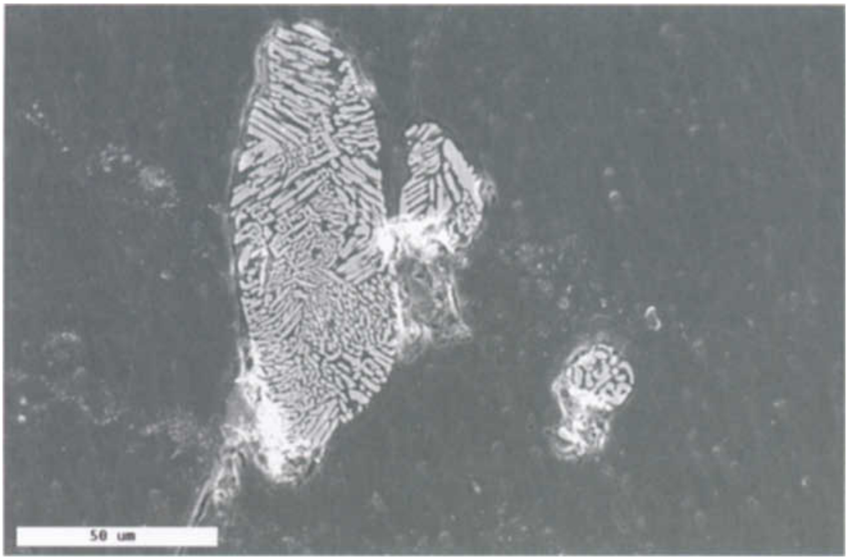

***Figure 3:** Back-scattered electron image of original zircon inclusions showing total replacement by ZrO_2 and the glassy phase. Note the distinctive and regular intergrowths characteristic of quench melt textures of these two phases. Bar scale in microns.*

(13 analyses gave a mean of 2.44 wt.%). Niobium was the only other element significantly above background (up to 0.9 wt.% Nb_2O_3). However, traces of thorium and phosphorous were also tentatively identified. Radiating fractures and spheroidal cavities within the zircons are also apparent, in keeping with previous observations under a normal light microscope (Rankin, 2002).

Other zircons displayed unusual embayment features (*Figure 2*). On closer inspection these appeared as two separate phases; brighter, sub-rounded to elongate blebs, up to about 10 microns in size, and a darker interstitial phase with irregular, sinuous boundaries with both the host corundum and unaltered zircon. In other areas, these light and dark features predominate (*Figure 3*) and even totally replace the original zircon. The light blebs typically showed preferred orientations and distinctive interlocking textures suggestive of eutectoid quenched melt textures commonly observed in high temperature melting experiments by petrologists (J. Clemens, pers. com., 2002). The X-ray spectra for these lighter and darker areas are distinctly different. The only elements detected in the lighter blebs, other than those attributable to interference from the host corundum, were Zr, Hf and O. The stoichiometric compositions are very close to ZrO_2 (*Table I*), with between 3.1 and 4.8 wt.% HfO_2 (n = 15, mean = 4.19) substituting for ZrO_2 in the crystal structure.

The X-ray spectra for the darker areas revealed significant but variable quantities of SiO_2, Al_2O_3 and ZrO_2 and minor amounts of Na, K, Ca and Fe. Semi-quantitative analyses showed variable compositions (*Table II*). These analyses do not correspond to the stoichiometric compositions for any known crystalline phase in the system ZrO_2-Al_2O_3-SiO_2 (Guo *et al.*, 1996; Lebeau *et al.*, 1995) and are more likely to reflect quenched silica-alumina-zirconia glass compositions as discussed later.

Only qualitative analyses of the contents of the radiating fractures and rounded inclusions within the zircons (e.g. *Figure 2*) were possible because of their non-planar surfaces. But, interestingly, their

Table II: Representative analyses of the institial glass-like phase between zircon and the m-ZrO_2 phase (A) and between zircon and corundum (B) in thermally decomposed zircons.

	A			B	
Wt.%	J1 213	J1 200	J1 197	J1 202	J1 187
Na_2O		2.52	1.97	3.02	
Al_2O_3	62.61	13.67	12.36	13.16	73.65
SiO_2	28.84	48.10	41.46	56.18	23.52
K_2O		0.37	0.39	0.48	
FeO		0.76	0.58	0.61	
ZrO_2	5.01	31.06	39.36	24.17	0.78
Total:	96.46	96.48	96.12	97.62	97.95

compositions are similar to the interstitial material surrounding the ZrO_2-rich blebs associated with altered zircons.

Optical properties and Raman/fluorescence spectra

Under a normal petrographic microscope the rounded ZrO_2-rich blebs exposed on polished surfaces appeared weakly birefringent whereas the darker interstitial phase appeared isotropic. The Laser-Raman spectra for these two phases were also distinctly different. The interstitial dark phase showed insignificant peaks between 100 and 1000 cm^{-1}, and only a strong to moderate, broad, continuous spectrum more typical of fluorescence commonly observed in corundums and rubies (e.g. Rankin, 2002). In contrast, the lighter blebs showed a number of major and minor peaks both above and below 1000 cm^{-1} (*Figure 4*).

Interpretation of the Raman spectra and identification of phases present

There are three known polymorphs of crystalline ZrO_2, or zirconia (e.g. Stefanc *et al.*, 1999), and the observed ZrO_2-rich phase could be any one of these:

- monoclinic m-ZrO_2 – stable below 1170°C (the mineral baddeleyite)
- tetragonal t-ZrO_2 – stable between 1170°C and 2370°C
- cubic c-ZrO_2 – stable between 2370°C and 2680°C (up to the melting point)

Monoclinic zirconia (baddeleyite) is the expected stable phase at room temperature, but the tetragonal or cubic forms could also exist as metastable phases at this temperature (Stefanc *et al.*, 1999). Cubic zirconia can be ruled out because of the complete mismatch with the Raman spectrum for this phase. Only a broad peak at around 600 cm^{-1} is observed in ZrO_2-rich end-members in yttrium and scandium stabilized samples (Nomura *et al.*, 2000. Raman spectra for both m-ZrO_2 and t-ZrO_2 up to 1000 cm^{-1} have been published recently by Stefanc *et al.* (1999) and Fredericci and Morelli (2000). The characteristic Raman peaks reported for t-ZrO_2 at 148, 267, 280 and 462 cm^{-1} are absent in the Raman spectra for the ZrO_2-rich blebs. However, the characteristic doublet at around 180 and 192 cm^{-1} noted for m-ZrO_2 by both sets of authors, together with additional peaks and bands for m-ZrO_2 at 224, 308, 335, 349, 383, 476, 503, 539, 561, 617 and 637cm^{-1} (Fredericci and Morelli, 2000) and for natural baddeleyite (McKeown *et al.*, 2000) are in excellent agreement with those for the ZrO_2-rich blebs which we can now

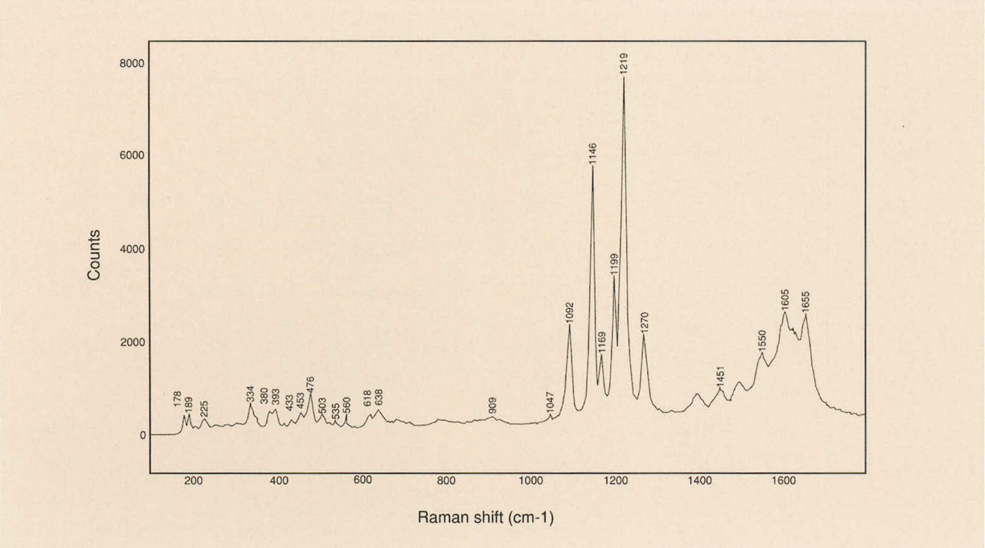

Figure 4: *Laser-Raman and laser-induced fluorescence spectra of the ZrO_2 phase in altered zircons. The Raman bands below 640 cm^{-1} are characteristic of m-ZrO_2 (baddeleyite). The peaks above 1000 cm^{-1} are not true Raman bands but are attributable to laser-induced fluorescence.*

positively identify as m-ZrO_2 (baddeleyite). Raman bands above 1000 cm^{-1} (*Figure* 4) have neither been reported nor predicted on theoretical grounds by any of these authors. The observed regularities in peak shapes and distributions are more characteristic of fluorescence spectra as often seen, for example, in fluorite where it is attributable to rare-earth element and associated luminescence activators (Burruss *et al.*, 1992). However, it is beyond the scope of the present paper to assign these peaks to rare earth elements or other trace elements.

The lack of significant Raman peaks, optical isotropism, non-stoichiometric and variable chemical composition of the darker interstitial phase leaves little doubt that it is an alumino-silicate-(zirconia) glass.

Discussion and estimates of heating temperatures

The observed embayment textures and identification of m-ZrO_2 (baddeleyite) within an alumino-silicate-(zirconia) glass demonstrates that the thermal breakdown of zircon was accompanied by melting and reaction with the corundum. Reactions can be modelled within the Al_2O_3-ZrO_2-SiO_2 system and may be summarized as follows:

Equation 1:

$Al_2O_3 + ZrSiO_4 = SiO_2\text{-}Al_2O_3\text{-}ZrO_2$
(corundum) (zircon) (melt)
represents melting on heating

Equation 2:

$SiO_2\text{-}Al_2O_3\text{-}ZrO_2 = ZrO_2 + SiO_2\text{-}Al_2O_3\text{-}ZrO_2$
(melt) (t-zirconia) (glass)
represents crystallization of t-zirconia and quenching of the residual melt to a glass on cooling

Equation 3:

$ZrO_2 = ZrO_2$
(t-zirconia) (m-zirconia)
represents solid-state recrystallization of t-zirconia to m-zirconia below 1170°C

The melt developed in Equation 1 also appears to have migrated into associated thermally-induced fractures to become trapped as planes of secondary inclusions during cooling and subsequent rehealing.

Melts within the system Al_2O_3-ZrO_2-SiO_2(AZS), co-existing with crystalline ZrO_2, only occur above the eutectic (minimum) melting temperature of 1750°C (Fredericci and Morelli, 2000). This suggests that in the Chimwadzulu corundum where melt textures are observed, and the resulting glass has a simple Al_2O_3-ZrO_2-SiO_2 composition (e.g. analyses J1 213 and J1 187 in *Table II*), heating is likely to have occurred above this temperature.

As previously noted, t-ZrO_2 is the stable zirconia polymorph at this elevated temperature but it readily converts to m-ZrO_2 (analogous to the mineral baddeleyite) below 1170°. This is the stable phase at room temperature, as observed in the present study and indicated in equation 2. Only exceptionally, as a result of extremely rapid quenching, for example, following fusion in an arc imaging furnace, is metastable t-ZrO_2 likely to be detected at room temperature (Yoshimura *et al.*, 1985).

Below the solidus in the model AZS system, mullite should appear as a stable aluminosilicate phase. However, the lack of characteristic Raman bands for this phase at 411 and 309 cm^{-1} (Shoval *et al.*, 2001), coupled with non-stoichiometric compositions shown in *Table II* suggest that it is not present, at least in significant quantities. Instead, the melt appears to have quenched to an amorphous glass.

Wider implications

In the wider context, the recognition of quench melt textures in zircon inclusions may be used as an indication of extreme heat treatment in rubies, sapphires and corundums (above 1750°C). However, this does not imply that all zircon inclusions displaying radiating haloes and dark borders in either heat treated or natural corundums (Guo *et al.*, 1996) have been heated above the eutectic melting temperature for the Al_2O_3-ZrO_2-SiO_2 system. Solid-state subsolidus, crystalline decomposition products can produce ZrO_2, and if the glass contains significant amounts of other components the liquidus and eutectic temperatures may be lowered somewhat (Rao *et al.*, 1997). Recognition of both crystalline ZrO_2 (as the stable monoclinic form) and an Al_2O_3-ZrO_2-SiO_2 glass would be needed to infer these higher temperatures. In subsurface inclusions it would not be possible to use ED analysis, and the relatively weak Raman bands for m-ZrO_2 might be difficult to detect if there is significant absorption of the Raman-scattering. However, the characteristic fluorescence spectrum for this phase between 1000 and 1800 cm^{-1} is very much stronger and would be much easier to detect. This provides a more widely applicable criterion for recognition of this phase as a thermal decomposition product of zircon inclusions in these and other ruby, sapphire and corundum samples from other localities.

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A new chrome chalcedony occurrence from Western Australia

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ABSTRACT: Chrome chalcedony, an ornamental rock variety new to Australia, has been identified from an occurrence in the Newman area of Western Australia (WA). Formed by silicification of serpentinite, some relict mineralogy and texture is retained. Gemmological properties are within the range characteristic of chalcedony with RI 1.539 and SG 2.57. The dark green colour is attributed to chromium (Cr_2O_3 0.24%) with strong red reaction to the Chelsea filter. The petrology and mineralogy of the material are described. The material was characterized using the techniques of XRF, XRD, UV-Vis-NIR and Raman spectroscopy. Mogánite, recognized in 1999 as a silica polymorph, was detected by XRD, and confirmed by Raman spectroscopy. Mogánite and α-quartz form part of the chalcedony matrix. Mtorolite, a variety of chrome chalcedony first described from Zimbabwe, was used for comparison.

Keywords: chrome chalcedony, mogánite, Raman spectroscopy, serpentinite, silicification, XRD

Introduction

Thirty years ago a prospector in the northwest of Western Australia (WA) noticed flaked chips of a green rock in an area of brown boulder rubble. In 1990 the area was registered as a mining tenement and the site investigated for the source of the green rock.

Identification now confirms that the rock is chrome chalcedony, a new variety to Australia. Where fractured pieces are sufficiently thin it is translucent, and of a fairly uniform deep green hue. When traversed by later quartz veins the colour grades to brown.

Several forms and varieties of siliceous gem materials are already exploited from many localities within WA. Most valuable is chrysoprase, a pale green chalcedony, with colour due to nickel. The green chrome chalcedony from this new occurrence in WA differs from chrysoprase in two significant aspects:

- The colour is attributable to chromium rather than nickel.
- It occurs in masses representing whole-rock silicification of the original serpentinite. Chrysoprase, in contrast, occurs as late-stage well-defined fracture fillings.

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Terminology

α-Quartz: Stable silica polymorph, trigonal, occurs in lenses, crystalline granular anhedral form within chalcedony groundmass and as euhedral encrustations, and vug fillings.

Chalcedony: An assemblage of micro-fibrous α-quartz, occurring as:

- granular groundmass type.
- wall-lining type where fibres nucleate from points (grains), and radiate at right angles to vein borders.
- spherulitic and sub-radiating groups within groundmass.

Mogánite: Metastable silica polymorph, monoclinic. Aggregates composed of platelets ranging in thickness from 110Å to 1000Å (Miehe and Graetsch, 1992). Occurs as an infilling of seams, etc., in some of the ignimbrite flows of the Mogán Formation on Gran Canaria. Also occurs in agate, chalcedony and chert (Heaney and Post, 1992).

This mode of occurrence also differs from other documented occurrences of chrome chalcedony, notably those in Zimbabwe and Bolivia (Smith, 1967: Hyrsl, 1999).

Location

The deposit is located in the northwest of Western Australia within Sheet SF 50-16, Newman, of the 1:250 000 State Government

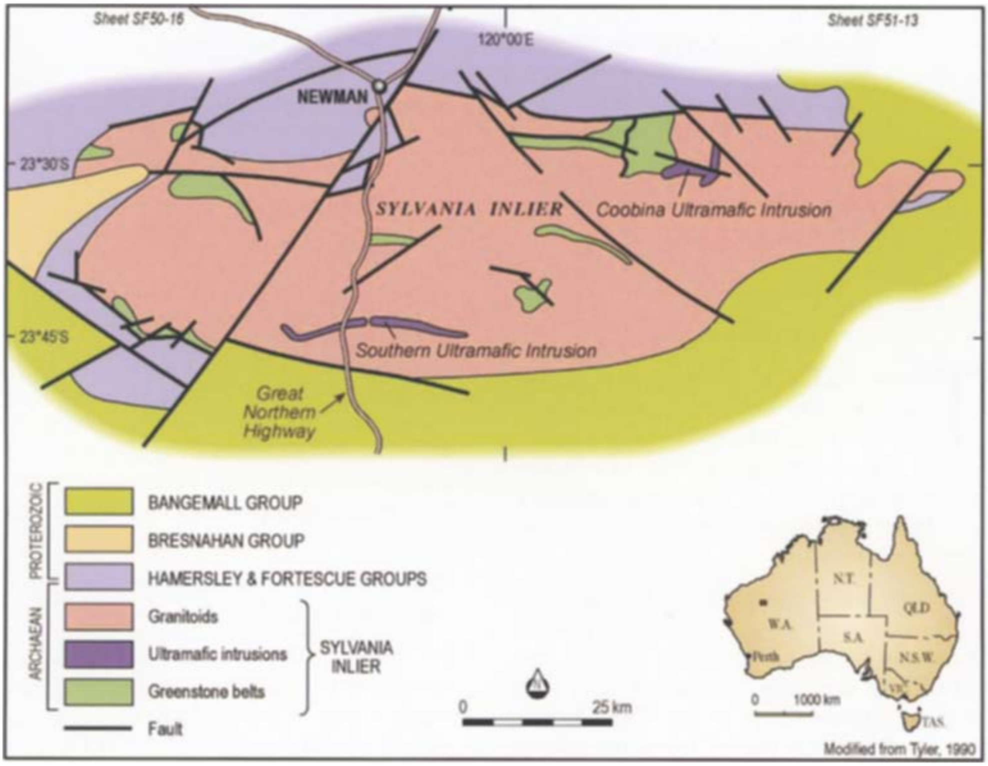


Figure 1: *Simplified geological map of the Sylvania inlier showing the Southern Ultramafic Intrusion (SUI). Map of Australia inset with the position of the area shown by a square.*

geological and topographical map series (Daniels and Macleod, 1965).

The important economic focus of the region is the mining of the huge iron ore deposits occurring within the extensive banded iron formations (BIF) that make up much of the Hamersley Ranges. The town of Newman is the main centre of mining in the eastern Hamersley Ranges; others, located further west, are Tom Price, Paraburdoo and Panawonnica.

The chrome chalcedony deposit lies within the southern portion of the Sylvania Inlier and is located 40 km south-southeast of the town of Newman, and a few kilometres to the east of the Great Northern Highway at approximately lat. 23° 43' S, long. 119° 50' E *(Figure 1)*.

Geological Setting

The Sylvania Inlier which is some 5600 square kilometres in area, comprises a geologically discrete terrain of mixed granite-greenstone of Archaean age (> 2 500 Ma). Within the Inlier are several mafic and ultramafic intrusions, including dolerite dykes of varying ages and crosscutting relationships (Tyler, 1990 a and b). The Inlier is bordered by some Archaean and younger Proterozoic units; namely the Hamersley and Fortescue Groups to the north, the Bresnahan Group to the west and Bangemall Group to the south and east.

There are two significant ultramafic bodies, Coobina and the Southern Ultramafic Intrusion (SUI). The smaller, Coobina, is situated near the northeastern margin of the Inlier. It is a remnant of a differentiated complex containing narrow lenses of chromite and is currently being mined. The host rock serpentinite was generally deeply weathered during the Tertiary resulting in the development of magnesite veins and widespread surface silicification.

The SUI is more dyke-like and has a sinuous east-west strike of around 40 km and width varying between 200 and 800 m.

Figure 2: *Typical red-brown boulder of source rock. Photo: J. Flint.*

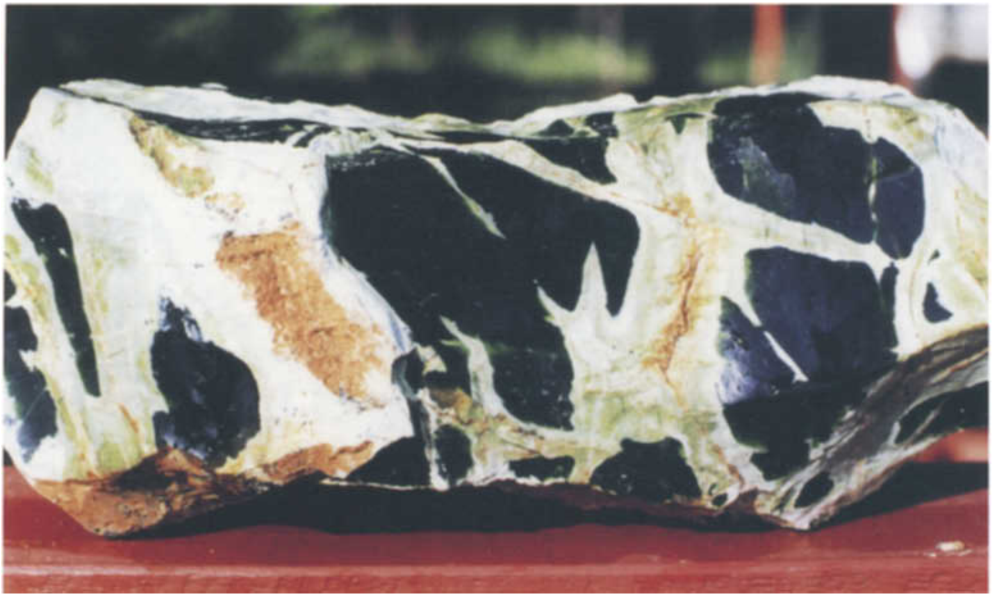


Figure 3: Boulder with irregular zones of chrome chalcedony (dark) and relict parent rock (light). Photo: J. Flint.

Although the actual age of the SUI has not been determined, it is considered to be Archaean-Proterozoic (I.M. Tyler, pers. comm.). It post-dates the granites of the Inlier, and aplites and pegmatite veins common in the granitoid are absent from the ultramafic. It also truncates one of the series of dolerites (Tyler 1991).

The recently discovered chrome chalcedony deposit is located on a small hill of red-brown stained rubble and boulders overlying weathered serpentinite, which forms part of the eastern section of the SUI. The effects of the pervasive and intense weathering during the Tertiary are readily observable and fresh outcrop is rare. Much of the bedrock is obscured by Recent colluvium and alluvium.

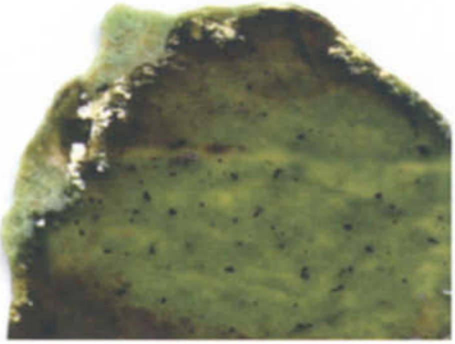


Figure 4: Thin polished slab of chrome chalcedony showing colour variation and opaque mineral inclusions. Scanned image: M. Willing.

The geology of the SUI as described from fresh rock exposed only at its western extent, is serpentinite (Tyler, 1991). It consists dominantly of serpentine with minor talc and secondary magnetite, derived by low-grade metamorphism of an olivine and olivine-pyroxene bearing parent rock.

Chalcedony, chrysoprase and common opal are all reported as common capping materials over ultramafic rocks within the Inlier (Tyler, 1991 and Nagase *et al.*, 1997). Some of these materials have already been exploited for their gem potential (Geol. Survey, 1994).

The new occurrence of chrome chalcedony and chrysoprase occur in close proximity in geologically similar environments and were formed as a result of the same processes.

Field Occurrence

The red-brown stained boulder rubble rock at the mine site is shown in *Figure 2*. In these boulders the boxwork appearance of the gem ore is apparent.

Irregular dark-coloured zones of green chrome chalcedony form the dominant component between subordinate areas of light green relict serpentinite, the parent rock *(Figure 3)*.

The chrome chalcedony is a tough material, breaking with a conchoidal fracture, resulting in flakes with sharp edges. Fractured surfaces have a waxy lustre. The colour appears to be a fairly uniform deep green; however, examination by transmitted light shows a banded texture and colour variation in the greenness with a speckled appearance due to finely disseminated grains of an opaque ore mineral *(Figure 4)*.

Fine veins of quartz traverse the rocks, and in places have developed into small agate-filled vugs. Quartz encrusts some of the chrome chalcedony as a thin bluish coating *(Figure 5)* that fluoresces bright yellow/green under short wave ultraviolet light.

Figure 5: *Chrome chalcedony (dark) with surface encrustation of coarse quartz. Scanned image: M. Willing.*

Characterization of WA chrome chalcedony

Materials and methods

Chrome chalcedony (mtorolite) from Zimbabwe was used in the ultraviolet/visible/near infrared (UV-Vis-NIR) and Raman spectroscopy methods as a reference material. Mtorolite was discovered in 1955 and is mined from the 'Jester' claims.

Comparative results: Data from this study were compared with published gemmological data on chrome chalcedony from Bolivia ('chiquitanite') and one intaglio from a private collection in Vienna.

Petrology: Petrographic sections were prepared from the massive green chalcedony and a sample of the present serpentinite material and studied by polarized light microscopy (PLM). Polished sections were examined by reflected light microscopy.

Gemmological properties: Determined on cut cabochons *(Figure 8a)* and one faceted chrome chalcedony. Refractive Indices were taken with an Eickhorst refractometer illuminated with a monochromatic sodium light source. Specific Gravity was determined by the hydrostatic method using a Sartorius electronic balance. Fluorescence to ultraviolet radiation was observed using a LW and SW ultraviolet light. Absorption Spectrum was observed with an MGL-450 prism spectroscope.

Mineral Composition: Determined using X-ray diffraction (XRD) analysis in packed powder mounts of the sample. A Phillips X'Pert system with copper Kα and diffracted beam monochromator was used for the analysis.

Chemical composition: Quantitative chemical analysis was determined by X-ray fluorescence (XRF) analysis of fused glass discs prepared from 1.6 g sample powder and 6.4 g lithium borate flux. A Phillips PW1480 XRF instrument was used under routine conditions. Detection limits for most trace elements reported are ~ 10 ppm; major oxides have detection limits between 0.002% and 0.01%.

Chromophore, water speciation: Ultra-violet-visible-near infrared (UV-Vis-NIR) spectroscopy using a Fieldspec Pro instrument (ASD Inc.) with a fibre-optic probe 50 watt DC light. Probe height set at 15mm, area of illumination 0.34 cm^2, angular field of view (25°) 'Spectralon' was used as the reflectance standard. The UV-Vis reflectance spectra of the polished slabs were collected from 350nm to 700nm. The NIR reflectance spectra were collected from 0.8 to 2.5 μm.

Raman Spectra: The Raman spectra were measured with a Dilor Labram 1B instrument equipped with an Olympus (BX40) optical microscope with ×50 objective for micro sampling. The 488 nm line from a Uniphase 2010 Ar^+ laser was directed at 0° incidence with 180° collection angle. The beam power was 10 mW. Data accumulation occurred over a 10 minute period.

Petrology

Silicified serpentinite parent rock

A prepared thin section of the serpentinite shows a mixed association of serpentinite with zones of invasive microcrystalline quartz *(Figure 6a).* The serpentinite is heterogeneous with schistose texture and is composed dominantly of fibrous antigorite in lenticular layers (0.5 mm to 2 mm in thickness) intercalated with zones of shredded flaked serpentine talc that is altered and clouded by ultra-fine undetermined minerals, possibly smectitic clay. These latter zones have a white clouded appearance in reflected light.

Chalcedony occurs in regular small lenses up to 5 mm across with stringers and veinlets together forming about 15% of this section, representing minor silicification of the parent rock. Examined in polished section an opaque mineral, representing about 2–3% of the section, occurs throughout the rock. These grains are easily visible and are ~ 0.5 mm in diameter, anhedral in form, highly fractured with finely dissected margins, intergrown with antigorite. They represent residuals of primary chromite and magnetite, now partly converted to hematite. Some with very small cores of chromite are evidence of the original ultramafic nature of the rock. Since its formation as a dunite or olivine pyroxenite the rock has been sheared, serpentinized and finally partially silicified.

Chrome chalcedony

Sections of the massive chrome chalcedony are shown in *Figures 6b* and *6c*. The groundmass of microcrystalline silica, forming about 90% of the sample, has an ultrafine texture, with individual grain size of about 0.02 mm (20 μm) characteristic of chalcedony. Texturally the rock is homogeneous and unbanded, and individual grains are of a fibrous nature demonstrating undulose extinction. Quartz fibre orientation is length fast.

Localized rosettes and micro-fans of sub-radiating chalcedony, ± 0.5 mm diameter, occur within the groundmass *(Figure 6b).* These rosettes display a cross-pattern of extinction in polarised light as a result of fibre-orientation and behave as single crystals of quartz. In PPL a botryoidal texture appears where several rosettes are grouped together.

As in the parent rock, opaque mineral grains occur throughout the gem rock *(Figure 6c).* Examined in polished section, the grains were identified as magnetite with irregular margins altered to hematite and small cores of original chromite *(Figure 6d).*

Rarely small shreds of very fine micaceous mineral (0.15 × 0.6 mm) occur in the section. These minor residuals of schistose serpentinite together with the chromite grains are considered to be evidence of the original ultramafic rock.

Figure 6a: *Photomicrograph of silicified serpentinite parent rock showing fibrous antigorite/talc and lenses of chalcedony. A late veinlet of fibrous quartz crosscuts the section. Photomicrograph: S. Stocklmayer.*

Figure 6b: *Chrome chalcedony showing a granular texture with groundmass of fairly even-sized grains. Centre – a coarse chalcedony rosette of 0.58 mm diameter, with fibres producing a cross pattern and undulose extinction in PL. Photomicrograph: S. Stocklmayer.*

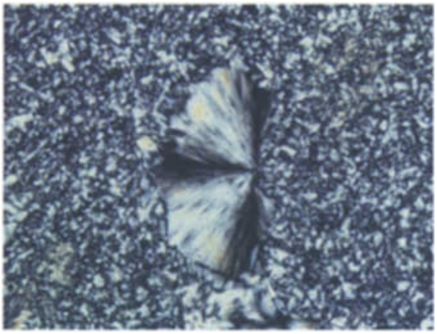


Figure 6c: *Chromite grains within the chalcedony groundmass. A late veinlet of chalcedony has a boundary of opaque granules. Photomicrograph: S. Stocklmayer.*

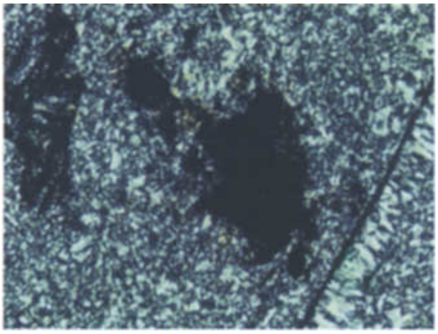


Figure 6d: *Polished section of chrome chalcedony with an ore grain inclusion. The relict core is chromite (0.05 mm) with border of magnetite and hematite. Photomicrograph: Pontifex.*

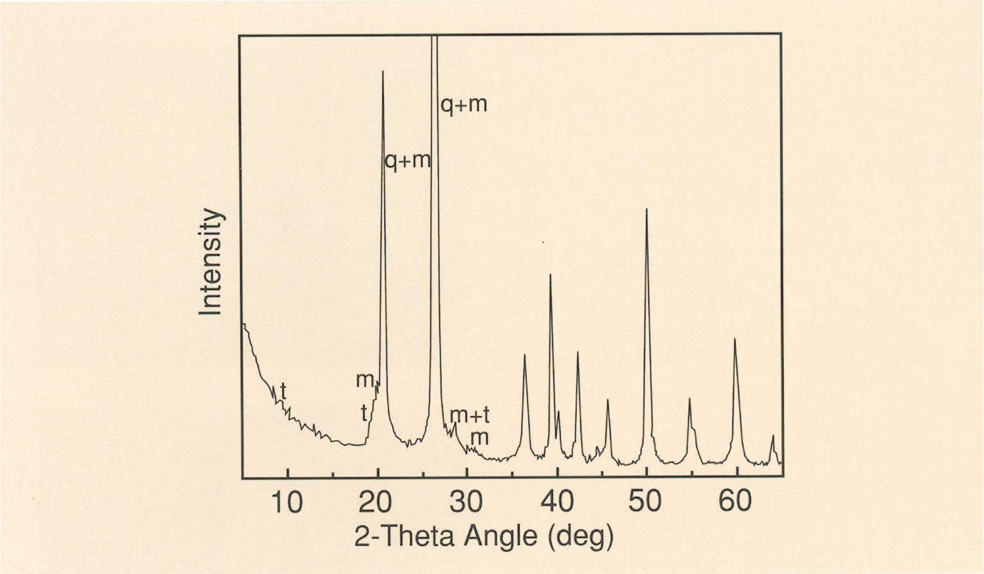


Figure 7: *X-ray powder diffraction pattern of chrome chalcedony with peaks labelled q-quartz, m-mogánite and t-talc.*

Mineral composition

X-ray diffraction

The X-ray diffraction (XRD) pattern *(Figure 7)* of chrome chalcedony shows quartz as the major mineral component with traces of talc and mogánite, a monoclinic polymorph of microcrystalline silica. 'Silica-G' was initially proposed as a working name for the new silica polymorph (Flörke *et al.*, 1976); after further characterization the mineral name 'mogánite' was introduced (Flörke *et al.*, 1984). The mineral occurs in ignimbrites of the Mogán Formation on Gran Canaria.

Examination of 150 microcrystalline quartz-rich silicas from the mineral collection of the US National Museum of Natural History, by Rietveldt refinement of the powder X-ray diffraction patterns (Heaney and Post, 1992) confirmed the presence of mogánite, in varying amounts, in agates, chalcedonies, cherts and flints. In 1999, the Commission on New Mineral Names of the International Mineralogical Association accepted 'mogánite' as a new mineral.

Mogánite has been detected in XRD patterns of dark green chrysoprase from Marlborough Creek, Australia (Gawel *et al.*, 1997). Concentrations of mogánite in the order of 15-29 vol.% have also been recorded in light green chalcedonic chrysoprase from Eucalyptus (WA) and Marlborough Creek, Queensland (Rodgers and Cressey, 2001).

Chemical composition

X-ray fluorescence analysis

The bulk chemical composition of the chrome chalcedony determined by X-ray fluorescence (XRF) analysis is listed in *Table I* below. The major component is silica. The Cr_2O_3 and Fe_2O_3 contents are 0.24 and 1.45 wt.%, respectively, and the NiO content is negligible (0.01 wt.%). Traces of aluminium and magnesium are present.

Water content

Water loss *(Table I)* at 100°C (H_2O) 0.56%, is attributed to the desorption of loosely bonded molecular 'water' ($H_2O_{(mol)}$) whereas the loss at 1050°C (H_2O^+) 1.66% is due to tightly bound molecular 'water' and chemically bound silanol-group 'water' ($H_2O_{(SiOH)}$).

Although chrome chalcedonies from Zimbabwe and Bolivia and intaglios fom various sources are described in the gem literature (Hyrsl and Petrov, 1998, Hyrsl, 1999) different analytical methods and incomplete data make comparison of results difficult.

Gemmological properties

Optical/Physical

A summary of the gemmological properties of chrome-chalcedony is listed in *Table II.*

Diaphaneity and lustre: the chrome chalcedony cabochons tested in this study are dark green, translucent with a vitreous lustre *(Figure 8a).*

Hardness: due to texture, variable, ~ 7, sharp edges able to score quartz crystal surfaces.

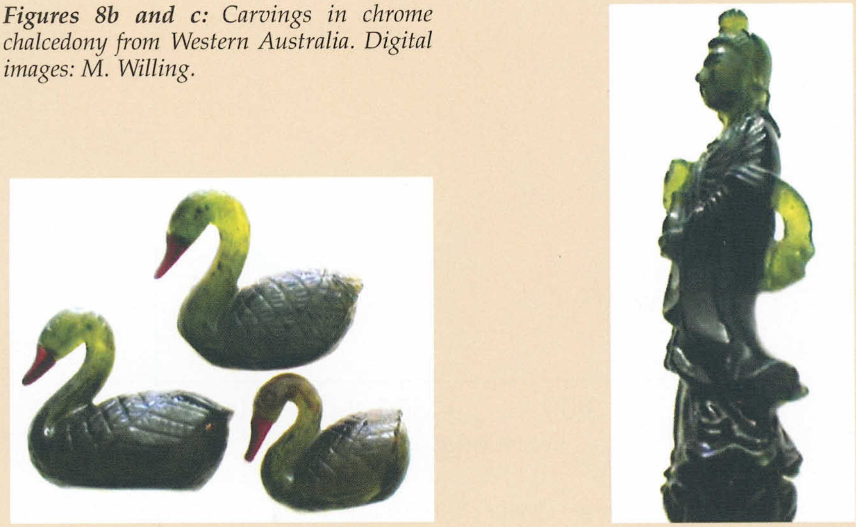
Polariscope reaction: the samples remained light under crossed polarised filters, due to aggregate polarization.

Refractive index: the RI was determined to be 1.539, corresponding to the upper limit quoted by Webster, 1994, p.233.

***Figure 8a:** Cabochons of chrome chalcedony from Western Australia. Digital image: M. Willing.*

***Table I:** XRF analysis of chrome chalcedony.*

	Wt.%
SiO_2	95.01
Al_2O_3	0.29
Fe_2O_3	1.45
MnO	0.01
MgO	0.46
Cr_2O_3	0.24
NiO	0.01
H_2O^-	0.56
H_2O^+	1.66
Total	99.70



***Figures 8b and c:** Carvings in chrome chalcedony from Western Australia. Digital images: M. Willing.*

Specific gravity: was determined as 2.57.

Absorption spectrum: shows a diffuse band in the orange from 570nm to 640 nm, absorption of the blue violet and transmission of the green region. All specimens appeared intense red under the Chelsea colour and Hanneman-Hodgkinson (HH) filters. In contrast, chrysoprase remains green.

Table II: *Summary of gemmological properties.*

Diaphaneity	Translucent
Hardness	~ 7
Fracture	Conchoidal (brittle)
Structure	Microcrystalline aggregate
SG	2.57
RI	1.539
Absorption spectrum	Absorption of orange; sharp increase in absorption from blue to violet.
Luminescence under UV, LW and SW	Inert
Chelsea colour filter and Hanneman-Hodgkinson filter	Intense red

Figure 8 shows cabochons and small carvings fashioned in chrome chalcedony mined from the new WA deposit. In selected material the intense greenness and high translucency is demonstrated by transmitted light in the objects shown in *Figures 8b* and *c*.

Results from spectroscopic methods

UV-Vis reflectance spectrum – WA chrome chalcedony

Comparison ultraviolet visible reflectance (UV-Vis) spectra for chrome chalcedony and mtorolite are shown in *Figure 9*. The UV-Vis spectrum for the chrome chalcedony reveals a decrease in reflectance due to absorption between ~ 540 and ~ 660 nm with a maximum absorption at ~ 610 nm. A distinct small absorption peak is present in the red at 681 nm. There is heavy absorption in the blue-violet/violet region from ~ 450 nm to

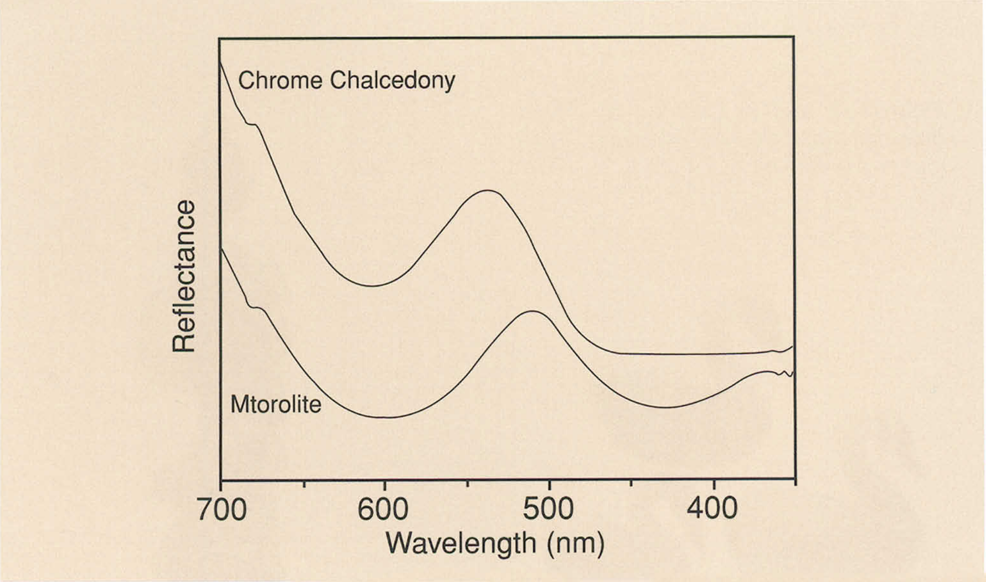


Figure 9: *UV-Vis reflectance spectra for chrome chalcedony (WA) and mtorolite (Zimbabwe). Spectra displaced vertically for clarity.*

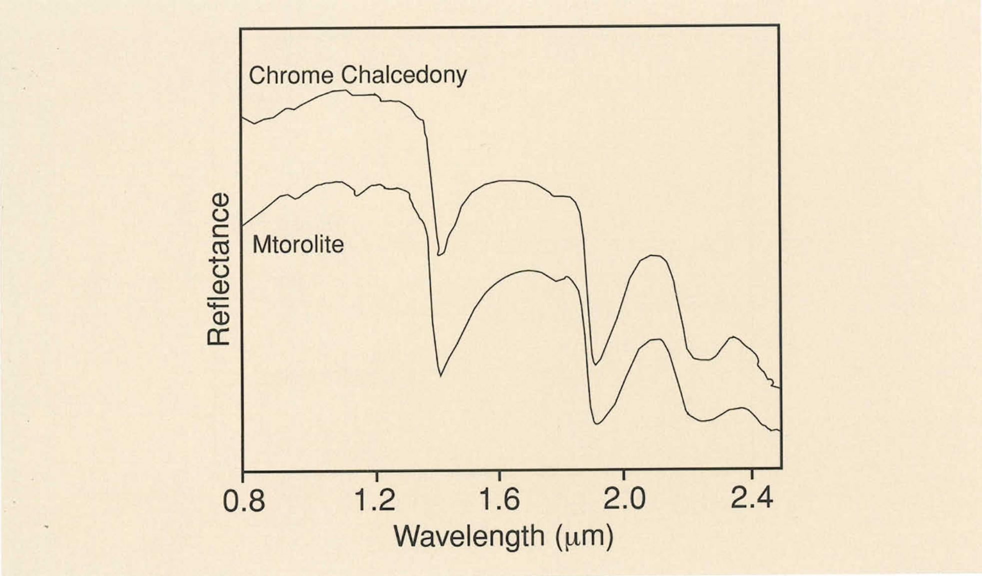


Figure 10: *Near-infrared spectra of chrome chalcedony and mtorolite obtained from plane-polished plates: 2 mm thick for the chrome chalcedony, and 4.2 mm thick for the mtorolite Spectra displaced vertically for clarity.*

shorter wavelengths and maximum reflectance occurs in the green at ~ 535 nm.

UV-Vis reflectance spectrum – Zimbabwean mtorolite

The UV-Vis spectrum for the mtorolite reveals a decrease in reflectance due to broad absorption from the edge of the blue-green at ~ 510 nm to 670 nm with a maximum absorption at ~ 600 nm. A broad absorption band extends from the blue at 475 nm beyond the violet with a maximum at ~ 427 nm. A distinct small absorption peak occurs in the red at 681 nm, reflectance occurs in the blue-green at ~ 510 nm.

The reflectance spectrum shown by the WA chrome chalcedony exhibits absorption characteristics similar to that reported by Hyrsl (1999) for the Mercury intaglio. The reflectance spectrum for the mtorolite examined in this study is similar to the spectral data for mtorolite and 'chiquitanita', Bolivia (Hyrsl and Petrov, 1998 and Hyrsl, 1999).

The chalcedonies examined show absorption bands characteristic of Cr^{3+}, confirming the presence of the chromophore (Rossman, 1988). The reflectance curves also reflect slight differences in the hue of the materials; chrome chalcedony tending toward green, mtorolite, towards blue-green.

Near infrared spectroscopy

Near infrared (NIR) reflectance spectra of chrome chalcedony and mtorolite are graphically displayed in *Figure 10*. The chrome chalcedonies show strong absorption features due to 'water' and hydroxyl (OH). The absorption features at 1.4 and 1.9 μm result from vibrations of molecular water (H_2O), with the 1.9 μm feature being diagnostic for water. The 1.4 μm feature indicates an overtone which may be in H_2O or hydroxyl in the structure (R.N. Clark, pers. comm.). Weaker features caused by vibration of silanol (Si-OH) groups occur at 2.22 and 2.27 μm, as an unresolved doublet. In a comprehensive infrared study of chalcedony, Frondel (1982) assigned the absorption feature at 2.2 μm to weakly

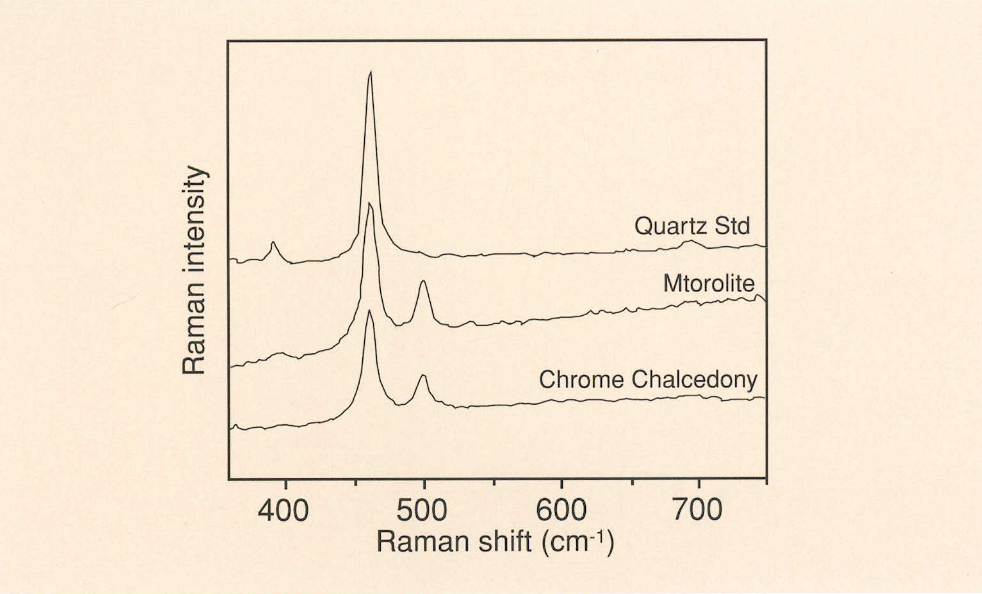


Figure 11: *Raman spectra of quartz standard, chrome chalcedony and mtorolite, obtained from plane-polished plates: quartz 3.5 mm, chrome chalcedony 2.0 mm, and mtorolite 4.2 mm thick. Spectra displaced vertically for clarity.*

H-bonded internal silanol (Si-OH). In the study of water in agates, Flörke *et al.* (1982) assigned the 2.27 μm absorption feature to strongly H-bonded surface silanol (Si-OH). In studies of Brazilian agate geodes, Graetsch *et al.* (1985) found water and silanol groups on hydrated surfaces.

The NIR spectral data in this study compare favourably to the NIR characterization of water in opal (Langer and Flörke, 1974) and recorded NIR spectra of opals (Fritsch and Stockton, 1987) including natural white and black opal from Australia, transparent yellow opal from Idaho and transparent red-orange opal from Mexico.

The NIR spectra of the chrome chalcedony and mtorolite examined in this study confirm the existence of three categories of water (Frondel, 1982).

The water content of this microcrystalline variety of quartz may account for the low refractive indices and density in comparison with the values for coarse quartz (Frondel, 1982; Heaney, 1993).

Raman micro-spectroscopy

Gem quality α-quartz comprising SiO_2 as the ideal formula was the standard used to characterize chrome chalcedony and mtorolite by Raman micro-spectroscopy. The Raman spectrum of the α-quartz standard *(Figure 11)* displays a characteristic peak at ~ 463 cm^{-1} due to vibrations of Si-O-Si (six-membered rings of SiO_4 tetrahedra).

Chrome chalcedony and mtorolite *(Figure 11)* show an additional Raman active mode at ~501 cm^{-1}, corresponding to the most intense Raman peak for the pure phase of mogánite. This peak, uncharacteristic of α-quartz, may be attributed to the four-membered rings of SiO_4 tetrahedra in mogánite (Kingma and Hemley, 1994).

In this study, the XRD pattern *(Figure 7)* of chrome chalcedony shows evidence of the intergrowth of the two silica polymorphs, α-quartz and mogánite. Raman spectroscopy, sensitive to minor differences in crystal structure, confirmed the presence of mixed phases of α-quartz and mogánite in the WA chrome chalcedony and the mtorolite.

The Raman spectra of the chrome chalcedonies in this study are similar to the results from a mixed-phase chalcedony containing α-quartz and mogánite from near Johannesburg, California (Kingma and Hemley, 1994). The spectra are identical to the Raman spectra of Roman chalcedonic chrysoprase intaglios in Paris (Smith and Robin, 1997); however, the name chrysoprase was based only on the apple-green colour, and it is possible that these are of chrome chalcedony as no analytical data are yet available (D.C. Smith, pers.comm.).

Discussion

Genesis

Vast areas of Western Australia were subjected to the weathering, leaching and depositional processes that resulted in widespread lateritization in the Tertiary (<65 Ma) during what was a warm temperate climate. The most obvious effect of this is the iron duricrust of hydrated iron oxides that characterize much of the landscape. In places, laterite thickness attained hundreds of metres.

Within the Sylvania area, the siliceous gem materials – chrome chalcedony, chrysoprase and chrome opal all occur within laterite horizons overlying serpentinite and all in close proximity to one another. Silica derived by leaching of ferromagnesian minerals from the original olivines and pyroxenes of the ultramafic rocks was deposited by secondary processes as nodules, veins or boxworks at or near the palaeo watertable. With climatic change to increasing dryness, these horizons, deposited under ambient temperatures, have been preserved due to lack of seasonal water to remove them. This secondary silica is usually of little gem interest, occurring as a grey or brown banded opaque jaspilitic material and its widespread occurrence in the area on hilltops overlying ultramafic rocks has already been discussed.

In more unusual circumstances, as happened in the Newman area, the processes of silica deposition have resulted in partial replacement of the original weathered country rock and the chrome chalcedony represents a whole-rock pseudomorph. In the process of replacement the original banded nature of the rock with its lenses of antigorite and talc and scattered chromite-magnetite granules have been preserved. Chromium, responsible for the green colouration of the chalcedony (0.24% Cr_2O_3) is most likely to have originated from chromite, which exists in relict form largely leached and oxidized to magnetite and hematite. As previously described, chromite occurs regularly throughout the chalcedony and serpentinite country rock. XRF analysis *(Table I)* shows negligible nickel. Crosscutting fractures filled by vein quartz and chalcedony represent a final process in the rock formation and silica of this generation is not coloured green.

Although silicified serpentine has been described from a nearby part of the SUI (Nagase *et al.*, 1997) and from the Widgee area of Queensland (Krosch, 1990) this occurrence near Newman is the first report of quality material with gem-potential formed by whole-rock replacement and coloured green by chromium.

Worldwide occurrences

Zimbabwe

The first discovery of chrome chalcedony in modern times was made in 1955 in Zimbabwe (Smith, 1967). The material derives from a horizon of the Great Dyke, a chrome-bearing differentiated ultramafic complex of Archaean age. Chrome chalcedony occurs as a boxwork of narrow veins varying in width from 5 mm to 25 mm. Although serpentinization may have reached depths of 300 m in the Great Dyke, the chrome chalcedony was formed in more recent times by silica deposition from near-surface ground waters in ambient temperatures and weathering conditions similar to those described for chrysoprase development. The material is known commercially as mtorolite, and was named after the settlement nearby at Mtoroshanga. Gem material is still exploited at the 'Jester' claims, the source of the original discovery (J. Rheiner, pers.comm.)

Bolivia

Chiquitanite is the commercial name for chrome chalcedony found recently in Bolivia (Hyrsl and Petrov, 1998). The material as described, varies from opaque to translucent and some stones show a fine agate-like structure and network of brown iron oxides. The best quality material compares favourably with mtorolite (Hyrsl, 1999).

Archaeological material–Museum and private collections

Chrome chalcedony is one of a range of green siliceous materials that have been identified among Roman artifacts, engraved as intaglios. An intaglio forming part of the Roman finds from Wroxeter, Shropshire, England is described as translucent, coloured green by chrome and speckled with black spots (M. Hutchinson, pers. comm.).

A recent review of chrome chalcedonies used in ancient and antique gems includes Roman intaglios (3rd century AD) in the Cabinet de Medailles, Paris, two intaglios forming part of a necklace in the collection of the Museum of Decorative Arts (age uncertain), two intaglios (13th century) housed in Prague, Czech Republic and one intaglio in a private collection in Vienna (Hyrsl, 1999). The origin of the chrome chalcedony intaglios described above could not be from any of the sources so far described. Recent communication (C. Whipp, pers. comm.) on chrome chalcedony found in Anatolia, Turkey indicates that this may be the source material for some of these intaglios.

Conclusions

There are limitations in the mineralogical and petrological nomenclature which hamper one in accurately classifying occurrences of secondary silica formed in the weathering environment such as described in this paper. The WA chrome chalcedony, characterized in this study, is an ornamental rock composed of silica polymorphs. The name is derived from its dominant mineralogy comprising α-quartz as chalcedony and macroquartz; however mogánite, the metastable silica polymorph is also present. Minor talc is also present according to the XRD pattern.

No commercial name has yet been adopted for the rock, unlike mtorolite and chiquitanite for other worldwide occurrences herein described. The range of objects shown *(Figure 8 a–c)* is the first to have been produced and to date excavation work indicates that a reasonable tonnage exists.

The potential for the production of large decorative objects is good as the chrome chalcedony is not restricted to veins but occurs in massive form.

Acknowledgements

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A note on sky-blue glass with needle-like inclusions

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ABSTRACT: The gemmological properties of a sky-blue square cut stone of 2.44 ct indicate that it is glass. These properties are similar to those of ekanite, and needle-like inclusions might mislead the unwary into thinking the stone was natural.

Introduction

Recently the author was asked to identify a 2.44 ct square cut sky-blue stone which looked very similar to aquamarine or blue topaz (*Figure 1*).

As mentioned in the literature: "Any stone which is isotropic (especially when showing anomalous double refraction) and has RI between 1.50 and 1.70 is more likely to be glass than anything else." (1) It is also known that most glasses used as gemstone simulants have specific gravities (SG) that lie in a range from 2.2 to 4.2.

Figure 1: *Enlarged view of the sky-blue square cut stone of 2.44 ct.*

The SG is especially affected by the lead content. The higher the lead content, the higher the SG of the glass(2). What is less well known is that occasionally glass can show the same refractive index (RI) and SG as that displayed by a natural species. When the inclusions contained in the glass consist of needles intersecting in different planes, this adds to the possible confusion with a natural gemstone. Such is the case of the sky-blue square cut stone of 2.44 ct described in detail below.

Gemmological properties

The 2.44 ct square cut sky-blue transparent gemstone (length 8.08 mm, width 8.00 mm, depth 4.84 mm) displayed a vitreous lustre.

The RI determinations were carried out using a Rayner Dialdex refractometer and monochromatic sodium light. A single value of 1.593 was obtained from the table facet and showed that the stone was singly refractive (isotropic). The absorption spectrum was observed in daylight conditions, through a Beck spectroscope, and revealed an

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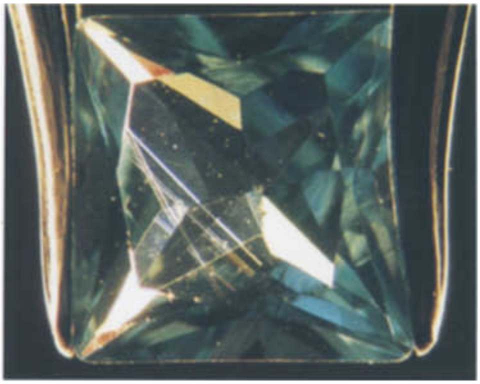

Figure 2: *Numerous intersecting needle-like inclusions in the sky blue square cut stone of 2.44 ct (dark field illumination 10×).*

Figure 3: *Enlarged view of the intersecting needle-like inclusions of Figure 2 (darkfield illumination 15×).*

absorption from 400–420 nm, with three fine lines at 640, 660 and 670 nm.

The stone was examined with a Multispec combined LW/SW ultraviolet unit and fluoresced a strong chalky greenish-yellow to SW, and a moderate orange to LW.

The SG was obtained by hydrostatic weighing in distilled water using a Mettler PL 300C carat scale; the stone was found to have a value of 3.28.

Except for the sky-blue colour, these properties are similar to those encountered for ekanite, a metamict radioactive calcium thorium silicate(3), with the chemical formula $ThCa_2Si_8O_{20}$.(4) Ekanite is typically dark green although some is chalky greenish-yellow, but it has not been reported as sky blue; it is also typically strongly radioactive, so the next test was to determine its radioactivity. The stone was submitted to a Solar Electronics Radiation Alert Monitor 4, and was found to be free of radioactivity.

The inclusions were examined using a Bausch & Lomb Mark V Gemolite binocular microscope using dark field illumination or overhead lighting as appropriate. Numerous intersecting 'needle-like' inclusions (*Figures 2 and 3*) as well as few gas pinpoint inclusions (*Figure 4*), were observed under the table facet or lying in the pavilion.

The composition of the stone was determined by Energy-Dispersive X-ray fluorescence (EDXRF), and indicates the presence of silica, lead, potassium and calcium, with minor contents of copper, iron, titanium, zinc and nickel.

Discussion

The RI of 1.593 and the SG of 3.28 alone could lead a novice to think that the stone might be ekanite. Had the colour been green instead of blue, this would have added even more to the confusion.

Figure 4: *Enlarged view of a gas bubble lying at the junction of intersecting needle-like inclusions, in the sky-blue square cut glass of 2.44 ct (dark field illumination 25×).*

It is a well established fact that glass is characterized by gas bubbles and swirl marks. Although a very few tiny isolated gas bubbles were observed, these can easily be missed and could lead to a wrong identification. Sometimes angular material (copper flakes mainly) has been included in glass to simulate natural inclusions displayed by certain species of gemstones (eg. aventurine quartz), but this is the very first time that the author has encountered long intersecting needles in a glass.

Bearing this in mind, the needles encountered were carefully examined and are most probably hollow canals similar to those used in fibre optics. Nevertheless, this 'gemstone' was most probably cut deliberately to fool a potential buyer.

A cursory inspection with a 10× lens by such a buyer could have led to a view that the stone was natural.

Conclusion

The physical and optical properties are consistent with those given by Bannister's graph for lead glass(5) and is confirmed by the composition determined by EDXRF.

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Behaviour of Brazilian imperial topaz at high temperature

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ABSTRACT: The effect of heating on the structure and composition of imperial topaz has been studied by thermal mechanical analysis, magnetic nuclear resonance and X-ray diffraction. It was found that imperial topaz is a stable mineral below 1000°C, i.e. it does not undergo any structural or chemical alterations on heating. However, at higher temperatures, there are structural changes and chemical decomposition of imperial topaz due to the loss of fluorine, hydrogen, and silicon leading to a complete transformation to mullite above 1300°C.

Keywords: Imperial topaz, mullite, thermal stability

Introduction

Imperial topaz from Ouro Preto, Brazil, with colours ranging from yellow orange to reddish-brown, are considered the rarest and most precious in the world.

The mineral topaz is a fluorine aluminium silicate and its varieties can be described by a chemical formula given by $Al_2SiO_4[F_x(OH)_{1-x}]_2$, where the hydroxyl group can replace fluorine up to ~30 mol% (Barton 1982). In a recent work it was shown that for imperial topaz the value of x is close to 0.8 (da Costa *et al.*, 2000).

The geological and gemmological characteristics of imperial topaz varieties from Ouro Preto are described elsewhere (Olsen, 1971; D'Elboux and Ferreira, 1975; Cassedane and Sauer, 1987; Menzies, 1995; Sauer *et al.*, 1996). In this region, it occurs in hydrothermal veins associated with quartz, dolomite and sometimes muscovite, hematite and rutile. The colours commonly found are orange-yellow, brownish-orange, orange-pink and violet.

Heat treatment of imperial topaz has been empirically performed for a long time in some mines in Ouro Preto (Sauer *et al.*, 1996) in order to give a pink colour to the reddish-brown crystals (*Figure 1*), which is appreciated in the gem market. This pink colour is formed at about 600°C and is stable up to 900°C; on further heating a white and opaque material is formed. In addition, depending on the temperature, topaz may decompose with the loss of hydrogen, fluorine and silicon, giving a new phase, mullite, which is an aluminium silicate of composition $2SiO_2.3Al_2O_3$.

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Figure 1: Pink topaz obtained from imperial topaz by thermal treatment.

In order to improve the yield from the topaz heat treatment in Ouro Preto, we have initiated a profound and systematic study that includes a description of the thermal stability and chemical behaviour of imperial topaz from room temperature up to its transformation to mullite.

It is worth noting that the knowledge of the chemical and structural behaviour of topaz at high temperature is important not only for the treatment of imperial topaz, but also for giving to colourless topaz a certain colour by means of thermochemical treatment, as shown in *Figure 2*. This treatment consists of heating colourless topaz mixed with chemical reactants at a previously well-defined temperature. Different colours and hues, which are stable at normal conditions, can be obtained by using different dopants; some details of this treatment are the subjects of patent applications (Sabioni and Ferreira, 2000, Sabioni *et al.*, 2000).

The present work, a continuation of da Costa *et al.* (2000), deals with the study of the behaviour of imperial topaz when it is heated from room temperature to 1400°C.

Thermal mechanical analysis, together with X-ray diffraction have been used to check the structural changes upon heating, and nuclear magnetic resonance (NMR) has been used to follow the changes that occur in the chemical composition of topaz during its transformation to mullite.

Experimental

Topaz samples

This work was performed using imperial topaz from the Capão Mine in Ouro Preto, Brazil. The characteristics of the topaz from this mine are described elsewhere (Sauer *et al.*, 1996; da Costa *et al.*, 2000). A number of samples were cut from one large single-crystal specimen in order to ensure that all samples had very similar characteristics.

Thermal treatments

Samples were submitted to a range of thermal treatments: raising the temperature from 300°C to 1400°C in one hour; a few samples were heated from 800°C to 1400°C over four hours; and finally isothermal treatments were carried out at 1000°C for 1, 2, 4, 6 and 23 hours. All thermal treatments were performed in static air.

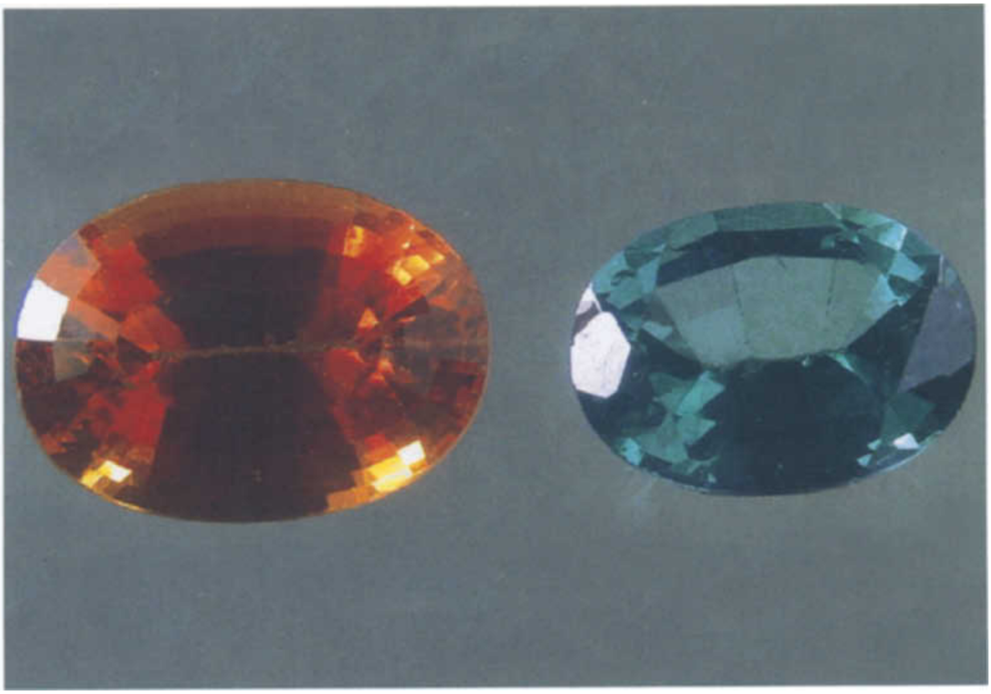

Figure 2: *Orange and blue topazes obtained by thermochemical treatment of colourless topazes.*

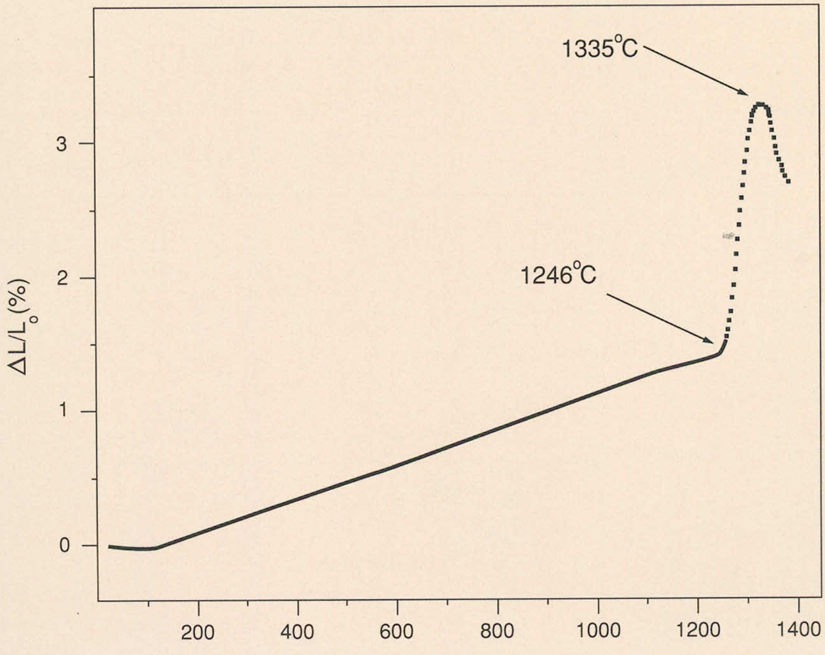

Figure 3: *Thermal mechanical analysis of imperial topaz. The graph shows linear expansion ($\Delta L/L_o$) over the temperature range 0–1380°C.*

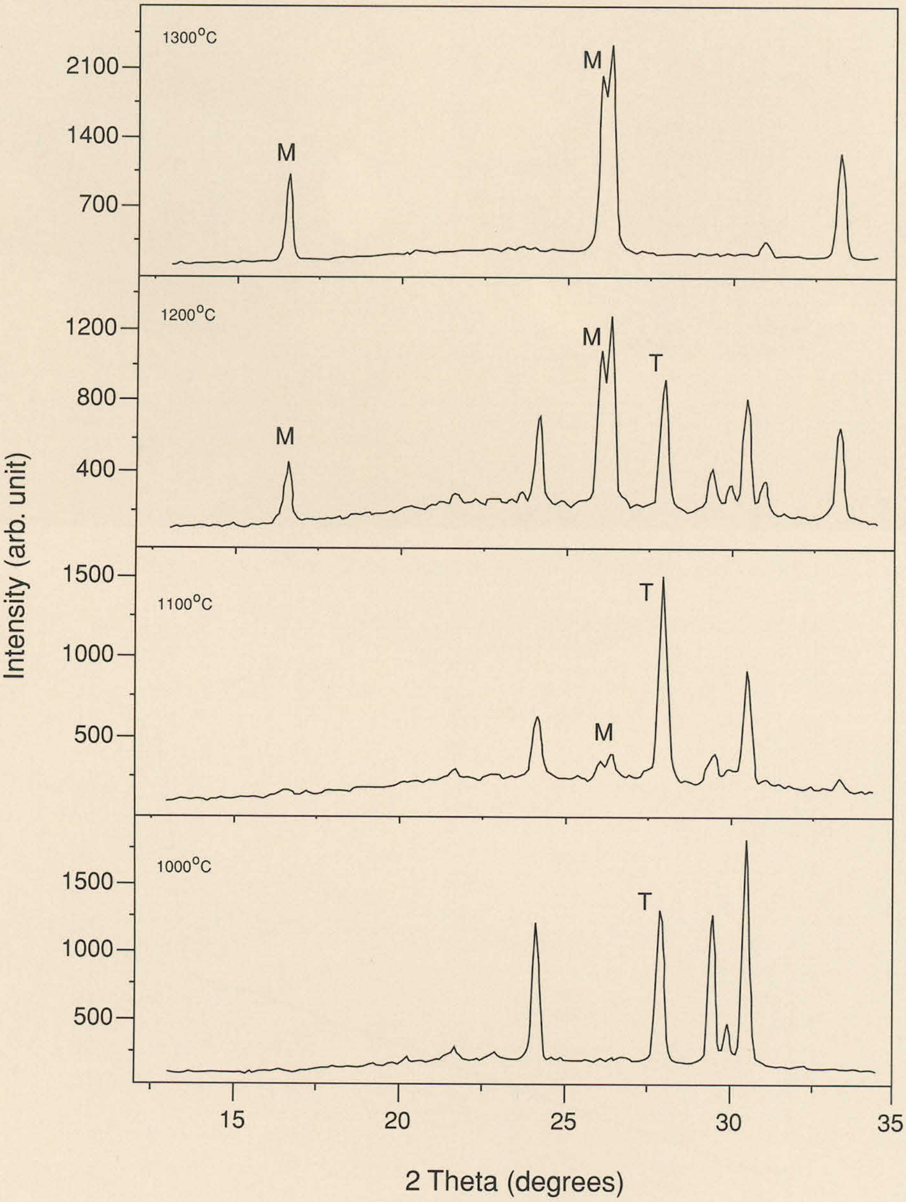

Figure 4: *Powder X-ray diffraction patterns for topaz samples heated for 4hrs at 1000°C, 1100°C, 1200°C and 1300°C; characteristic peaks for topaz (T) and mullite (M) are marked.*

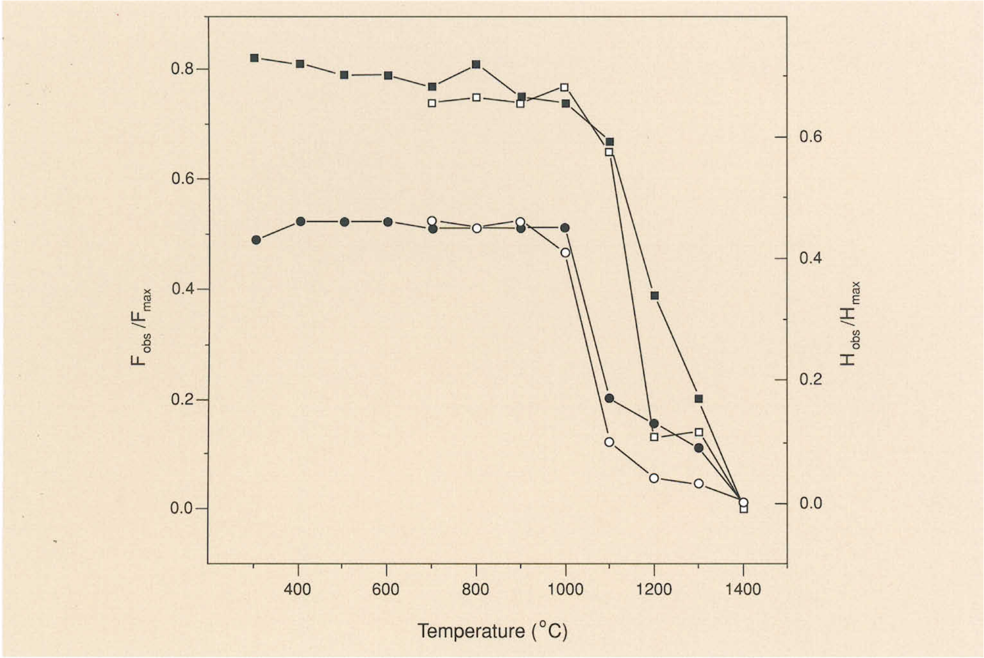

Figure 5: *Fluorine (squares) and hydrogen (circles) contents in topaz samples heated up to 1400°C for one hour (full symbols) and four hours (open symbols). Solid lines are a guide for the eye.*

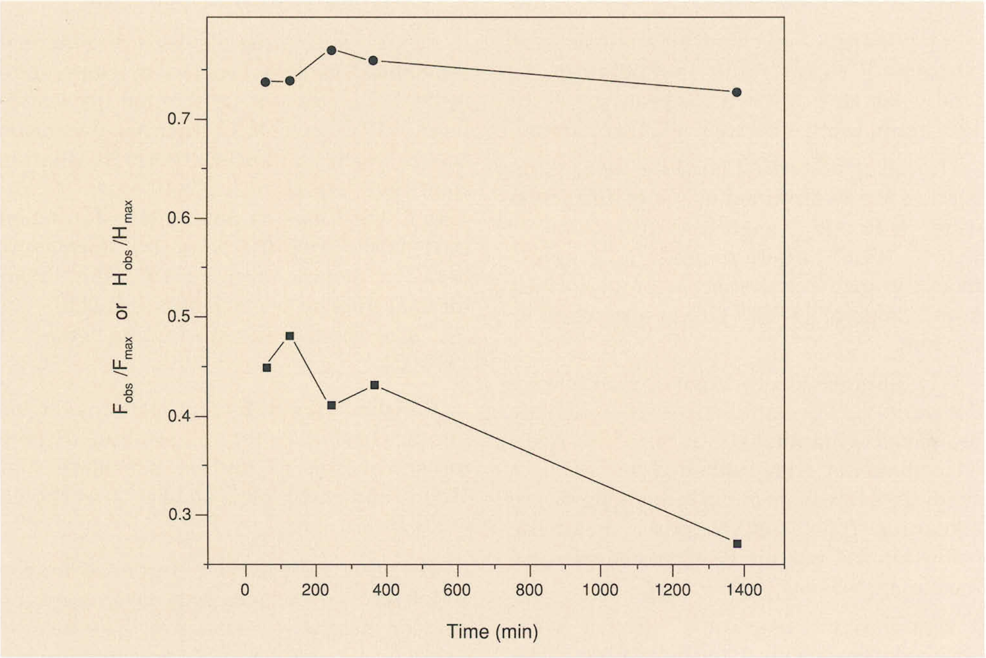

Figure 6: *F (circles) and H (squares) contents in samples heated at 1000°C for different times. Solid lines are a guide for the eye.*

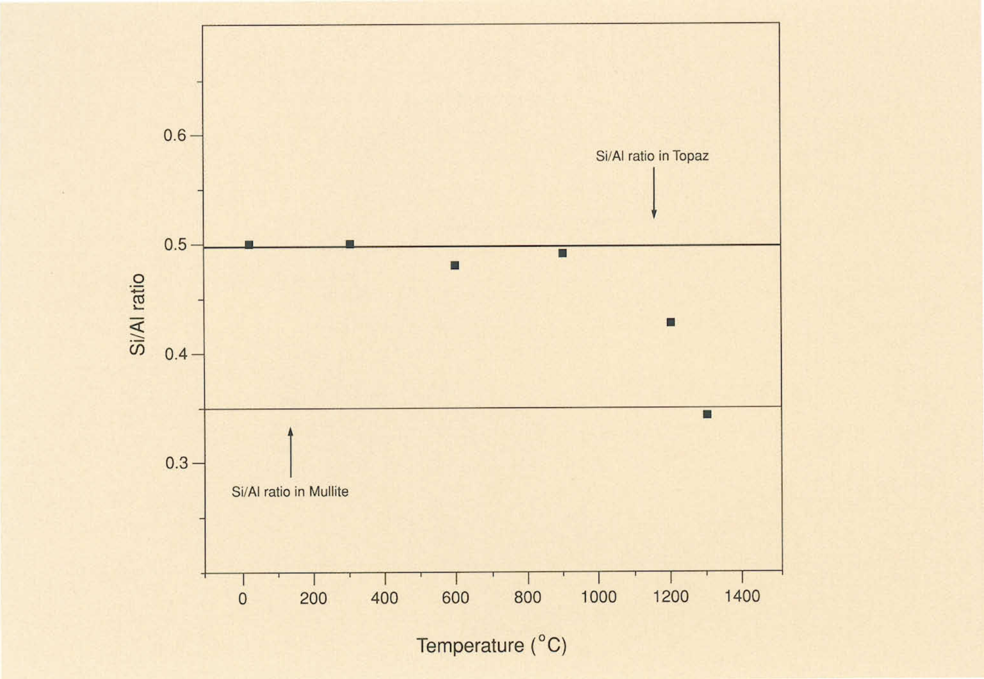

***Figure 7:** Si/Al ratio in samples heated up to 1300°C.*

Characterization techniques

The thermal mechanical analysis was performed from room temperature to 1380°C, in static air with a heating rate of 10°C/min, using a Netzsch 402 E apparatus.

The structural variation of the topaz upon heating was determined by X-ray diffraction using a Rigaku Geigerflex diffractometer with CuKα radiation and a graphite monochromator. The scans were performed in the range of 15°–70° (2θ) at a speed of 1° per min.

The fluorine and hydrogen contents were determined by using nuclear magnetic resonance. Quantitative ^{1}H and ^{19}F NMR measurements were obtained by using a small (20°) flip angle and a rather long (5 sec) relaxation time. Calibrations were made using known quantities of saccharose and sodium fluosilicate.

Unpolarized uv-visible spectra were obtained using a Shimadzu spectrophotometer in the range of 300–1100 nm using 1 mm thick slabs.

Results and Discussion

Figure 3 shows the results of the thermal mechanical analysis. From room temperature up to 123°C, there is no thermal expansion. From 123°C to 1246°C, thermal expansion occurs with a linear thermal dilation coefficient equal to 1.27×10^{-5} per °C. At 1246°C the topaz to mullite transformation starts and during the phase transformation, between 1246°C and 1321°C, the linear thermal dilation coefficient is 25.14×10^{-5} per °C. The phase transformation ends at 1335 °C.

Powder X-ray diffraction patterns for the samples heated for four hours show that the transformation to mullite has started at 1100°C and is complete at 1300°C, as shown in *Figure 4*.

The effect of the temperature on the fluorine and hydrogen contents was determined by nuclear magnetic resonance. The results observed for the F and H contents after the thermal treatments from 300°C to 1400°C, for one and four hours, are shown in *Figure 5*.

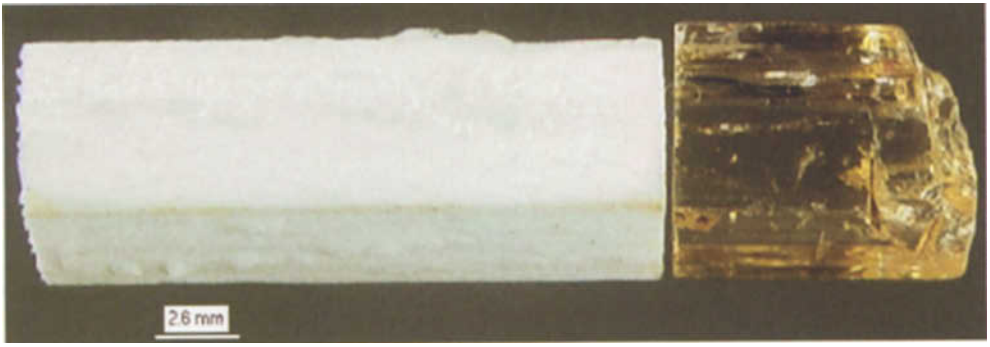

Figure 8: Mullite on the left formed by heating topaz at high temperature. The apparent difference in thickness is due to different orientation of the two crystal samples and is not an effect of the heat treatment.

Up to 1000°C, the F and H contents in the treated samples are constant and equal to their contents in the untreated samples. Above 1000°C, there is a steady loss of both elements, but the loss of hydrogen is faster at 1100°C, whereas the fluorine is rapidly lost at 1200°C.

The influence of time on the hydrogen and fluorine contents when the topaz is heated at 1000°C is shown in *Figure 6*. Hydrogen and fluorine contents in topaz remain approximately constant when the sample is heated at 1000°C for up to six hours, but when heated for 23 hours, the

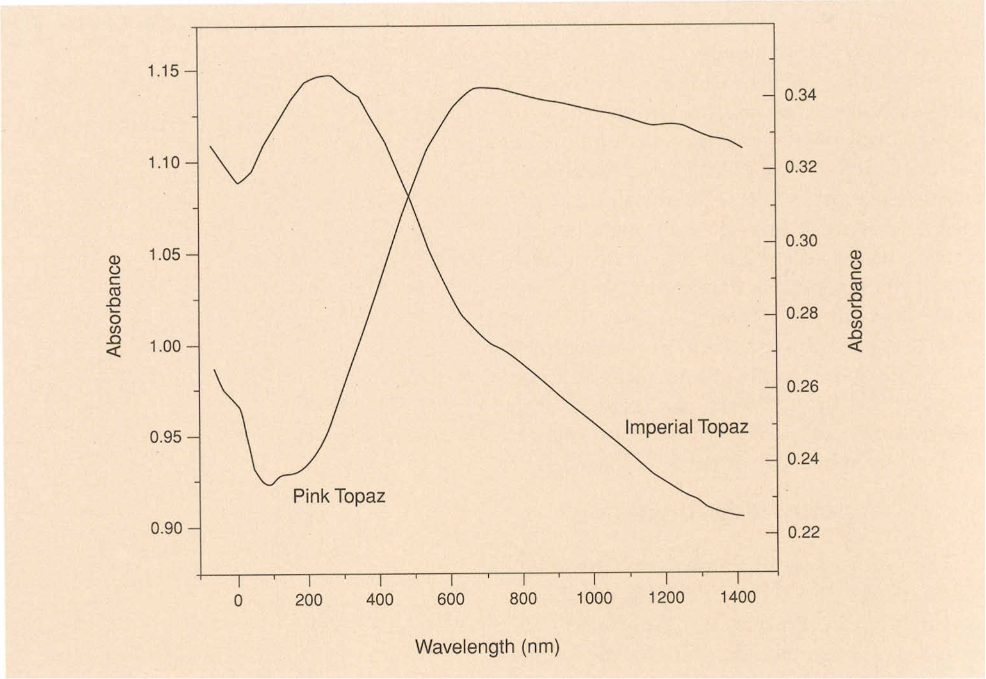

Figure 9: Unpolarized uv-visible spectra of imperial (right axis) and pink topaz (left axis). The pink topaz was obtained by heating the imperial topaz at 600°C.

hydrogen content falls to about 60% of its original value, whereas the fluorine content remains approximately constant. These results are in good agreement with those reported by da Costa *et al.* (2000) who proposed that the first loss of mass in the thermogravimetric analysis is due to the release of OH groups.

The chemical decomposition of topaz is due to the loss of fluorine, hydrogen and also of silicon as shown in *Figure 7*. It can be seen that the Si/Al ratio decreases, above 1000°C, from 0.5 (in natural topaz) to 0.34 at 1300°C (0.33 in mullite), which means that silicon has been released from the structure, probable as SiF_4 or SiO_2 (Day *et al.*, 1995). According to the X-ray diffraction results there are no traces of topaz in the samples heated above 1300°C and they appear opaque and white, as shown in *Figure 8*. Mullite is stable up to ca 1850°C, where it congruently melts.

In conclusion, the results presented in this work, by using different characterisation techniques, clearly show that imperial topaz is a stable material below 1000°C, i.e. it does not undergo any structural or chemical modifications upon heating. In contrast to this stability, the optical properties do change: on heating, imperial topaz first becomes pink at about 600°C, and then turns colourless above 900°C. The unpolarized uv-visible spectra of imperial topaz and of the sample heated at 600°C are shown in *Figure 9*. The former shows a maximum absorption centred at about 400 nm, similar to that reported by Schwarz (1997), whereas the latter shows the maximum near 700 nm. The changes in the colours are due to the destruction of colour centres, by a mechanism which is not yet well known.

Acknowledgements

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Natural versus hydrothermal synthetic Russian red beryl: chemical composition and spectroscopic measurements

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ABSTRACT: Two natural red beryl samples from Utah have been compared with six hydrothermal synthetic specimens recently produced in Russia, in order to determine the most significant chemical-physical parameters for discrimination. Classical gemmological observations have been coupled with results from electron probe microanalysis wavelength-dispersive spectrometry (WDS) and measurements by Fourier transform infrared (FTIR) and Raman spectrometry. The results are discussed in the light of previous published investigations.

Keywords: chemical composition; FTIR; natural red beryl, Raman spectroscopy; synthetic red beryl

Introduction

In the last decade beryl has grown significantly in importance among hydrothermal synthetic gemstones, in terms of the amounts produced and marketed (Koivula *et al.*, 2000). In particular, hydrothermal synthetic emeralds from China and Russia have motivated many a study devoted to investigate growth mechanisms and physical-chemical properties helpful for characterisation (see for instance: Schmetzer, 1988; Brown *et al.*, 1989; Sosso and Piacenza, 1995; Koivula *et al.*, 1996; Schmetzer, 1996; Schmetzer *et al.*, 1997a; Sechos, 1997). Coloured synthetic beryl has attracted much interest too, especially as to the possibility of controlling its colour by means of addition of appropriate ionic species: purple is attained by doping with a combination of chromium and manganese, pink by manganese alone (like morganite and natural red beryl from Utah), blue by copper and orange-red by traces of cobalt (Koivula and Kammerling, 1988; Koivula and Kammerling, 1991; Johnson *et al.*, 1999a). Biron synthetic pink beryl has been reported by Fritsch (1992)

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Techniques and equipment

IR and Raman measurements were carried out (i) by a Nicolet NEXUS FTIR spectrophotometer equipped with a diffuse reflectance (DRIFT) accessory, operating over the range 400-7400 cm^{-1} at a resolution of 2 cm^{-1}, and (ii) by a BRUKER 100 FT-Raman spectrophotometer in backscattering mode, with a Nd-YAG laser at 1064 nm, operating over the range 50-4000 cm^{-1} at a resolution of 2 cm^{-1}, respectively. A 2 mm^2 facet is sufficient to carry out FTIR measurements in reflectance mode, while Raman spectra can be collected regardless of the shape of the surface (Tretyakova *et al.*, 1997). All the samples were studied by FTIR using two settings to assess the dependence of the IR-spectra on the specimen's orientation (Stockton, 1987; Fritsch and Stockton, 1987; Martin *et al.*, 1989). In the case of 1b, 2b, 3b, 4b and 6b measurements were performed with the samples oriented with their *c*-axis first parallel and then normal to the light path in the instrument; the *c*-axis in specimens 5b, 7b and 8b, was not located and they were studied using two facets at approximately 90° to each other. Before performing Raman and FTIR measurements the samples were meticulously cleaned by acetone to remove residual traces of grease or of any other environmental organic contamination.

Quantitative chemical analyses were carried out using an Allied Research Laboratories electron microprobe equipped with six wavelength dispersive spectrometers and a Tracor Northern energy dispersive spectrometer. The system was operated using an electron beam at an accelerating voltage of 15kV, a sample current on brass of 15 nA and a counting time of 10 or 20 sec on the peaks, and of 5 or 10 sec on the backgrounds. The samples were embedded in a resin, and their facets used as flat surfaces for analysis. A series of minerals (kaersutite for Mg, Na, Ti, K; rhodonite for Mn; sodalite for Cl; niccolite for As and Ni; galena for S and Pb) and pure elements (for Co and Cu) were used as compositional standards. The results were corrected for matrix effects by a conventional ZAF routine from the Tracor Northern TASK set of programmes. The instrument sensitivity can be estimated about 0.05% in weight of the analysed element, on the basis of previous calibrations on standards; elemental concentrations smaller than 0.05% in weight, though detected, cannot be considered fully reliable. A normalization according to 15 oxygen atoms per formula unit was used, in the case of beryl. The chemical composition of each sample was determined as an average over 10 independent measurements, to account for compositional inhomogeneities, which were of the same order or less than the variation due to instrument sensitivity. The detection of the light elements Be and Li, is not possible with this microprobe, though their presence is indicated by the apparently non-stoichiometric contents of the other oxides.

and by Brown (1990); bicoloured 'water melon' synthetic beryl was produced in Japan (see Koivula *et al.*, 1986), while hydrothermal synthetic aquamarine from Russia has been described by Schmetzer (1990). Henn and Milisenda (1999) gave a detailed account of hydrothermal synthetic red beryl from Russia, characterizing their samples by IR-spectroscopy, in terms of atomic scale properties, and by optical observations, to describe inhomogeneous growth structures. Shigley *et al.* (2001) have recently reconsidered the comparison between natural and synthetic red beryl for diagnostic identification purposes.

We here report a study of natural versus hydrothermal synthetic red beryl based on a combination of classical gemmological observations with Raman and FTIR measurements, and with chemical composition determinations from electron probe microanalysis in wavelength dispersion mode (WDS = Wavelength Dispersion Spectroscopy). The present investigation complements the earlier ones in terms of a characterization of the samples over the infrared energy range by means of both FTIR and Raman spectroscopy, and provides a precise compositional determination by WDS, which is particularly appropriate to determine the minor element contents (Potts, 1987). Note that hereafter we often address 'natural (synthetic) red beryl' simply as 'natural (synthetic) beryl', for the sake of brevity.

Specimens

In total eight red beryl samples were studied: six synthetic (1b, 2b, 3b, 4b, 5b, 6b) and two natural (7b, 8b) specimens. The former, from Russia, obtained by hydrothermal synthesis and between 1.4 and 4.1 ct in weight, were kindly supplied by ARS AURA (Milan, Italy); the latter, from Utah and less than 0.5 ct in weight, were provided by the Italian Gemmological Institute (IGI). Four

Table I: *Gemmological details of six synthetic and two natural samples of red beryl.*

Sample no.	*Weight ct*	*Dimensions mm*	*Colour*	*Pleochroism*	*UV fluorescence*	*Inclusions*
Hydrothermal synthetic red beryl from Russia						
1b	1.42	9.0×7.0×3.7	purplish-pink	medium: ω violet ε rose	none	inhomogeneous growth structures
2b	2.28	10.0×8.0×4.1	purplish-pink	medium: ω violet ε rose	none	inhomogeneous growth structures
3b	3.70	12.1×10.0×4.9	red	strong: ω red ε orange	none	inhomogeneous growth structures
4b	4.10	12.0×10.0×6.2	red	strong: ω red ε orange	none	inhomogeneous growth structures
5b	19.37	rough	red	strong: ω red ε orange	none	inhomogeneous growth structures
6b	15.87	rough	red	strong: ω red ε orange	none	inhomogeneous growth structures
Natural red beryl from Utah						
7b	0.40	4.8×2.9×3.2	purplish-pink	weak: ω violet ε rose	none	no inhomogeneous growth structures
8b	0.27	5.0×4.0×2.0	purplish-pink	weak: ω violet ε rose	none	no inhomogeneous growth structures

out of the six synthetic beryl samples are faceted, whilst the others are cut as parallelepipeds.

Results and discussion

Gemmological features

The results obtained from traditional gemmological testing are summarized in *Tables I* and *II*. Inhomogeneous growth structures, common in Russian synthetic hydrothermal emeralds (Schmetzer, 1988; Schmetzer, 1996; Brown *et al.*, 1989; Sosso and Piacenza 1995; Koivula *et al.*, 1996; Schmetzer *et al.*, 1997b; Sechos, 1997), have been observed in our synthetic samples using a microscope at 50× magnification. These inhomogeneous growth patterns, described as 'chevron' or 'zig-zag' growth structures by Sechos (1997), or as 'angular' growth patterns by Schmetzer (1988), are among the most significant diagnostic features for

Table II: *SG and RI of red beryl samples, from the present study and from literature.*

SG	*RI*	*Sample no.*	*Reference*
Russian hydrothermal red beryls			
2.69	n_ω 1.580 n_ε 1.572	1b	
2.68	n_ω 1.580 n_ε 1.573	2b	
2.70	n_ω 1.580 n_ε 1.573	3b	
2.70	n_ω 1.580 n_ε 1.573	4b	
2.70	n_ω 1.580 n_ε 1.572	5b	
2.70	n_ω 1.580 n_ε 1.572	6b	
2.63-2.65	n_ω 1.578-80 n_ε 1.570-76		Henn and Milisenda (1999)
2.67	n_ω 1.576 n_ε 1.570		Henn and Milisenda (1999)
2.69	n_ω 1.580 n_ε 1.574		Henn and Milisenda (1999)
2.68	n_ω 1.572 n_ε 1.568		Johnson and Koivula (1997)
2.68	n_ω 1.581 n_ε 1.575		Johnson and Koivula (1997)
Natural beryls from Utah			
2.66	n_ω 1.570 n_ε 1.565	7b	
2.65	n_ω 1.570 n_ε 1.564	8b	
	n_ω 1.572 n_ε 1.568		Harding (1995)
2.63-2.72	n_ω 1.567-71 n_ε 1.561-65		Hosaka *et al.* (1993)
2.66-2.70	n_ω 1.568-72 n_ε 1.564-69		Shigley and Foord (1984)
2.67	n_ω 1.568-77 n_ε 1.561-70		Flamini *et al.* (1983)
2.65	n_ω 1.569 n_ε 1.561		Miley (1980-81)
2.67	n_ω 1.576 n_ε 1.570		Nassau and Wood (1968)
2.66-2.70	n_ω 1.568-72 n_ε 1.564-69		Webster (1994)
2.67	n_ω 1.570-77 n_ε 1.561-68		Leone and Cumo (1985)

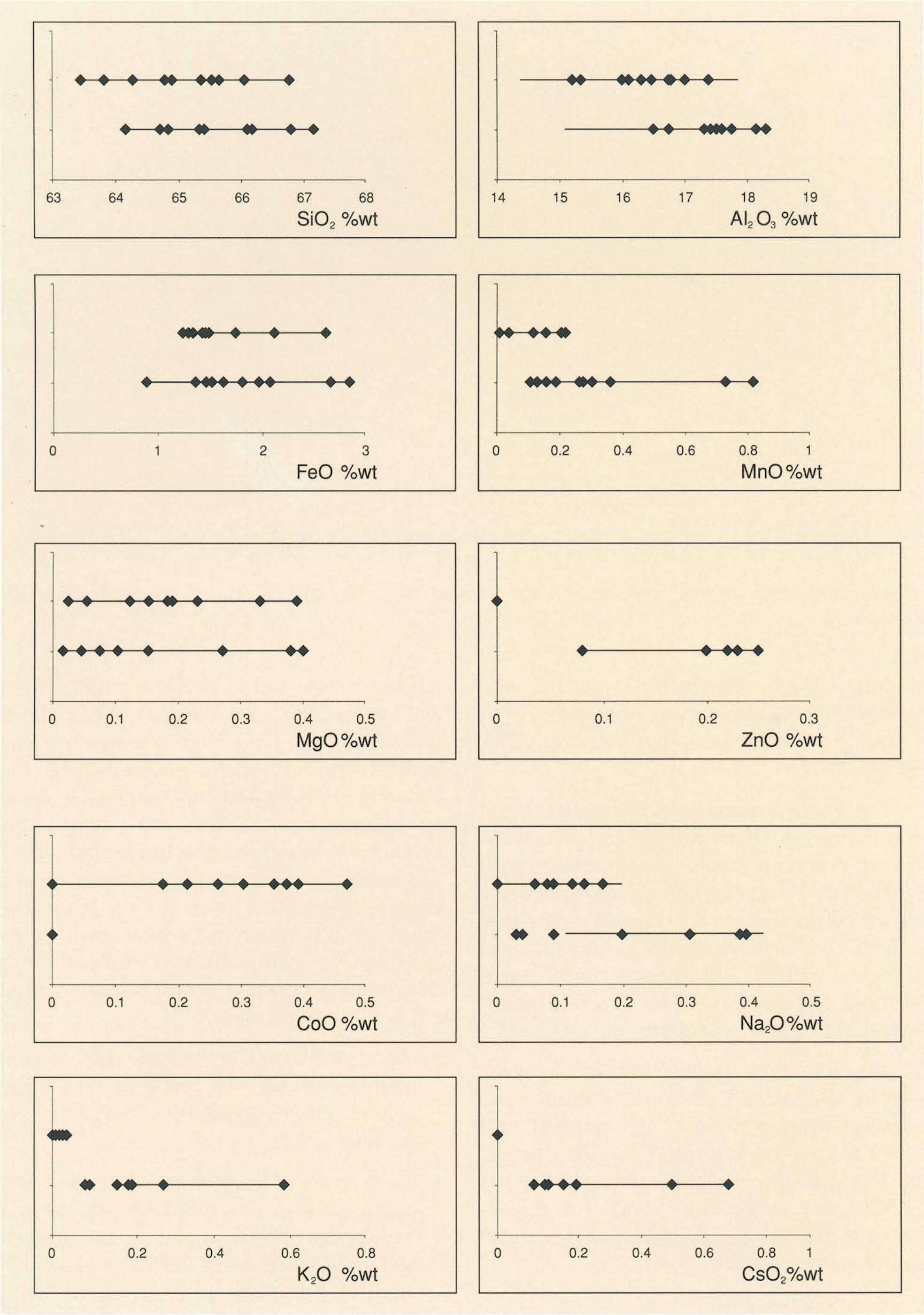

Figure 1: *Oxide contents in red beryl from the present study and from the literature. Contents in synthetic beryl are plotted on the upper line, those in natural beryl on the lower line.*

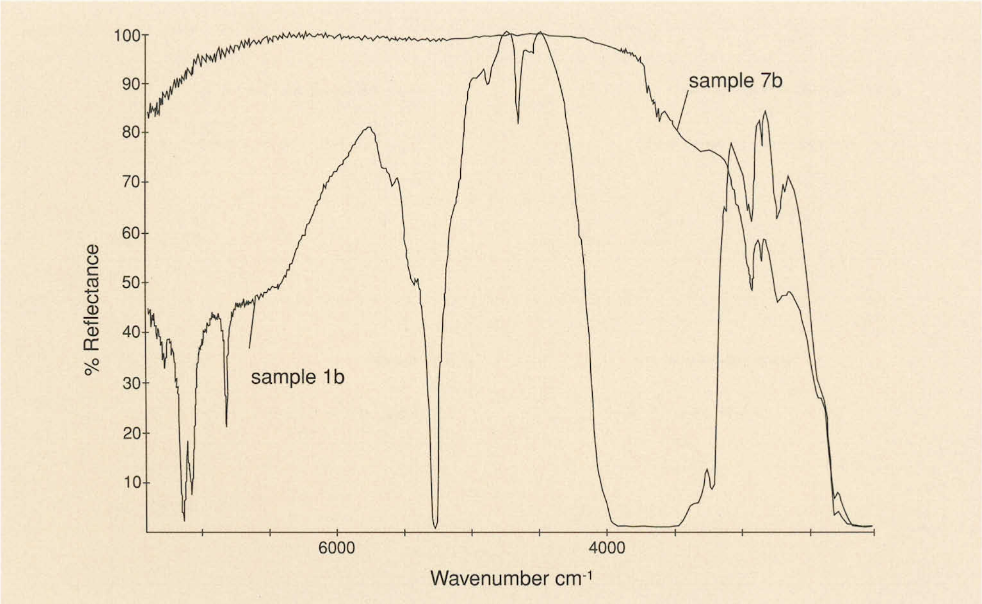

Figure 2: Typical infrared spectra of a natural red beryl (sample 7b) and a synthetic red beryl (sample 1b).

distinguishing between natural and synthetic beryl (Henn and Milisenda, 1999; Brown *et al.*, 1989: Sosso and Piacenza, 1995; Sechos, 1997).

The hydrothermal synthetic red beryl specimens are markedly more pleochroic than the natural stones (in agreement with Johnson and Koivula, 1997), presumably due to the occurrence of extended structural defects, but neither synthetic nor natural samples exhibit any fluorescence when exposed to long-wave (365 nm) and short-wave (254 nm) UV radiation.

The refractive index (RI) and specific gravity (SG) values (*Table II*) of the natural samples overlap those of the synthetic red beryl. SG ranges from 2.63 to 2.72 whereas the RI values lie in the following intervals: n_ω (1.572-81)/n_ε(1.568-76) and n_ω(1.564-77)/n_ε(1.561-72) for synthetic and natural samples, respectively.

Chemical composition

The distinction between natural and synthetic emeralds using chemical criteria has been discussed by Stockton (1984), Stern and Hänni (1982) and Schrader (1983). Minor quantities of Cl have been detected in some hydrothermal synthetic emeralds and the contents of Na_2O and MgO were suggested as diagnostic markers to distinguish synthetic from natural specimens. In *Figure 1* the oxide contents of our samples of red beryl are plotted with those from the literature. It is apparent that some oxides can be used as compositional indicators to discriminate between synthetic and natural red beryl in particular:

- Zn systematically occurs in natural samples, though in different quantities, whereas in synthetic beryl it is undetectable;
- Co is usually present in synthetic beryl samples as a chromophore (Henn and Milisenda, 1999) to impart a more marked red hue; in contrast, cobalt is absent in natural samples, in agreement with Sinkankas and Read (1986). However Co is also absent in our synthetic samples 1a and 1b, and this

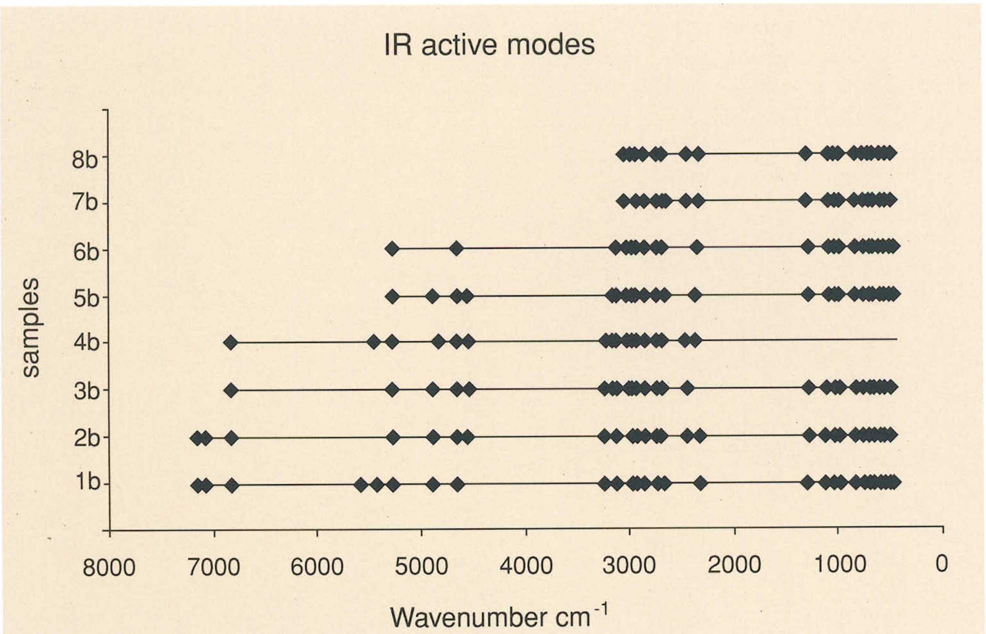

***Figure 3:** Infrared vibrational frequencies of the eight red beryl samples studied.*

absence causes the colour of the stones to tend towards a purplish-red;

- K occurs in significantly larger amounts in the natural samples than in the synthetic ones, where it is below the detection limit of the instrument;
- Cs has been detected in natural samples only, and it can be a distinctive indicator of the growth environment of natural beryl;
- Na and Mn occur in larger amounts in natural than in the synthetic samples, although if their concentration values lie below about 0.20% they cannot be considered reliable indicators for discrimination.

The other elements analysed are not useful for diagnostic purposes, as their ranges in natural and synthetic red beryl overlap.

Infrared spectra FTIR

The observed infrared spectra (*Figure* 2) yield vibrational frequencies which allow one to readily distinguish synthetic from natural red beryl (*Figure* 3). In the former the region ranging from 3500 to 3800 cm^{-1} is characterised by vibrational modes involving H_2O molecules (Stockton, 1987) and are seen as broad and intense bands; in contrast, weak peaks are only just detectable in the natural stone (*Figure* 2). The synthetic samples exhibit peaks at 5100, 5270 and 5455 cm^{-1}, corresponding to combination modes of water molecules of type I related to the low amount of alkali (Wood and Nassau, 1967; Wood and Nassau, 1968), consistent with the composition reported above. H_2O combination modes are also observed at 7150 cm^{-1}. The chlorine related bands in the 2500-3100 cm^{-1} range which were described by Schmetzer *et al.* (1997), Fritsch *et al.* (1992) and Stockton (1987) for some kinds of hydrothermal synthetic emeralds, are not present in the red beryl. This is consistent with the absence of chlorine indicated by the chemical analyses.

In the natural red beryl samples, very weak peaks appear in the spectral range 2000–7400 cm^{-1}; in particular, there are

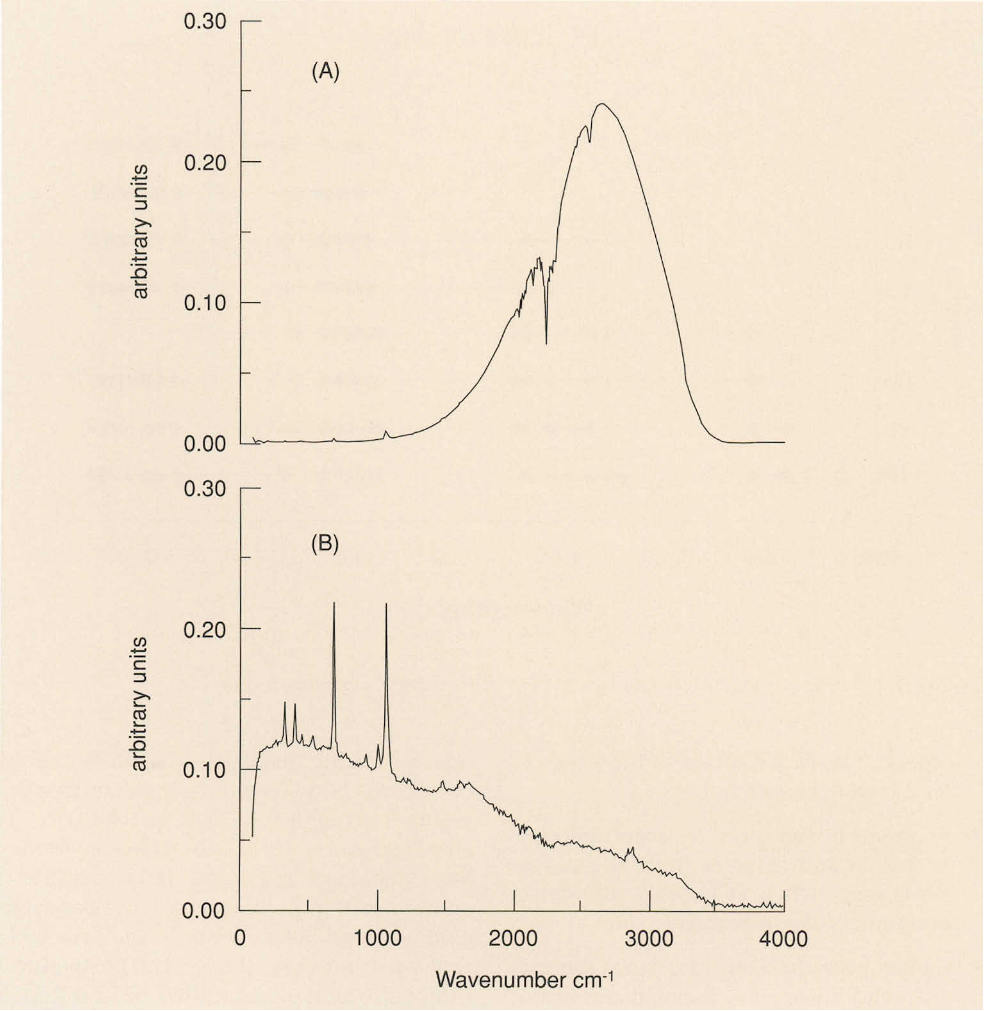

***Figure 4:** Raman spectra of (A) synthetic sample 5b and (B) natural sample 7b.*

signals at 3692 cm^{-1}, attributable to water molecules of type I, and at 3651 and 3598 cm^{-1}, due to asymmetric and symmetric stretching modes of water molecules of type II, respectively (Wood and Nassau, 1968). The nearly negligible amount of water in natural red beryl is ascribable to the growth conditions, as claimed by Nassau and Wood (1968), Flamini *et al.* (1983) and Shigley and Foord (1984). Hence, H_2O plays a role helpful for discrimination between natural and synthetic red beryl, given that (i) it is present in significantly different amounts, and (ii) it occurs as types I and II in the former, and as type I only in the latter. More generally, features due to water are easily detected by the infrared spectroscopy of beryl, and are useful in discriminating natural stones from their synthetic counterparts (Fritsch and Stockton, 1987; Stockton, 1987; Martin *et al.*, 1989; Schmetzer, 1990; Schmetzer and Kiefert, 1990; Yan *et al.*, 1995).

Lastly, we also observed vibrational bands in the range 3100–2800 cm^{-1} (in particular at 2957, 2925 and 2851 cm^{-1}) attributed to fissure fillers such as resins or

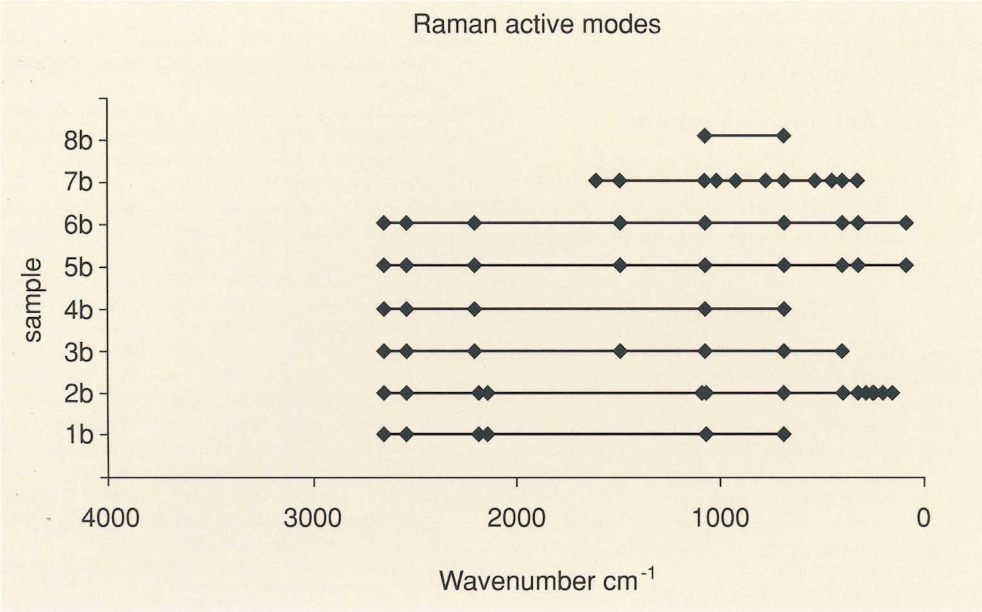

***Figure 5:** Vibrational frequencies observed by Raman spectroscopy in the eight red beryl samples.*

oil impregnations (Kiefert *et al.*, 1999; Johnson *et al.*, 1999b; Johnson and Muhlmeister, 1999) in both synthetic and natural samples.

Raman scattering

Raman spectra of natural and synthetic beryl have been collected by a variety of techniques (see Tretyakova *et al.*, 1997; Zwaan and Burke, 1998; Hänni *et al.*, 1997; Pilati *et al.*, 1997; Hageman *et al.*, 1990; Hofmeister *et al.*, 1987; Adams and Garden, 1974). *Figure 4* displays the spectra collected for samples 5b and 7b. Natural and synthetic samples reveal the presence of typical Raman peaks between 50 and 1200 cm^{-1}, and the strongest ones occur at 685 and 1070 cm^{-1} (*Figure 5*). The significant differences between synthetic and natural samples are that the former give Raman spectra characterized by:

(i) additional signals above 2000 cm^{-1}, due to overtones and extended structural defects;

(ii) a broad hump between 1500 and 3500 cm^{-1}, which is tentatively ascribed to fluorescence. This is consistent with the common presence of significant structural strain, indicated by broad X-ray diffraction peaks, in synthetic beryls.

NB: Detailed figures for the compositions, infrared and Raman spectral peaks can be obtained from Dr A. Pavese.

Conclusions

Traditional gemmological tests and observations allow one to distinguish synthetic from natural red beryl only on the basis of the occurrence of inhomogeneous growth structures in the former; such properties as refractive index and specific gravity are not diagnostic. Chemical composition may help in distinguishing natural from synthetic, because of the likely occurrence of Co in synthetic beryl or the characteristic presence of K, Na, Mn, Cs and Zn in natural samples. Infrared spectroscopy and Raman spectroscopy provide further indication for discrimination; with reference to the synthetic samples, the former reveals the significant presence of water, the latter shows additional peaks above 2000 cm^{-1}. Furthermore, the 1064 nm laser light causes significant fluorescence, appearing as a broad hump over the interval 1500-3500 cm^{-1}, in the synthetic red beryl samples.

Acknowledgements

The authors are grateful to ARS AURA (Milan, Italy) for providing the Russian hydrothermal synthetic red beryl samples used in the present investigation.

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Letter to the Editor

Birefringence vs. double refraction divergence

I am grateful to an individual who requested anonymity after asking for a specific clarification (case B.5) in my article 'Birefringence vs. double refraction divergence' (*J.Gemm.*, 2002, **28**(4), 223-6). I offer the following clarification as well as a correction to a typographical error in the references.

Reference 4 (p.226), "...instances where normal coincidence will yield no refraction" should read "...instances where normal incidence will yield no refraction".

On p.225 the final sentence in the paragraph before the Conclusions should say "...there are only two reversible directions of maximum double refraction divergence (max DD) for each optic axis!"

In the summary chart (p.225), the description for case B.5 that reads, "Two reversible directions equally oblique to both optic axes" should be changed to read, "Four reversible directions, two equally oblique to the optic plane at each optic axis".

Use of the term 'direction' in the above means wave-normal direction and not ray direction. Wave-normal coincides with ray direction when DD is nil, but is at a slight angle to at least one ray when there is DD.

Richard Cartier
Toronto, Canada

Abstracts

Diamonds

Gems and Minerals

Instruments and Techniques

Synthetics and Simulants

Diamonds

Les diamants de Guyane et le problème de la "Deuxième source".

R. CAPDEVILA. *Revue de gemmologie*, 145/146, 2002, 61-5.

Discussion of the metamorphosed komatiites of the Dachine area of Guyana and their role as a diamond host. M.O'D.

La certification des diamants de type II.

J.-P. CHALAIN. *Revue de gemmologie*, 145/146, 2002, 37-9.

Type II diamonds pose some problems when certificates need to be issued. HPHT stones are discussed in this context. M.O'D.

Le Koh-i-Noor.

M.-E. GIRARD AND D. GIRARD. *Revue de gemmologie*, 145/146, 2002, 30-5.

History of the Koh-i-Noor diamond with speculations on its origin and on the trade routes along which it may have travelled from its presumed Indian source which is shown on a map of Indian mines. M.O'D.

Noirs diamants bien incolore.

E. GONTHIER AND F. ROUMET, *Revue de gemmologie*, 145/146, 2002, 74-7.

Discusses the possibility of some diamonds which appear black in portraits taking their colour from alterations over time of the pigments used. In the pictures under consideration the black colour is now assumed to be an accurate representation of the stones. M.O'D.

Un diamant noir exceptionnel: Le Vulcain.

C. GROBON, *Revue de gemmologie*, 145/146, 2002, 78-9.

A diamond of 178.88 ct has a natural black colour and has been named 'Le Vulcain'. The black colour is due to the presence of graphite and ferric iron compounds as inclusions and the stone is H- and N-rich.

Noirs diamants bien incolore.

E. GONTHIER AND F. ROUMET, *Revue de gemmologie*, 145/146, 2002, 74-7.

Discusses the possibility of some diamonds which appear black in portraits taking their colour from alterations over time of the pigments used. In the pictures under consideration the black colour is now assumed to be an accurate representation of the stones. M.O'D.

Characterization and grading of natural-color pink diamonds.

J.M. KING, J.E. SHIGLEY, S.C. GUHIN, T.H. GELB AND M. HALL. *Gems & Gemology*, **38**(2), 2002, 128-47.

The GIA Gem Trade Laboratory (GTL) has collected gemmological data on 1490 natural-colour pink gem diamonds, including both types I and II. There is some overlap in gemmological properties between these two types; they show differences in their colour ranges, UV fluorescence, absorption spectra and microscopic features. The colour description terminology used for pink diamonds in GIA GTL grading reports is discussed and illustrated with a fold-out colour chart with purplish-pink, pink and orangy-pink subdivisions. There is a separate discussion on the very rare red diamonds. R.A.H.

Gem Trade Lab notes.

T.M. MOSES, I. REINITZ, S.F. MCCLURE AND M.L. JOHNSON (Eds). *Gems & Gemology*, **38**(1), 2002, 80-4.

Notes are given on a 1.55 ct oval diamond containing eclogitic inclusions (omphacite and garnet) and on only the second occurrence of a faceted 8.16 ct orange-red gem-quality genthelvite. R.A.H.

Traitement du diamant noir par graphitization "interne".

F. NOTARI. *Revue de gemmologie*, 145/146, 2002, 42-60.

Increasing numbers of black diamonds owing their colour to 'internal graphitization' have appeared on the markets in recent years. The diamonds so treated are of low quality and need to have many closed fractures and

Abstractors

R.A. Howie	R.A.H.	P.G. Read	P.G.R.
M. O'Donoghue	M.O'D.	E. Stern	E.S.

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

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cavities in order that induced pyrolitic graphites are isolated from oxygen. Four methods of achieving a satisfactory black are outlined. M.O'D.

Star of the South: a historic 128 ct diamond.

C.P. Smith and G. Bosshart. *Gems & Gemology* **38**(1), 2002, 54-64.

Star of the South, discovered in 1853, became the first Brazilian diamond to achieve international acclaim. This paper provides the first complete gemmological characterization of this 128.48 ct stone. The clarity grade is VS_2 and the colour grade Fancy Light pinkish-brown; it has the gemmological and spectroscopic characteristics of a type IIa diamond, including graining and strain patterns, UV–VIS–NIR and mid- to near-IR absorption spectra, and Raman photoluminescence. Khande Rao, Gaekwar of Baroda, had it mounted in a necklace also containing the 78.5 ct English Dresden from the same area in Minas Gerais, but it was sold in 2001 to owners who wish to remain anonymous, and was submitted to the Gübelin Gem Lab for a diamond grading report (hence this article). R.A.H.

Diamant, réalité fabuleuse.

G.S. Tolkowsky. *Revue de gemmologie*, 145/146, 2002, 66-8.
Short discussion and illustration of different styles of polishing diamonds originated by the author. M.O'D.

Gems and Minerals

Investigations and studies in jade. The Bishop collection.

H.R. Bishop. *Bulletin of the Friends of Jade*, **10**, 2002, 27-158.

This text is a near-complete reprint of the text of a celebrated work published in 1906 and includes short papers by Kunz, Pirsson and others. The original book [Sinkankas 661] was published in two volumes and is very rare, only 100 copies having been printed. M.O'D.

Louisiana opal.

G. Brown. *Australian Gemmologist*, **21**(6), 2002, 244-6, 6 colour illus., 1 map.
A unique variety of precious opal consisting of a light to dark sandstone cemented with precious opal has been found at Monks Hammock, central western Louisiana, USA. This deposit of opalised sandstone was originally discovered in the early 1990s, was worked as a commercial mining lease for about three years, fossicked intermittently, but has not been mined commercially since closure. Access to the deposit is no longer possible as it lies within the pine forest of the Bois Cascade Paper Company. Samples of this rare variety of opal can still be purchased on the internet. P.G.R.

Identification of some yellow-orange gemstones from Sri Lanka.

P.G.R. Dharmaratne. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 41-6, 1 photograph, 2 tables, bibl.

Sri Lanka is a small country and gem dealers can visit the major gem mines and centres in a short time and thus come across most gem varieties found in the country. The more common varieties are bought for trade, but often the unidentified stones are purchased for their own collection. This paper discusses the contents of such a parcel of yellow-orange stones found over a large part of the island; there were seventeen varieties, including enstatite, heliodor, chrysoberyl, citrine, zircon, yellow sapphire, hessonite, spessartine, orthoclase, tourmaline, aventurine feldspar, danburite, apatite, scapolite and moonstone. E.S.

Liddicoatite tourmaline from Anjanabonoina, Madagascar.

D.M. Dirlam, B.M. Laurs, F. Pezzotta and W.B. Simmons. *Gems & Gemology*, **38**(1), 2002, 28-53.

Most of the remarkable polychrome specimens of liddicoatite with varied geometric patterns of zoning have come from the Anjanabonoina pegmatite in central Madagascar, mainly sold as polished slices or carvings. Liddicoatite has physical and optical properties that overlap those of elbaite, necessitating quantitative chemical analyses to distinguish these two species; both may occur in a single crystal. The most common internal features are colour zoning, strain patterns, partially healed fractures, feathers, needle-like tubes, negative crystals and inclusions of albite. Liddicoatite has also been reported from several other localities in the world; results of microprobe analyses for specimens from non-Madagascar localities are tabulated. R.A.H.

Identification of yellow cultured pearls from the black-lipped oyster Pinctada margaritifera.

S. Elen. *Gems & Gemology*, **38**(1), 2002, 66-72.

Although the *Pinctada margaritifera* oyster is usually associated with the black pearls cultured in French Polynesia, it also can produce attractive large yellow cultured pearls, among other colours. An absorption feature at 700 nm can be used to distinguish these yellow cultured pearls from their more common counterparts produced in the area by the *Pinctada maxima*. This absorption feature has been attributed to the presence of black pigments and has been reported as an identifying characteristic of black cultured pearls from *Pinctada margaritifera*. An additional absorption feature in the UV region between 330 and 385 nm, is indicative of natural yellow colour in cultured pearls from the *P. margaritifera*. R.A.H.

Update on the identification of treated "golden" South Sea cultured pearls.

S. Elen. *Gems & Gemology*, **38**(2), 2002, 156-59.

Most of the 'golden' South Sea cultured pearls in a single strand were found to exhibit unusual brownish-orange fluorescence in long-wave UV radiation and atypical features at 405 and 558 nm. On this basis, and from visual examination, 33 of the 35 cultured pearls were identified as colour treated. This work shows how atypical absorption features, particularly in the blue region of the spectrum, can be used to positively identify colour treatment, even in the presence of the 330-85 nm UV absorption feature characteristic of natural-colour 'golden' pearls from *Pinctada maxima*. R.A.H.

Jade in British Columbia and Alaska and its use by the natives.

G.T. Emmons. *Bulletin of the Friends of Jade*, **10**, 2000, 183-98 plus 4 pages in colour.

Reprint of a paper first published as no. 35 in the series *Indian notes and monographs* (New York Museum of the American Indian, Heye Foundation, 1923). M.O'D.

Mexican gem opals.

E. Fritsch, M. Ostrooumov, B. Rondeau, A. Barreau, D. Albertini, A.-M. Marie, B. Lasnier and J. Wery. *Australian Gemmologist*, **21**(6), 2002, 230-3, 7 black-and-white illus.

This paper, which includes nano- and micro-structure details of Mexican opals, origin of colour and a comparison with other common opals of gemmological significance, is based on a lecture presented to the XXVIII International Gemmological Conference, Madrid, Spain on 8 October 2001. The elementary building blocks of all but highly porous play-of-colour opal, hydrophane or cachalong are shown to be formed by small silica grains grouped as fibres, blades or larger spheres. The body colour in opal is generally due to inclusions, sometimes submicroscopic. For example, fire opal is coloured by nanometre-size fibres of an iron-containing compound. P.G.R.

The peculiarity of olivine from Sri Lanka.

G. Graziani, L. Martarelli and G. Zoysa. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 29-39. 7 photographs, 1 map, 3 tables, bibl.

Although olivines are wide-spread, clear, transparent, yellowish-green peridot is much rarer. This paper deals with yellow-green to brownish-green stones found in Sri Lanka. Tests show that this magnesium-rich olivine has Mg/(Mg+Fe+Mn) ratios ranging from 0.77 to 0.85. Some dark crystals show a lot of inclusions, such as healed fractures, decrepitation haloes, fluorapatite, calcite, spinel group minerals, iron oxides and hydroxides, Mg-calcite, chrysotile and saponite. The data obtained seem to be consistent with olivine formation in a high-grade metamorphic environment. E.S.

Gemmologische Kurzinformationen. Cassiterit aus Bolivien.

U. Henn. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 50-1, photographs, bibl.

The author describes some botroyoidal laminated cassiterite from Bolivia. Originally found in Cornwall and Bohemia (Ore Mountains), it is now found in South East Asia, Africa and South America in Brazil and Bolivia. Cassiterite is pure tin oxide SnO_2, crystallizes tetragonally and has a hardness of 6.5, SG 6.95, RI 2.003-2.101, and birefringence 0.098. Some cassiterite is called 'wood tin' as its concentric composition is not unlike that of a tree. In the past it has sometimes been offered in the trade as petrified wood. E.S.

Gemmologische Kurzinformationen. Farbwechselnder Fluorit aus Indien.

U. Henn. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 52-4, 5 photographs, 1 graph, bibl.

The colour change fluorite offered to the author was an emerald cut weighing 75.44 ct. It was clear, transparent and changed from smoky brown in daylight to mauve in artificial light. SG 3.18, RI 1.432. The colour change is caused by an absorption in the yellow part of the spectrum with a maximum at 580 nm which is due to a colour centre. E.S.

Gemmologische Kurzinformationen. Schleifwürdiger Lithiophilit aus Brasilien.

U. Henn. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 47-9.

Gem-quality lithiophilite of a greenish-brown colour is found in the pegmatites of Minas Gerais, Brazil. RI 1.688-1.693, DR 0.005, SG 3.50, composition $Mn_{47}Fe_{53}$. The spectra show several absorption lines due to bivalent manganese and one broad band due to Fe^{2+}. E.S.

Burma Gazetteer. Myitkina District. Volume A, 1960.

W.A. Hertz. *Bulletin of the Friends of Jade*, **10**, 2002, 159-78.

Useful reprint of a work covering the jade-producing Myitkina District of Burma (Myanmar) and including a useful bibliography of similar sources. [The British Library's Oriental and India Office Collections holds the finest coverage extant of this type of literature: a Reader's ticket is needed to use the Library and is not issued lightly.] M.O'D.

A note on nephrite etymology.

D.B. Hoover. *Bulletin of the Friends of Jade*, **10**, 2002, 5-9.

Speculations on the origin of the noun nephrite draw upon classical and later sources. The word is believed to refer to a stone with curative powers in cases of kidney disorders or those of neighbouring parts of the body. M.O'D.

Sources of jade in Brazil.

D.B. Hoover. *Bulletin of the Friends of Jade*, **10**, 2002, 11-18.

Results of a literature search for references to occurrences of the jade minerals in Brazil with some comments on the quality of the 28 sources listed in the bibliography. M.O'D.

Interesting American Opals: wood replacement.

J.I. Koivula and M. Tannous. *Australian Gemmologist*, **21**(6), 2002, 242-3, 4 colour illus.

The four dark brown opalised wood cabochons that were examined all came from the Rainbow Ridge opal mine, Virgin Valley, Nevada, USA. All four opals still showed in detail the banded structure of the original wood. Three of the cabochons showed streaks of precious opal that were the result of opal filling cracks in the original wood before it was opalised. P.G.R.

Gem News International.

B.M. Laurs (Ed.). *Gems & Gemology*, Vol. **38**(1) 2002, 86-106.

Mention is made of a new high-T treatment producing orange and yellow sapphires from a variety of coloured corundums; it seems that the diffusion of Be may be involved. Other items include red andesine from Congo, faceted and cabochon-cut green fluorites from the Rogerley mine in Weardale, black spinels from Mexico, faceted blue biaxial positive kyanite from Nepal, vivid green pargasite from China and a 6.80 ct six-rayed star emerald from Madagascar. R.A.H.

Gem News International.

B.M. Laurs (Ed.). *Gems & Gemology*, **38**(2), 2002, 170-86.

Brief details are given of diamond-bearing kimberlites in the province of Quebec, faceted cassiterite from the Viloco mine in Bolivia, cabochons from Brazil of emerald in a plagioclase matrix, sapphires reportedly from a new locality in Afghanistan, a tourmaline slice from Vietnam resembling Madagascar liddicoatite, bluish green zoisite from Tanzania and a 9.84 ct irradiated fluorite which appears deep blue in daylight and purple in incandescent light. R.A.H.

A survey of jade literature.

R. Merk. *Bulletin of the Friends of Jade*, **10**, 2002, 179-82.

Short bibliography of the jade minerals with comments on content and availability. M.O'D.

Gemmologie Aktuell.

C.C.Milisenda. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 7-12, 6 photographs.

Short note on the origin determination of Paraíba tourmalines by working out the ratio between copper and structurally related trace elements which allow the separate identification of Nigerian and Brazilian copper-bearing tourmalines. A number of pinkish-orange corundums weighing between 1.5 and 4 ct have been offered on the market. The colour is the result of a heat treatment of pink sapphires from Madagascar. The thermal enhancement can be identified by altered crystal inclusions surrounded by expansion halos. Bicoloured beryls were recently mined in Tajikistan. A photograph shows a good blue-yellow sample weighing 13.81 ct, RI 1.570-1-578, SG 2.70. Some synthetic emerald druses have been produced in Russia by the flux method; they are clusters of synthetic emeralds grown on seed plates. E.S.

Update on Guatemala jadeite.

A. M. Miller. *Bulletin of the Friends of Jade*, **10**, 2002, 3-4.

A mine in the Motagua River valley of Guatemala is reported to be producing outstanding lavender jadeite as well as multi-coloured varieties; pink, blue, yellow and white varieties have been found. A short description of the find and of the local geology is given. M.O'D.

Gem Trade Lab notes.

T.M. Moses, I. Reinitz, S.F. McClure and M.L. Johnson (Eds). *Gems & Gemology*, **38**(2), 2002, pp.161-8.

Notes include details of a double-strand necklace of graduated diamond 'pearls', high-quality synthetic jade produced by General Electric, and cobalt-'diffused' sapphire. R.A.H.

Serendibite from Sri Lanka.

K. Schmetzer, G. Bosshart, H.-J. Bernhardt, E.J. Gübelin and C.P. Smith. *Gems & Gemology*, **38**(1), 2002, 73-9.

Two samples (0.35 and 0.55 ct) of faceted serendibite from secondary deposits in Sri Lanka are described. The bluish-green to green-blue cut stones are similar in colour, physical and optical properties, and chemical composition to low-iron-bearing non-gem-quality serendibite from various other occurrences. The cut serendibites may be confused with sapphirine or zoisite, but can be distinguished by their refractive indices, twinning and spectroscopic features. Microprobe analytical results are reported. R.A.H.

New chromium- and vanadium-bearing garnets from Tranoroa, Madagascar.

K. Schmetzer, T. Hainschwang, H.-J. Bernhardt and L. Kiefert *Gems & Gemology*, **38**(2), 2002, 148-55.

Spessartine-pyrope garnets from Tranoroa, 60 km SW of Bekily, S Madagascar, contain Cr_2O_3 0.68-0.75 an V_2O_3 0.35-0.51 wt.%. Despite having the elements often responsible for colour-change behaviour, these garnets show only a slight change in appearance from brownish-red in daylight to purplish-red in incandescent light. They contain characteristic inclusions of rutile needles and strain patterns causing anomalous double refraction. EPMA results, together with n and D are reported for six of these garnets and for a Cr-bearing spessartine ($spe_{88.46}$). R.A.H.

Gemmological study of corundum from Madagascar.

J. Shida. *Australian Gemmologist*, **21**(6), 2002, 247-52, 7 colour illus.

The most important variety of Madagascan corundum is sapphire, and as it is relatively inexpensive it is sometimes supplied to the market as sapphires from Myanmar, Sri Lanka and Kashmir. It is therefore of particular importance to a laboratory such as that of the GAAJ to be able to determine the country of origin of a sapphire. This paper also describes methods for discriminating natural coloured from heat treated Madagascan ruby and sapphire. The usefulness of laser tomography to assist in these discriminations is emphasised. P.G.R.

Nephrite in Brazil.

A.C. Simoens da Silva. *Bulletin of the Friends of Jade*, **10**, 2002, 19-26.

Description and discussion of greenish nephrite artefacts found in Brazil and manufactured by the ancient inhabitants of that country. M.O'D.

Spectroscopic properties of Möng Hsu ruby.

S. Siripaisarnpipat, T. Pattharakorn, S. Sanguanruang, N. Koonsaeng, S. Achiwawich, M. Promsurin and P. Hammungthum. *Australian Gemmologist*, **21**(6), 2002, 236-41. 2 colour, 1 black-and-white illus., 4 graphs, 1 table.

The electronic (UV-Vis) and infrared spectra of 140 Mong Hsu rubies were analysed to find any differences between unheated and heat-treated specimens. There were no significant changes in electronic spectra that would indicate heat treatment, but differences between infrared spectra of rubies that have and have not been heat-treated may be used as evidence of heat treatments in rubies. P.G.R.

Instruments and Techniques

Portable instruments and tips on practical gemology in the field.

E.W. Boehm. *Gems & Gemology*, **38**(1), 2002, 14-27.

Most purchases of gems or jewellery are made in environments that make it difficult to carry anything more than a loupe, a torch and a pair of tweezers. Practice with these and the addition of portable gemmological instruments described in this article should enable the buyer to develop the keen senses necessary to better ascertain the identity and quality of the material being considered. Descriptions are given of the darkfield loupe, the new London dichroscope, a long-wave portable UV lamp, a portable refractometer and a portable hardness kit. Practical tips are given on the use of all of these in the field. Common sense must dictate how a clue is applied; some tests will merely help narrow down the possibilities. R.A.H.

The magnetic index.

W. Wm. Hanneman. *Australian Gemmologist*, **21**(6), 2002, 234/5, 2 black-and-white illus., 1 graph, 1 table.

Figures obtained from B.W. Anderson's empirical formula for the magnetic pull of a gem material are tabulated against magnetic index readings produced by Hanneman using his magnetic index meter. This meter uses a combination of a vertically suspending nylon thread and a rare earth magnet to record the angle of rotation at which the gemstone breaks free of its magnetic attraction to the magnet. The scale of the meter is calibrated in terms of the sine of the angle of rotation multiplied by 100. The results, plotted against Anderson's readings for magnetic pull show a linear relationship between the two sets of figures. P.G.R.

Tri de diamants par les instruments de la DTC.

S. Lawson, *Revue de gemmologie*, 145/146, 2002, 69-71.

Appraisal by the Director of the Gem Defensive Projects group of DTC, a De Beers Group company, of the DiamondSure and DiamondView testing instruments devised by the Group. M.O'D.

Synthetics and Simulants

Zusammengesetzte Steine -eine aktuelle Betrachtung.

U. Henn. *Gemmologie. Z. Dt. Gemmol. Ges.*, **51**(1), 2002, 13-28. 20 photographs, bibl.

Due to the development in the production of synthetic stones and improvements in various treatments of gemstones, composite stones have been thrust into the background. However, there are many examples to be found in the market, which can be divided into four groups. (a) doublets and triplets as simulants of classical gemstones, (b) composite stones manufactured to protect materials of lower hardness by covering it with a harder substance, (c) composite stones made up of gem materials which occur in thick layers, or are more attractive in thin layers, and (d) assembled stones. Usually any unset, loose composite stone is easily recognized, while identification of a set composite needs greater care, although usually air bubbles in the adhesive layers between the stones and small colour alterations can be observed. E.S.

Recent observations of composite stones.

U. Henn. *Australian Gemmologist*, **21**(6), 2002, 253-7, 16 colour illus., 1 table

Daily work in a gemmological laboratory shows that the most frequently seen simulants of precious stones found in jewellery are Verneuil synthetic corundums and spinels, artificial glass and composite stones such as doublets and triplets. This paper provides descriptions and illustrations of classic, new and unusual composite stones seen at both the German Gemmological Association and the laboratory of the German Foundation of Gemstone Research in Idar Oberstein. P.G.R.

BOOK REVIEWS

Blood diamonds.

G. Campbell, 2002. Westview Press. pp xxv, 251.

Survey in journalistic style of the political breakdown in Sierra Leone following the rise of the Revolutionary United Front (RUF) and the eventual arrival of the United Nations Mission in Sierra Leone (UNAMSIL). The chain of events parallels to some extent the recent history of Angola and the part played by Unita in that country.

The author suggests that the sale of smuggled rough diamonds for guns was the secondary cause of the breakdown and that the activities of the De Beers organization in West Africa were the primary or at least the underlying cause. As always it is not easy to disentangle truth from convenient fiction when citations are few and mostly to general media sources. Details of the way diamonds are handled by the De Beers organization are described in somewhat pejorative terms and the description of the author's adventures place him safely on the side of the angels. M.O'D.

The Snettisham Roman jeweller's hoard.

C. Johns, 1997. The British Museum London. pp 128, illus. in black-and-white. Hardcover ISBN 0 7141 2310 2. £34.

Silver jewellery and engraved gems form part of the hoard of Roman treasure found at Snettisham, Norfolk, England, in 1985. The hoard was acquired by The British Museum after careful application of the laws of Treasure Trove concluding with the statutory Inquest. The book deals with the archaeological context and the varied contents of the hoard including textiles and the container. The catalogue of the hoard occupies pages 75-120 and the study concludes with a bibliography and index. M.O'D.

Photographic guide to minerals of the world.

O. Johnsen, 2002. Oxford University Press, Oxford. pp 439, illus. in colour. Hardcover. ISBN 0 19 851568 5. £17.99.

This is easily the best illustrated guide to minerals to be published for some years. First published in Danish under the title *Minerales verden* by Gads Forlag in 1994, the book draws for its illustrations on the collections of the Geological Museum of the University of Copenhagen. While the really beautiful photographs catch and retain the eye, the text is equally worthy of respect: clearly written and giving just the right amount of information it makes the book the ideal beginner's guide and as it is in quite a small format (21 × 15 cm) it can accompany its owner to museums and mineral shows without discomfort or inconvenience.

The explanation of the simpler rules of crystal morphology is the best I have seen so far in a popular book. In the descriptive section chemical composition, crystallographic and chemical notes, names and varieties, details of occurrence and diagnostic features, are given for each species included. The size of specimens illustrated is also given. Diagrams illustrating crystals are provided in many cases. There are also some ball-and-stick diagrams, in colour, illustrating some of the commoner structures.

Anyone with an interest in minerals should get this book, even if they already have an extensive personal library. M.O'D.

Gemstone buying guide. 2nd edn.

R. Newman, 2003. International Jewelry Publications, Los Angeles. pp 156, illus. in colour. Softcover. ISBN 0 929975 34 0. £14.50.

This is a book that should be at hand for everyone dealing with gemstones. As with all this author's publications, reviewed *passim* in *The Journal*, the text is concise, up-to-date and accompanied by very fine photographs, with price ranges for most of the major species. Enhancement and synthetic materials are described and there is a useful bibliography. This would be the ideal book for the beginner in gemmology as details of the simpler gemmological tests are given in a concise and lucid form. A great book. M.O'D.

Identification of gemstones.

M. O'Donoghue and L. Joyner, 2002. Butterworth-Heinemann, Oxford. xiv, 313 pp., illus in colour. Softcover. ISBN 0 7506 5512 7. £40.00.

In a style similar to that used in Michael O'Donoghue's *Synthetic, imitation and treated gemstones* (published by Butterworth-Heinemann in 1997) the authors have produced a work of reference which is packed with a mass of determinative information. The first chapter, however, is the only one which contains references to gem test instruments and their use, as it is argued that these subjects have been exhaustively covered in other gemmology textbooks. Instead, 23 of the following chapters contain identification information enabling the main inorganic and organic gem materials to be separated from their synthetic or imitation substitutes.

Natural and imitation glass have a chapter to themselves, and two more chapters deal with *Metals/ ceramics and plastics*. Another chapter covers *Composite stones*, and three more deal with *Less common gemstones*, *Rarely fashioned gemstones*, and *Gemstones in their rough state*. The final four chapters are titled *How crystals are grown*, *Synthetics crystals for the collector*, *The enhancement of gemstones* and *Locality information*. Each of the gem chapters concludes with a section 'reports of interesting and unusual examples from the literature'. Here, the authors have gathered together a valuable hoard of information from articles, laboratory reports gem shows and their own personal gem observations to give the reader faced with a puzzling specimen the chance to discover matching features among the more unusual gems described.

The book concludes with a glossary and *The literature of gemstone identification*. Although at first glance the many pages of unrelieved text may appear daunting (all the 60 colour plates illustrations are contained in two sections of four pages each) use of both the contents section and the index will quickly reveal a wealth of material to aid specific identification problems. A companion web page to the book is mentioned in the preface and on the back cover, and when eventually available will provide a useful method of updating the text. P.G.R.

Perlen.

ELISABETH STRACK, 2001. Rühle-Diebener-Verlag, Stuttgart, Germany. 696 pp, 657 illus. Hardcover ISBN 3 00 008636 6. Price on application.

This is a very well researched, comprehensive textbook on the history and development of the pearl industry up to the present time. Each chapter has its own bibliography and there are comprehensive indices to pinpoint any subject.

Roughly half of the book deals with natural pearls and their biological and physiological properties. The various geographical occurrences with the diverse characteristics of the pearls are described. There is a chapter on sweet [fresh] water pearls, mainly those found in Europe and North America. Pearls found in gastropods are not forgotten, especially abalone pearls which are described in detail. The market for and valuation of natural pearls is briefly described with the suggested values in DM. This part of the book finishes with quite an interesting survey of large and/or historical pearls or objects incorporating pearls ('Little Willie' is mentioned on p.306).

The second half of the book deals with cultured pearls. This is perhaps of greater interest to the commercial jeweller, who deals mainly with cultured pearls. It is comprehensive. The history as well as the geography and biology of these pearls are described. The grading systems are detailed and well arranged, but again, the valuation advice is in DM apart from the table of production and the one showing US $ prices from 1953-1998 (p.381).

The book finishes with a survey of available methods of examination, identification and differentiation between natural, cultured and imitation pearls. Methods of dyeing and other enhancement treatments are described. Care of pearls and nomenclature are mentioned. There is a register of useful addresses, although no UK addresses are given.

The illustrations are interesting and good, and the maps are comprehensive. For the serious gemmologist, this is an important book. E.S.

Myanma jade.

U NYAN THIN, 2002. Mandalay Gem Association [91(a) 77th St., Btn 26th and 27th St] Mandalay. pp 149. Illus. in colour. Softcover. Price on application.

This attractive and authoritative book was first published in Burmese and is especially welcome in English. After an introduction to Myanma jade, its properties and gemmological characteristics are discussed together with notes on simulants and how they may be distinguished. The marketing of jade is also described and the reader is told how dealers in the rough material assess the finest specimens. Appraisal and evaluation of finished pieces is also described.

The book now turns to the place of jadeite in the past and to the role of jadeite production in the history of Myanmar. The jade-producing regions of Myanmar are introduced with their locations quite closely stated and map coordinates given – the traveller could find them without too much difficulty. Their geology and the mode of working of particular deposits are also described.

Details of the way in which rough jade is sold will interest the reader – a diagram shows the way in which the dealers hold one another's fingers during negotiations over price. The book ends with tips for jade buyers: all kinds of useful hints are included, with the names and qualities of simulants given with identification points. There is a short bibliography.

In addition to the wealth of information there are many excellent colour photographs and the text is accompanied by advertisements which also show jade in a variety of colours. This is a charming and most useful book and throws light on an area of gemmology which has not been covered before in English. M.O'D.

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

Professor Dr Edward J. Gübelin

We send our congratulations to Professor Dr Edward J. Gübelin in celebration of his forthcoming 90th birthday.

Professor Gübelin has made a major contribution to gemmology during his extensive career and it is a pleasure to acknowledge his continuing involvement in the inspiring world of inclusions.

MEMBERS' MEETINGS

Gem-A Conference 2002

The Gem-A Annual Conference was held on Sunday 3 November at Kempton Park Racecourse. The Conference was followed on Monday 4 and Tuesday 5 November by visits to the DTC, a curatorial tour of the Jewels of JAR exhibition at Somerset House and a private viewing with David Thomas, the Crown Jeweller, of the Crown Jewels at the Tower of London.

A full report of the Conference was published in the December 2002 issue of *Gem & Jewellery News*.

London

On 25 October at 27 Greville Street, London EC1N 8TN, Joseph Tenhagen gave an illustrated talk entitled 'Emeralds of Colombia – a visit to the emerald mining districts of Colombia, South America'.

Midlands Branch

On 25 October at the Earth Sciences Building, University of Birmingham, Edgbaston, Alan Hodgkinson gave a talk entitled 'Tucson surprises – the highlights of Tucson 2002'.

On 7 December the Celebration 50th Anniversary Branch Dinner was held at Barnt Green.

North West Branch

On 16 October at Church House, Hanover Street, Liverpool 1, Rosemary McIver gave a talk entitled 'Jewels for a royal occasion'.

The Branch AGM was held on 20 November at Church House, at which Deanna Brady, Ray Rimmer and Elizabeth Franks were re-elected Chairman, Secretary and Treasurer respectively. The AGM was followed by a social evening.

Scottish Branch

On 15 October at the British Geological Survey, Murchison House, West Mains Road, Edinburgh, Joseph Bonnar gave a talk entitled 'Cameos and engraved gems: a history'.

On 19 November at the British Geological Survey Alan Jobbins gave an illustrated lecture on 'The British Crown Jewels'.

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DONATIONS

The appeal for donations to enhance membership and educational services has brought a good response, and the Council of Management would like to thank all those members who have contributed.

A list of those who have responded to the appeal will be published in the April issue of *The Journal*.

South East Branch

At the inaugural meeting of the South East Branch held on 8 December at Christie's, South Kensington, Colin Winter, Sally Everitt and Lawrence Hudson were elected Chairman, Secretary and Treasurer of the Branch respectively.

David Lancaster gave an illustrated talk entitled 'Gemstones at auction' and the meeting was followed by a private viewing of a jewellery sale being held at Christie's on 10 December.

South West Branch

On 17 November at the Bath Royal Literary and Scientific Institution, Queen Square, Bath, a practical afternoon was held to examine synthetic, imitation and treated gemstones under the title 'Trick or Treat?'.

OBITUARY

James (Jimmie) K. Cairncross FGA (D.1940), family jeweller of Perth, Scotland, died on 15 November 2002 at the age of 82. A tribute to him will be published in the April issue of *The Journal*.

Freda M.M. Parsons FGA, Bickley, Bromley, Kent, died recently.

ANNUAL GENERAL MEETING

The Annual General Meeting of Gem-A was held on 25 September 2002 at 27 Greville Street, London EC1N 8TN. Vivian Watson chaired the meeting and welcomed those present. The Annual Report and Accounts were approved.

Professor Alan Collins was re-elected President of the Association for the period 2002-2004. Noel Deeks was elected a Vice-President of the Association.

Ian Mercer, Jeffrey Monnickendam and Evelyne Stern were re-elected to the Council of Management. It was announced that Noel Deeks and Jean-Paul van Doren had resigned from the Council on 14 July 2002 and 22 November 2001 respectively.

Peter Dwyer-Hickey, John Greatwood and Laurence Music were re-elected to the Members' Council. Hazlems Fenton were re-appointed auditors.

Following the AGM, Stephen Kennedy gave a talk entitled 'Notes from the Laboratory: detection, disclosure and false description'.

PRESENTATION OF AWARDS

The Presentation of Awards gained in the 2002 examinations was held at Goldsmiths' Hall, Foster Lane, London EC2 on Monday 4 November. Professor Alan Collins, President of the Association, presided and welcomed those present, particularly students who had travelled from as far away as Canada, China, Hong Kong, India, Japan, Korea, Sri Lanka and the USA, as well as those from the UK and Europe. He announced that in January and June 2002 a total of 795 students had sat for the Preliminary and Diploma Gemmology and Gem Diamond Diploma examinations. A total of 184 students had qualified in the Gemmology Diploma examination and 123 in the Gem Diamond.

Professor Collins then introduced Noel Deeks, Vice-President of the Association, who presented the awards.

Noel Deeks delivered his address (see below) and a vote of thanks was given by Vivan Watson, who also thanked the Goldsmiths' Company for kindly permitting Gem-A to hold the ceremony at the Hall.

A Reunion of Members was held following the ceremony, attended by over 200 members and students.

Noel Deeks' address

"It has been a great pleasure for me to present the diplomas and awards this evening. Although it

GIFTS TO THE ASSOCIATION

The Association is most grateful to the following for their gifts for research and teaching purposes:

Sampat Singh Kothari, of Mumbai, India, for a collection of gemstones

David Pratt of Bradford, West Yorkshire, for ivory and other gem materials

Maria Sanchez of London for a Colombian emerald cabochon

Manfred Szykora of Munich, Germany, for two books about the old Hungarian opal mines: *Dubnicke opalove bane* by Semrad and Kovac, and *Dubnicky opal* by Barok and Semrad; also for copies of *extraLapis No. 23 – Beryl* and *extraLapis English No. 2 – Emerald*

Joseph Tenhagen of Miami, Florida, U.S.A., for a large collection of crystals and cut gems for use in education.

Included was a wonderful suite of natural emerald crystals of both geological and historical significance.

Joe is pictured below during his visit to London in October 2002 when he gave an illustrated talk to members entitled 'Emeralds of Colombia – a visit to the emerald mining districts of Colombia, South America'

PROAPEX INC., TAIPEI, TAIWAN

Two stereo zoom microscopes donated by Jack Liao of Proapex Inc.

These microscopes were first used for the Gem-A's 'Family day' workshop held at Somerset House, and are now installed in the London Gem Tutorial Centre as part of the teaching equipment used by students studying the Association's gemmology courses.

PRESIDIUM INSTRUMENTS PTE. LTD. SINGAPORE

Five Presidium Multi Testers (pictured below) and five Presidium Gauges donated by Paul Yeo on behalf of Presidium Instruments Pte. Ltd.

These instruments are used by Gem-A students studying diamonds in the Diamond Diploma Course and the Six-day Diamond Certification Course.

is over thirty years since I clambered up these steps to receive my diploma, I can remember it as if it were yesterday, and so it will be for those of you who have made your way up these steps tonight, in this magnificent Goldsmiths' Hall. You will remember this event for many years to come.

"Everyone at Gem-A looks forward to the Presentation of Awards; it is a time when we congratulate all those who have been successful in the examinations, whilst the staff at Gem-A can enjoy the satisfaction of a job well done. On behalf of all the Officers of the Association, I would like to express very sincere thanks to all the staff of the Education Department, together with the lecturers, tutors and the many other people in the training centres, who have worked hard to make your achievements possible.

"Those of you who are holding that nice new diploma in gemmology for the first time, who are already Ordinary Members of the Association, will automatically become Fellows. If you are not currently a member of the Association, it will be necessary for you to apply for membership. You are only able to call yourself a Fellow and put the letters FGA after your name whilst you remain a fully paid up member, as is the case with many other professional people such as solicitors, accountants and doctors.

"In fairness, you should be warned that in recent years qualified gemmologists who have claimed to be an FGA have been challenged in the courts if their membership has lapsed. So make sure your membership is up-to-date at all times if you display your qualifications after your name, especially if you are appearing as an expert witness or giving an opinion in circumstances where your qualifications could be questioned.

"In exchange for your continued membership you will receive the full support of the Association, including the quarterly publications *The Journal of Gemmology* and *Gem & Jewellery News*, and discounts on instruments, books and regalia. You will also benefit from reduced fees for admission to lectures, workshops and the Annual Conference, and may use the Laboratory services for testing purposes when you feel the need for a second opinion.

"The Gemmological Association of Great Britain is the most senior association in the world. It was on 6 July 1908, at the National Association of Goldsmiths' annual conference in Manchester, that a gentleman by the name of Samuel Barnett proposed that courses and examinations in gemmology should be organized. The resolution was adopted, which prompted the birth of the NAG's Education Committee with Mr Barnett as

Prize winners from Jaipur, India. Noel Deeks awards the Anderson Medal to Neha Sehgal (left) and the Preliminary Trade Prize to Avneet Verma (right).

chairman. A gemmology course was prepared and teaching began, followed by the first examinations in 1913. The list of passes in that first year contained just six names. Top of the list was Samuel Barnett, the man that had sown the very first seed just five years earlier.

"It was not until 1931 that the Gemmological Association was formally inaugurated and holders of diplomas became eligible for Fellowship of the new Association. In 1938 the title of the Association was to change yet again to the Gemmological Association of Great Britain, and in 1947 it was incorporated under the Companies Act as an independent organization.

"The Association has from those early days always upheld very high standards in its teaching and examination. However, in many respects the science of gemmology is still quite young and is still moving forward at a very rapid pace.

"The vast amount of treatments that gemstones are subjected to today, especially diamonds in recent years, have made our work and yours that much more of a challenge. There is so much more to teach and for the students to assimilate compared to the more simple course in the earlier days. Instead of just a single course in gemmology, today we have a number of courses, some of which are highly specialized especially where diamonds are concerned. Much of the work needed to identify the existence of treatments now falls to the better equipped laboratories and hopefully some of you here tonight will aspire to this level of opportunity.

"We would claim, even with our high standards, not to have done much more than place your feet on the rungs of the learning ladder where serious gemmology is concerned. We have been told on a number of occasions by our members that they have a difficulty in understanding some of the more technical papers in *The Journal of Gemmology*. So even after qualifying there are still many things left for us to learn, in fact one has to almost run to keep up with changes that are constantly taking place, including the so-called 'improvements' applied to natural gemstones.

"I really came into the jewellery trade by accident. Having agreed to help a friend for just a few weeks to re-open a jewellers in 1946, I stayed with the company for 38 years. I had originally trained as an engineer and this was to have been my career. However, I also had a fair knowledge of watchmaking, as this had been my father's trade, and it was this that caused me to be side-tracked into the jewellery trade.

Prize winners at Goldsmiths' Hall. From the left, Liyana Arachchige from Kandy, Sri Lanka (Christie's Prize for Gemmology), Julian Read of Goole, East Yorkshire (the Deeks Diamond Prize) and Sally Hudson from London (the Anderson-ank Prize).

"For the first few years I spent most of my time in the workshops repairing clocks and watches. I was awarded Craft Membership of the Horological Institute in 1953 and it was this that helped to get me noticed. However, it was about this time that I realized that I was limited, to some extent by what I could do with just one pair of hands. So I moved from the workshops shortly after qualifying into the jewellery sales side of the business and not long after into management. Having arrived at the sharp end of the business, I was soon fascinated by gemstones and wanted to know more about them. This led me to the Gemmological Association and more studying followed by examinations and to several trips up these steps.

"This all happened just at the time when the Distributive Industries Training Board came into being. I soon found myself creating a new training department for the company and responsibility for over two thousand staff. I very much enjoyed this period of my working life and it convinced me that good training does bring its rewards.

"From time to time I have asked students the question, 'What are you going to do with your newly acquired qualification?' Not all of them have been too sure. The best advice I can give is *make it work for you*. Ensure that your employment allows you to use your knowledge as often as possible. You must be worth more to your employer, but conversely your employer will expect you to be more professional and earn more for him, as well as yourself. It should also help to get you noticed, possibly for promotion to a better job. You may have your own business; it should help you to expand your horizons and enhance your reputation. Whatever you do, make good use of your knowledge.

"Earlier I told you something of the beginning of the Gemmological Association. It would not be too difficult to write a substantial book on the history of such an organization, but that is not my intention tonight. However, it would be very remiss of me not to mention a very important addition that was added in 1990 and that is the Laboratory which has a very interesting history of its own. In the early 1920s the London Chamber of Commerce was under some considerable pressure to protect the status of the natural pearl business which was being seriously upset by the importation of cultured pearls from Japan. It was therefore decided that a testing station should be set up to distinguish natural pearls from cultured pearls. A laboratory was duly set up and was officially known as the Diamond, Pearl and Precious Stone Section of the London Chamber of Commerce and Industry. I wonder if they ever used the abbreviation DPPSSLCCI – it certainly makes GAGTL sound quite attractive! "It was fortunate for the London Chamber of Commerce that, in 1925, there was a young man with a recently acquired degree in chemistry and geology who was looking for employment. He was Basil Anderson, a name you will all know and one that did so much in the ensuing years to further the cause of gemmology. The diaries that were kept at the time reveal the long hours worked and the very considerable volume of items tested. In 1928 Basil Anderson tested no less than 49,000 pearls (using an endoscope) and many gemstones – a great achievement.

"Shortly after this in the late 1920s Basil Anderson was joined by another famous name – C.J. Payne. Later in the post war years Robert Webster and Alec Farn were added to the team. These four highly respected gemmologists worked together for 25 years during which time they tested thousands of pearls and gemstones. They also lectured on gemmology, were authors of a number of books which are still used as textbooks today, and also found time for research which included the development of the 1.81 contact fluid for the refractometer and much more.

"In 1990 the Gemmological Association parted from the NAG and merged with the Gem Testing Laboratory who occupied the third floor at 27 Greville Street. The Gemmological Association moved into the first floor which it shared with Gemmological Instruments Ltd. The following few years saw a rapid expansion of the Education Department in London, during which time we took over the second and fourth floors at Greville Street which are used as teaching floors. This has enabled the department to hold more regular classes both for gemmology and diamond students. This is in addition to the many students who are taught our courses in other London colleges.

"I trust that this very sparse potted history may help you to understand the work that has been carried out by a number of very dedicated people to help raise the gemmological standard of knowledge, not only in the UK but in many other countries as well.

"I have been heard to say on a number of occasions, 'Life is like a garden, you only get out of it what you are prepared to put into it.' I hope that some of you will become gemmological gardeners and play your part."

MEMBERSHIP

Between 1 November 2002 and 2 January 2003 the Council of Management approved the election to membership of the following:

Fellowship and Diamond Membership (FGA DGA)

Cheung Fung Wan, Hong Kong. 2002

Fellowship (FGA)

Agarwal, Vibha, Pitampura, Delhi, India. 2002
Aubert, Rebecca, Tunbridge Wells, Kent. 2002
Blanshard, Ruth H., Devizes, Wiltshire. 2002
Chan Miu Ching Lavinia, Hong Kong. 2002
Cheng Wai Yee, Tsuen Wan, New Territories, Hong Kong. 2002
Chow, Lorraine M., Shatin, Hong Kong. 2002
Dorrell, Clare Georgina, Perth, Scotland. 2002
Every, Susanne, Petworth, West Sussex. 2002
Galibert, Olivier, Calas, France. 1989
Hessels, Lutina Albertje, Schoonhoven, Holland. 2002
Hoff, Jan-Siebe, Haarlem, The Netherlands. 2002
Hui Chau Ming, Kowloon, Hong Kong. 2002
Joshirao, Ajey, Nagar Pune, Maharashtra, India. 2002
Kwok Wai Lee, Tuen Mun, N.T., Hong Kong. 2002
Lau Kam Yin Mabel, Tai Po Kau, Tai Po, Hong Kong. 2002
Lee, Chun Ming, Ma On Shah, New Territories, Hong Kong. 2002
Lee Sui Kam Monita, Tsuen Wan, New Territories, Hong Kong. 2002
Liyana Arachchige, Nilmini Susanthi, Lewella, Sri Lanka. 2002
Lui Sze-Wai Alice, Quarry Bay, Hong Kong. 2002
Middleton, Tara, Toronto, Ontario, Canada. 2002
Mukhopadhyay, Nita, Kolkata, West Bengal. 2002
Nessi, Veroniki, Athens, Greece. 2002
Roussou, Zoi-Kiriaki, Kolonaki, Athens, Greece. 2002
Samarasekera, Prabha P.H., Anniwatta, Kandy, Sri Lanka. 2002
Sancheti, Amishaa, Indore, India. 2002
Schooling, Clare, London. 2002
Sikanen, Essi Maarit, Lahti, Finland. 2002
Somboom, Chaniya, Tlingcham, Bangkok, Thailand. 2002
Straub, Bernard, Wokingham, Berkshire. 1987
Sueters, Brigitta M.T.H., Aalsmeer, The Netherlands. 2002
Tennakoon, Indrani, Maida Vale, London. 2002
Thu, Latt Myat, Mayangone Township, Yangon, Myanmar. 2002
Verma, Avneet, Rohini, India. 2002
Vincent, Patricia, Wokingham, Berkshire. 1987
Voutsinas, Dimitris, Athens, Greece. 2002
Whitehouse, Keith, Marston, Nr Church Eaton, Staffordshire. 2002
Wong, Bick San Patricia, North Point, Hong Kong. 2002
Wong Tai-wai, Fanling, New Territories, Hong Kong. 2002
Zhou Fangfang, Phrakanong, Bangkok, Thailand. 2002

Diamond Membership (DGA)

Bryant, Susan, Sutton Colldfield, West Midland. 2002
Burton, Lola Clare, Hastings, East Sussex. 2002
McLeod, Fiona J., Yellowknife, N.W.T., Canada. 2002
Paraskevopoulos, Michael, Athens, Greece. 2002
Quilley, Claire J.A., Aylesbury, Buckinghamshire. 2002
Taylor, Andrew James, Basingstoke, Hampshire. 2002
Taylor, Susan Jane, Kings Heath, Birmingham. 2002
Tong Chi Chueng, Kowloon Bay, Kowloon, Hong Kong. 2002
Verganelakis, Vassilis, Athens, Greece. 2002

Ordinary Membership

Adeyemi, Hackney, London
Anderson, Judith, Manchester, New Hampshire, U.S.A.
Bjerre Janson, Marianne, Enebyberg, Sweden
Braham, Adrian David, Reigate, Surrey
Bryant, Helen, Discovery Bay, Hong Kong
Buckley, Noreen Anne, Walton-on-Thames, Surrey
Daniels, Catharine, London
Donovan, Kate, Carlsbad, California, U.S.A.
Durand, Anthea, Brockley, London
Gram-Jensen, Margarethe, Overijse, Belgium
Haas, Laura, Fishers, Indiana, U.S.A.
Jarman, Thelma Ruth, Hawick, Scotland
Johnson, Edward, London
Khin, Thet, Penge, London
Kirchner, Roy, London
Kuo Yaw-Bao, Yung-Ho, Taipei, Taiwan, R.O.China
Lathom-Sharp, Denise, Widmoor, Wooburn Common, Buckinghamshire
Lee, Hsiang-Ju, Nan-Gang District, Taipei, Taiwan, R.O.China
Li Kehan, Enfield, Middlesex
Lindroos, Ulla Kristina, Brussels, Belgium
Morris, Peter D., Acton, London
Nilsson, Annica, Pokfulam, Hong Kong
Pearson, Isabel Jane, Tilehurst, Reading, Berkshire
Reedie, Kathie, London
Roser, Lisa-Marie, Cuffley, Hertfordshire
Shih, Meng-Hsin, Taiping, Taichung, Taiwan. R.O.China
Taylor, Russell M., Winslow, Buckinghamshire
Wang Ying-Ling, West District, Taichung, Taiwan, R.O.China
Yantzer, Peter, Las Vegas, Nevada, U.S.A.
Zwozdiak-Southall, Mahailia, Old Warden, Bedfordshire

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FORTHCOMING EVENTS

26 February	**Scottish Branch.** *Some gemmological and lapidary diversions.* Doug Morgan
28 February	**Midlands Branch.** *Pearls of wisdom.* Michael Houghton
25 March	**Scottish Branch.** *Tucson surprises.* Alan Hodgkinson
26 March	**North West Branch.** *Jewellery at auction.* Richard Slater
28 March	**Midlands Branch.** *An auctioneer's lot is not a happy one.* Stephen Whittaker
6 April	**South East Branch.** *Tucson 2003.* Alan Jobbins, Peter Wates and Colin Winter
25 April	**Midlands Branch.** Annual General Meeting followed by *The interface of gem and jewel.* John Wright

SCOTTISH BRANCH CONFERENCE

2 to 5 May

Queen's Hotel, Perth

Speaker's will include:

David Callaghan, Professor Dr Henry Hänni, Alan Hodgkinson, Dorothy Hogg, Stephen Kennedy and Dr Hanco Zwaan

Workshop sessions and social events

18 May	**Midlands Branch.** Gem Club *Edwardian Britain: the politics, lifestyle and jewellery: a Golden Age.* Brian Dunn
21 May	**North West Branch.** *A jade tour.* Ian Mercer
18 June	**North West Branch.** *Crystal care.* Wendy Simkiss
21 June	**Midlands Branch.** Midsummer Supper

Contact details

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South East Branch: Colin Winter on 01372 360290; e-mail ga_seb@hotmail.com
South West Branch: Bronwen Harman on 01225 482188; e-mail bharman@harmanb.freeserve.uk

Gem-A Website

For up-to-the-minute information on Gem-A events visit our website on www.gem-a.info

Guide to the preparation of typescripts for publication in *The Journal of Gemmology*

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.

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.

B *This is a second level heading*

Second level headings are in italics and are flush left on a separate line.

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. Collins, 2001, 341). 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 Collins 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 Collins, A.T., 2001. The colour of diamond and how it may be changed. *J.Gemm.*, **27**(6), 341-59

Books Balfour, I., 2000. *Famous diamonds.* 4th edn. Christie's, London. p. 200

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 28 No. 5 January 2003

The Journal of Gemmology

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Cover Picture

Boulder with irregular dark-coloured zones of chrome chalcedony and light green relict serpentinite, the parent rock. Photo: J. Flint. (See 'A new chrome chalcedony occurrence from Western Australia', pp. 265-79.)

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