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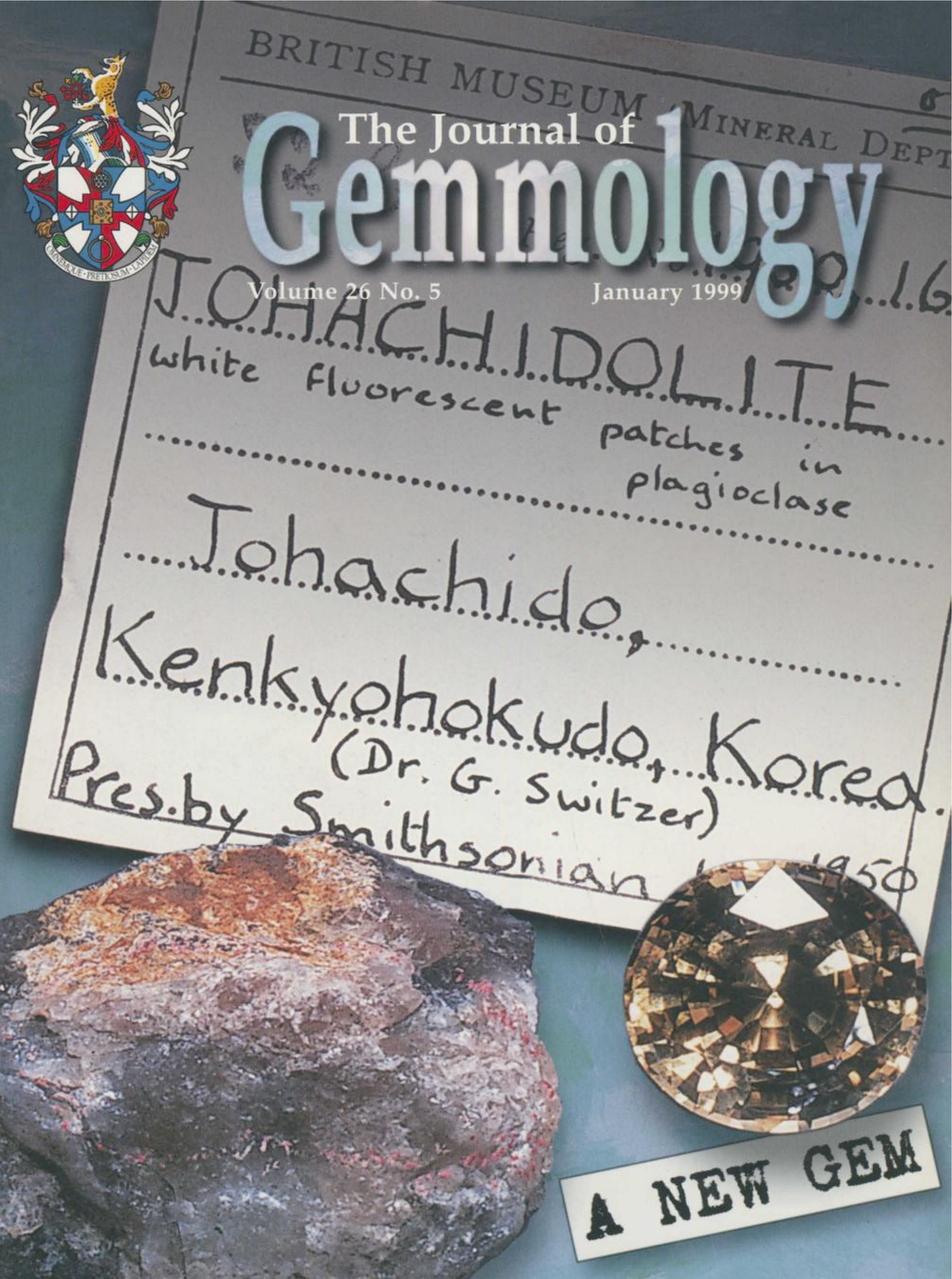

BRITISH MUSEUM MINERAL DEPT

JOHACHIDOLITE

white fluorescent patches in plagioclase

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(Dr. G. Switzer)
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The Gemmological Association and Gem Testing Laboratory of Great Britain

Gemmological Association and Gem Testing Laboratory of Great Britain

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Element mapping of trapiche rubies

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ABSTRACT: Chemical zoning in trapiche rubies was examined by X-ray microfluorescence analysis and by electron microprobe analysis. Two-dimensional element maps indicate a chemical variability of Al, Si, Ca, Ti, Cr and Fe within the samples. This chemical variation is mainly due to primary growth zoning as well as due to carbonate and in places silicate inclusions in orientated channels of the host rubies. Secondary iron staining caused by intense weathering of the samples is also observed.

Keywords: electron probe, element map, ruby, trapiche, X-ray microfluorescence

Introduction

Trapiche rubies from south-east Asia with a fixed six-rayed star, similar in effect to trapiche emeralds from Colombia, were recently described by Schmetzer *et al.* (1996a). Information available at present indicates that the trapiche rubies come from Myanmar and Vietnam. They consist of six transparent-to-translucent ruby sectors separated by the yellow- or white-appearing arms of a six-rayed star. In some crystals, the six arms (which, unlike typical asteriated gems, are fixed - that is, they do not move when the stone or light source is moved) intersect at one small point, forming six triangular ruby sectors. In many specimens, however, the arms extend outward from a hexagonal central core, producing six trapezohedral ruby areas. The cores are usually opaque yellow or black, but transparent red central areas are also present occasionally.

In the yellow or white arms of the star and in the boundary zones between the core and the six trapezohedral ruby sectors, a massive concentration of tube-like inclusions is observed. These inclusions are orientated perpendicular to morphologically dominant dipyramidal crystal faces; they contain liquid, two-phase (liquid/gas) and solid fillings identified as magnesium-bearing calcite and dolomite by a combination of electron microprobe analysis and micro-Raman spectroscopy. In black or yellow cores, tube-like structures with identical fillings also run parallel to the *c*-axis, i.e. perpendicular to basal faces of the trapiche rubies.

Because tube-like structures that extend into the gem-quality ruby sectors are almost colourless, and the calcite and dolomite inclusions are iron-free, it was concluded that the yellow colour of the arms and some cores must be due to intense weathering and secondary iron staining of the cavities and tubes. This interpretation was supported by

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Table I. *Chemical zoning of trapiche rubies*

	Sample description	*Zoning in*	*Mg*	*Al*	*Si*	*Ca*	*Ti*	*V*	*Cr*	*Fe*
A	Six-rayed star with sharp yellowish-white arms intersecting at one small point	Triangular ruby sectors							z	
		Yellowish-white arms		—	+	++			–	+
B	Six-rayed star with sharp yellow arms intersecting at one small point	Triangular ruby sectors							z	
		Yellow arms		–		++				++
C	Six-rayed star with sharp yellow arms, black core	Trapezoidal ruby sectors								
		Black core		–	+	+++	+	*	–	++
		Yellow arms		–	+	++	+	*		+++
D	Six-rayed star with yellow arms that widen toward the edge, black core	Trapezoidal ruby sectors								
		Black core		—	+	++	+	*		+++
		Yellow arms		—	+	++	+	*		+++
E	Six-rayed star with zoned, sharp yellowish-white (inner part) to yellow (outer part) arms, black core	Trapezoidal ruby sectors							z	
		Black core		–		++			–	+
		Yellowish-white to yellow arms		–		++				+ or ++ (z)
F	Six-rayed star with thin yellow arms without distinct, continuous boundaries to the host, small red core	Trapezoidal ruby sectors							z	
		Red core							+	
		Yellow arms		–		+				+

–	smaller concentration than in the six trigonal or trapezohedral ruby sectors
—	much smaller concentration than in the six trigonal or trapezohedral ruby sectors
+	higher concentration than in the six trigonal or trapezohedral ruby sectors
++	much higher concentration than in the six trigonal or trapezohedral ruby sectors
+++	very much higher concentration than in the six trigonal or trapezohedral ruby sectors
z	zoning from centre to rim
*	not observable in small concentrations due to an overlap of VK_{α} with TiK_{β}

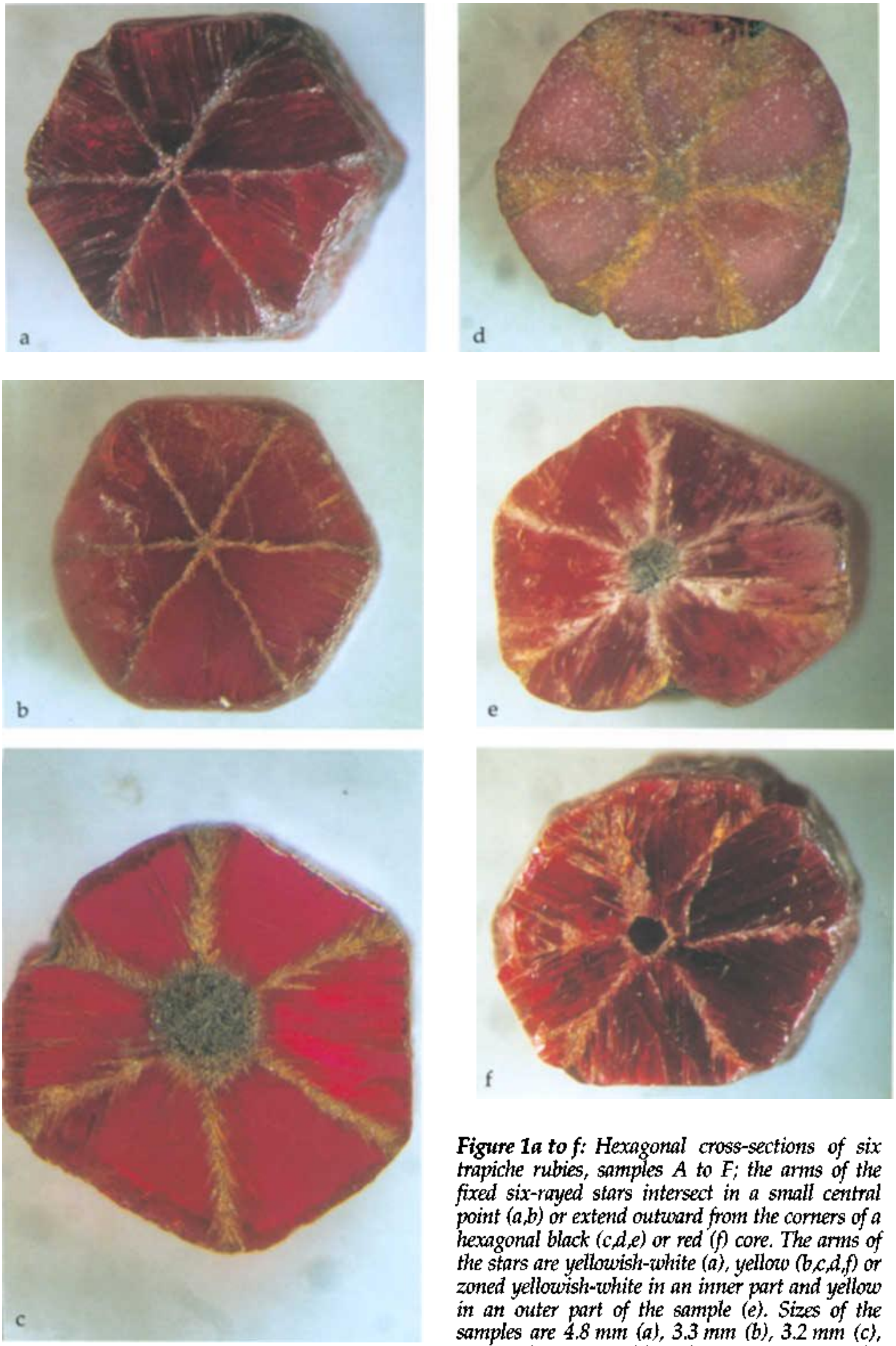


Figure 1a to f: *Hexagonal cross-sections of six trapiche rubies, samples A to F; the arms of the fixed six-rayed stars intersect in a small central point (a,b) or extend outward from the corners of a hexagonal black (c,d,e) or red (f) core. The arms of the stars are yellowish-white (a), yellow (b,c,d,f) or zoned yellowish-white in an inner part and yellow in an outer part of the sample (e). Sizes of the samples are 4.8 mm (a), 3.3 mm (b), 3.2 mm (c), 4.1 mm (d), 4.2 mm (e), and 4.5 mm × 5.0 mm (f).*

X-ray fluorescence analyses of selected trapiche ruby areas with or without a part of a yellow arm.

Two methods were applied to determine the chemical properties of trapiche rubies by Schmetzer *et al.* (1996a) providing analytical data that represent different-size areas within a sample. X-ray fluorescence analysis reveals an average composition of that part of the ruby in an area exposed to the X-ray beam that can be measured in the range of square millimetres. The electron microprobe, on the other hand, is able to analyse much smaller areas with diameters down to about one micrometre.

The chemical variability of a mineralogical sample is, in general, detectable by electron microprobe using two conventional techniques. Preparing X-ray scanning images for selected elements, the intensities of single spots within an image of the area covered by the electron beam are approximately proportional to the concentration of the respective elements. A typical example for trapiche rubies, which was given in the previous paper, showed the distribution of calcium and magnesium in calcite and dolomite as fillings of single orientated tube-like structures and covered an area of approximately 100 x 100 µm (0.1 x 0.1 mm). According to the experimental conditions of the instrument, this technique – which is performed with a fixed, non-moving sample – is limited to the examination of sectors which cover a maximum area of about 200 x 200 µm (0.2 x 0.2 mm).

Another technique for the evaluation of chemical variability of a sample by electron microprobe is performed with a moving stage, i.e. a moving sample and a fixed electron beam, in order to prepare various scans across the surface of the sample. A typical traverse across a ruby crystal or another gemstone to show its chemical variability consists of about 30 to 120 point analyses within a scan length in the mm range (see Peretti *et al.*, 1995; Schmetzer *et al.*, 1996b). Using this particular technique, information about chemical zoning along single traverses across a sample is obtainable.

The application of the two conventional methods described, however, is unable to provide two-dimensional information about element concentrations and chemical variability in minerals, which is of great interest in trapiche rubies.

The present paper describes two different techniques for the determination of two-dimensional element maps in trapiche rubies, which have been only rarely applied to the characterization of gem materials. Using trapiche rubies as an example, the techniques described are able to fill the gap between conventional X-ray fluorescence analysis and conventional electron microprobe techniques.

Materials

For the present study six slices of trapiche rubies were cut in a direction perpendicular to the c-axis of the corundum crystals. The samples were selected in order to cover the variability of structural features in trapiche rubies (see *Table I*). In detail, samples were selected with six-rayed stars intersecting at one small point (*Figure 1a, b*) as well as trapiche rubies with black (*Figure 1c, d, e*) or red (*Figure 1f*) cores. Parts of the samples revealed sharp yellowish-white (*Figure 1a*) or yellow (*Figure 1b, c*) arms, and one sample showed a colour zoning within the six sharp arms of the star with yellowish-white central parts and stronger yellow outer parts (*Figure 1e*). In one sample, the six yellow arms of the star widen toward the rim of the crystal (*Figure 1d*), and in one trapiche ruby, only thin yellow arms without continuous boundaries to the six trapezohedral ruby sectors were observed (*Figure 1f*).

Results

X-ray microfluorescence (XRMF) analysis

Chemical zoning was observed in all six samples of trapiche rubies examined with the OMICRON XRMF system. Different element concentrations were found for Al, Ca and Fe in all samples as well as for Si, Ti and Cr in parts of the samples. No chemical inhomogeneities were proven for Mg and V with the experimental conditions applied (*Table I*).

Methods

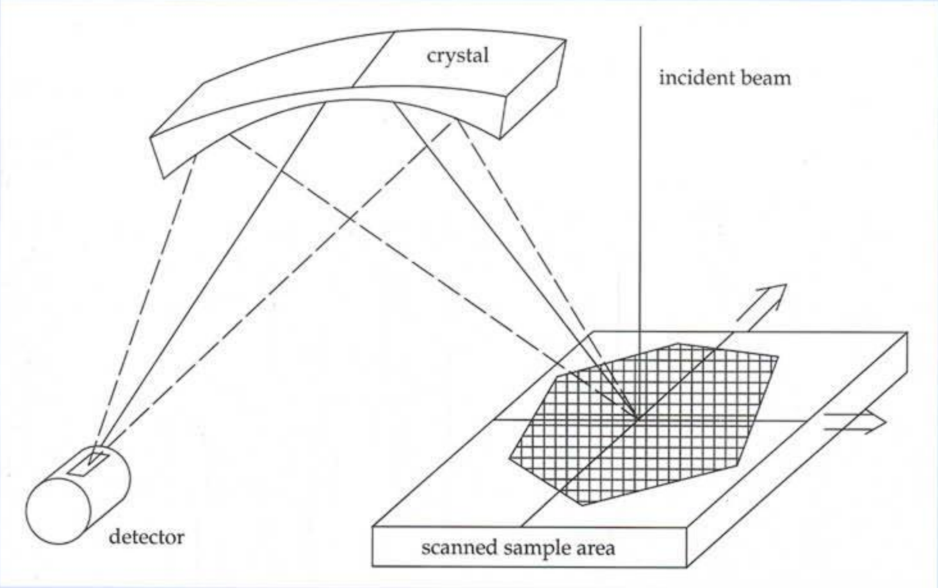
Data collection procedures

A well-known technique to display two-dimensional element distributions of sample areas is to scan the electron beam of an electron microprobe (or of a scanning electron microscope) and to collect the signals for image development using a wavelength dispersive spectrometer (WDS), which has been set to the position of the required characteristic X-radiation. Another possibility is to use the signals of a selected range of channels of an energy dispersive spectrometer (EDS) representing the requested radiation. The signals are displayed in real time on a screen which is synchronized with the scanning system of the microprobe. In modern systems, these signals may be stored and accumulated in order to display the complete image. In the latter case the signals of more than one element can be acquired simultaneously. Limiting factors are the number of WDS facilities available on the microprobe or the maximum number of energy regions allowed by the EDS software.

Using WDS systems, the analysed sample, the diffracting crystal and the detector must be on one circle (*Figure 2a*). According to these optical and geometrical conditions, only small areas of a sample can be examined with a fixed sample stage. Because it is not possible to scan an X-ray beam, X-ray fluorescence techniques cannot be used for this kind of imaging procedure.

In order to overcome the problems mentioned, a different kind of image generation can be applied. For these techniques the electron beam or a strongly collimated beam of primary X-rays of a microfluorescence system remains fixed at one position and the sample with its sample stage is moved in two orthogonal directions under the fixed beam covering the sample area of interest. In these

Figure 2a: *Schematic drawing of the experimental conditions in the electron microprobe for element mapping of larger areas showing the incident electron beam, the moving sample stage, the fixed diffracting crystal and the X-ray detector; the diffracting crystal and the detector form a wavelength dispersive spectrometer (WDS).*



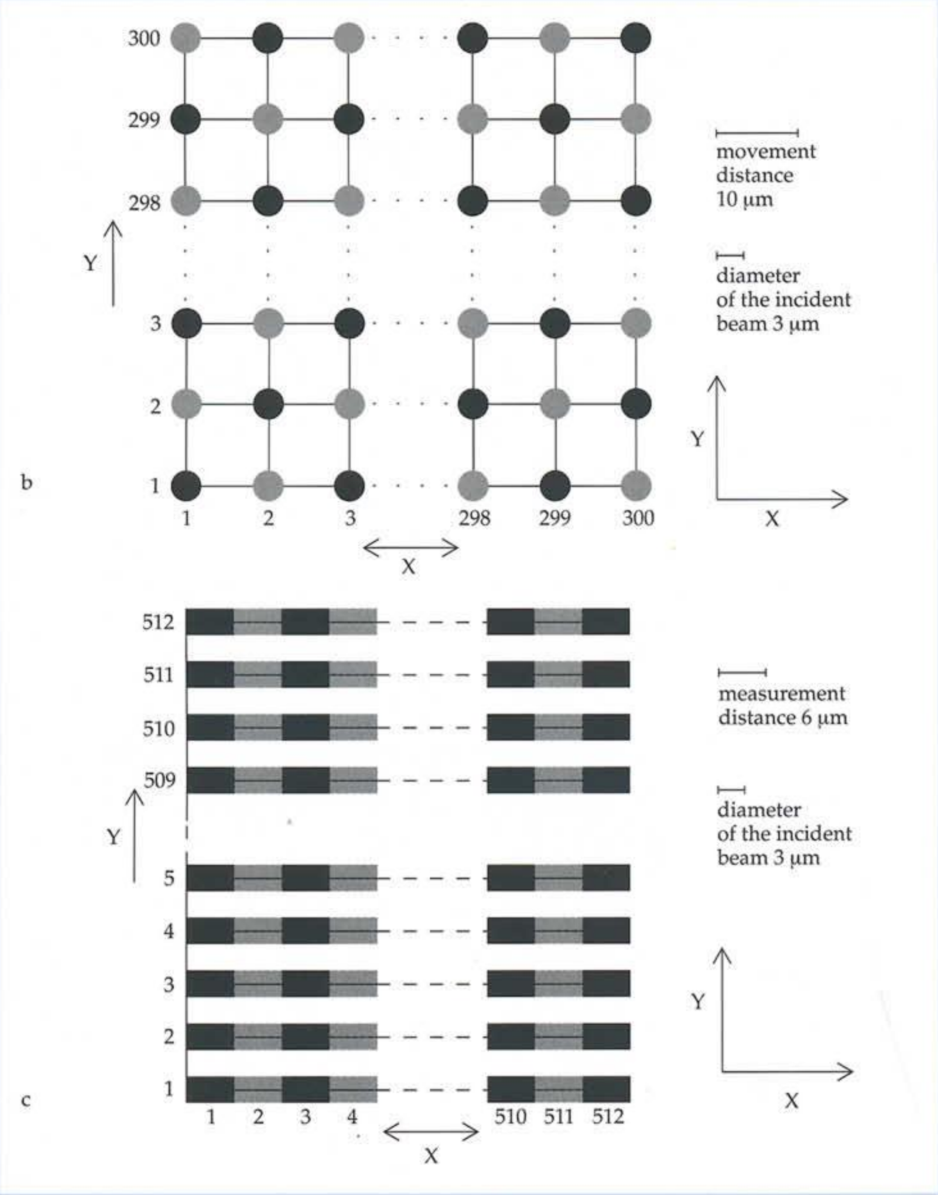


Figure 2b, c: *Data collection for element mapping by XRMF and EMPA in a step-by-step (b) or continuous raster mode (c); the analytical details of Figure 2b represent the data collection for a trapiche ruby by electron microprobe with a step-by-step measuring distance of about 10 µm and a beam diameter of approximately 3 µm; the analytical details of Figure 2c represent data collection for a trapiche ruby by electron microprobe in a continuous raster mode with a beam diameter of approximately 3 µm and a line length of about 6 µm; analysed areas are hatched, arrows indicate the direction of the moving stage. For element mapping by XRMF analysis an X-ray beam with a diameter of 70 µm was used in a continuous raster mode, i.e. overlapping areas within the sample were measured several times.*

systems, in addition to the elements to be analysed and the sample area, the user has also to select the desired resolution, i.e. the number of data points on the analysed sample area which form a regular, rectangular grid on the sample surface. Each point of such a grid represents one pixel in the later X-ray image. Furthermore, the counting time for each measuring point has to be selected. Two slightly different data collection procedures are possible:

(a) In a non-continuous analysis mode (*Figure 2b*) the sample is moved to a point of the rectangular grid and then the counting time is started. The measured intensity signal of the fluorescence radiation represents the element concentration of the currently excited sample volume which mainly depends on the beam diameter. On completion of the selected counting time, the measuring procedure is stopped and the sample is moved to the next point of the grid. This is a step-by-step procedure.

(b) In a continuous analysis mode (*Figure 2c*) along the movement of the sample between two grid points, the intensity of the specified characteristic X-radiation is continuously measured by the detector. The resulting intensities represent the average element concentrations of the excited sample volume between the two points of the rectangular grid. The position of the data point in the pixel-by-pixel image is set to the middle between the two adjacent points of the grid in the direction of movement.

In both modes the counting results of each point for each element are stored. Subsequent to the complete measuring procedure of the selected sample area, using special computer software the intensities of each element are linked to a colour or to a grey scale. Each data point is classified and plotted on a screen according to a corresponding colour with respect to its original position on the sample surface. Thus, an enlarged image of the sample is produced representing the element composition of one element in the sample. The images can be treated mathematically, e.g. intensity relations between two elements may be computed and depicted. The element distribution can be stored and printed depending on the capabilities of the computer programme in use.

Element mapping using X-ray microfluorescence analysis (XRMF)

Element mapping by XRMF was developed in the mid-'eighties by several working groups in Japan and in the United States (Kobayashi *et al.*, 1985; Nichols and Ryon, 1986; Wherry and Cross, 1986). A commercially available analysis system was designed by Kevex Instruments and marketed with the trade name OMICRON. The OMICRON system and similar facilities were applied for element mapping of metals, alloys, rocks and minerals, but also for organic matter, e.g. leaves, tissues and bones (Boehme, 1987; Nichols *et al.*, 1987; Cross and Wherry, 1988; Wherry and Cross, 1988; Carpenter *et al.*, 1989; Carpenter and Taylor, 1991; Kobayashi *et al.*, 1991; Cross *et al.*, 1992; Rindby *et al.*, 1992; Voglis *et al.*, 1993; Carpenter *et al.*, 1995a,b). XRMF was compared by Pozsgai (1991) with similar techniques, e.g. X-ray fluorescence in the electron microscope or X-ray fluorescence excited by synchrotron radiation.

For the preparation of element images of trapiche rubies, a conventional OMICRON system (*Figure 3*) was used. The data collection and handling of this analytical facility was briefly described by Nichols *et al.* (1987) and a schematic drawing of the OMICRON analysis system is given by Cross and Wherry (1988).

In the analytical facility available for the present study, the diameter of the primary X-ray beam could be varied between 50 and 2000 μm. However, the best spatial

Figure 3: The OMICRON XRMF analysis system consisting of the basic measurement unit (right) colour TV sample display (centre) and computer-based data processor (left).

resolution and intensity versus background conditions were obtained in vacuum with a collimator diameter of 70 µm. The examination of the six trapiche ruby samples of about 3 to 5 mm in size was performed in a continuous raster mode (see *Figure 2c*) with 250 analytical data collection steps along both X and Y directions of the sample stage. Consequently, a single X-ray image of one sample contains information from 62 500 single grid points. With a beam diameter of 70 µm, each grid point represents an area of ruby and a possible range of inclusions in that area. The energy dispersive X-ray fluorescence spectra obtained during the continuous movement were collected with a Si (Li) detector. The required measuring time was about two to three hours. As the data collection was repeated up to four times for each ruby sample, the examination of one trapiche ruby was carried out over 8 to 12 hours. The collected data were processed by image-forming software to complex two-dimensional element images consisting of 62 500 pixels each. Element maps were prepared for eight elements, namely Mg, Al, Si, Ca, Ti, V, Cr and Fe (the OMICRON system allows the simultaneous acquisition of up to 25 element maps from one set of analytical data).

Element mapping using electron microprobe analysis (EMPA)

The data acquisition procedure by electron microprobe is similar to that of XRMF. As WDS facilities (see *Figure 2a*) have much better wavelength resolution than EDS systems and better peak-to-background ratios, WDS images are much clearer than EDS images. Thus, data collection by WDS systems is preferred for element mapping by electron microprobe. According to the number of WDS facilities available in the analytical system of a microprobe (up to five spectrometers in modern instruments), the number of elements which can be mapped simultaneously is limited to five. For mapping of additional elements, the run is repeated with new spectrometer settings. From experience it was found that expressive images should consist of at least 30 000 pixels representing single points in the rectangular grid. This corresponds to about 12 hours of acquisition time with, for example, one second counting time for each analytical point (plus processing time, plus time for moving the sample stage if data collection in a non-continuous raster mode is applied). Consequently, this technique is time consuming and requires an extremely stable microprobe system (Bernhardt *et al.*, 1995).

For the evaluation of this technique to gemmological problems element maps were performed for one trapiche ruby (sample C, *Figure 1c*) in both analytical modes mentioned above, i.e. in non-continuous and continuous raster modes.

A first run was done with a CAMECA Camebax electron microprobe for three elements, Al, Ca and Fe. Data were collected step by step along a rectangular grid with point distances of 10 µm during an analysis time of 1 second at each of the 90 000 analysis points (see *Figure 2b*). For this measurement, an analysis time of 35 hours was needed.

A second run was performed with a CAMECA Camebax SX50 electron microprobe facility for Al, Si, Ca and Fe. Using the four wavelength dispersive spectrometers of the microprobe, data were collected in continuous raster mode along a scan line of approximately 6 µm for 512 lengths along the X and for 512 lengths along the Y direction of the sample (*Figure 2c*). Consequently, the element images consist of 262 144 pixels each. Data collection was performed during a period of 0.2 seconds along each measuring distance of about 6 µm, and approximately 15 hours were needed for the complete measurement procedure for mapping of the four elements mentioned.

For image formation, special data handling and image-forming software written by one of the authors (H.-J.B.) was applied.

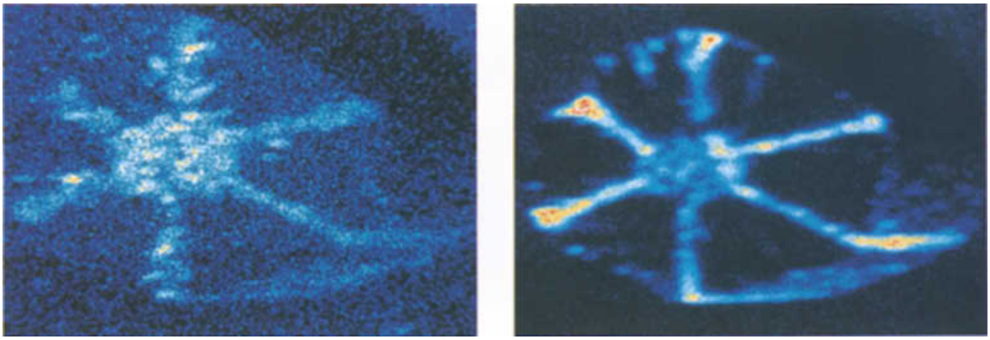
Characterization of inclusions

The examination of the six trapiche rubies by X-ray microfluorescence analysis revealed extraordinarily high concentrations of Si, Ti and Fe in the six arms of the samples C and D. For the characterization of inclusions in the orientated channels of these two trapiche rubies (in addition to the previously identified calcite and dolomite fillings), several channels in both samples were analysed by electron microprobe using conventional energy dispersive and wavelength dispersive systems of a CAMECA Camebax SX50 electron microprobe.

The image processing software of the analytical system generates element images of the samples, in which a colour code is used for varying concentrations between different analysis points. Variable element concentrations are displayed pixel by pixel in the X-ray image in the sequence (from low to high concentrations) violet → blue → green → yellow → red and examples of Ca and Fe are shown in *Figure 4a, b.*

Element distribution maps of samples A, B and D are presented in *Figures 5 to 7*. In all samples, we observed a distinctly smaller aluminium concentration in the yellow or yellowish-white arms of the stars as well as in the black cores of samples C, D and E compared to the aluminium concentration of the six triangular or trapezohedral ruby sectors. This was also observed for chromium in the yellowish-white arms of sample A (*Figure 5*) and in the black cores of samples C and E. The red core of sample F, on the other hand, revealed a higher chromium concentration than the six trapezohedral ruby sectors of the sample. In four trapiche rubies, a distinct chromium zoning within the six triangular (samples A and B; *Figure 6*) or the six trapezohedral ruby sectors (samples E and F) was also observed.

Figure 4a, b: *Element maps of Ca (left) and Fe (right) for trapiche ruby, sample C, obtained by XRMF analysis. Different element concentrations are displayed pixel by pixel in the XRMF map; increasing concentrations are colour coded in the sequence violet → blue → green → yellow → red.*



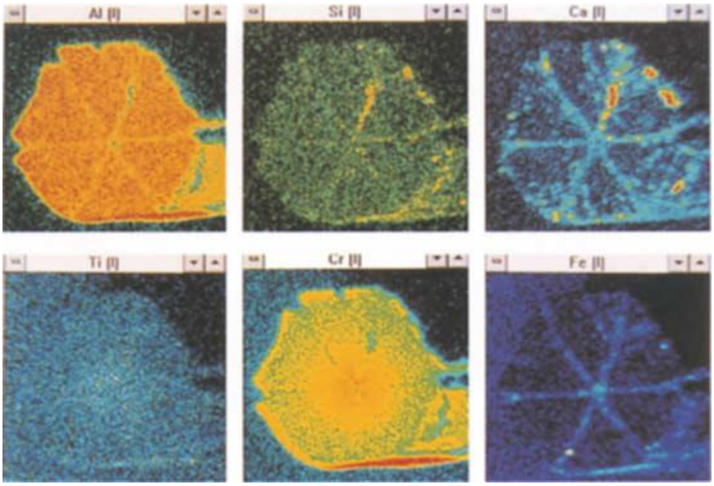


Figure 5: Element distribution maps for trapiche ruby, sample A, obtained by XRMF analysis; the six yellowish-white arms of the sample intersect at one small central point.

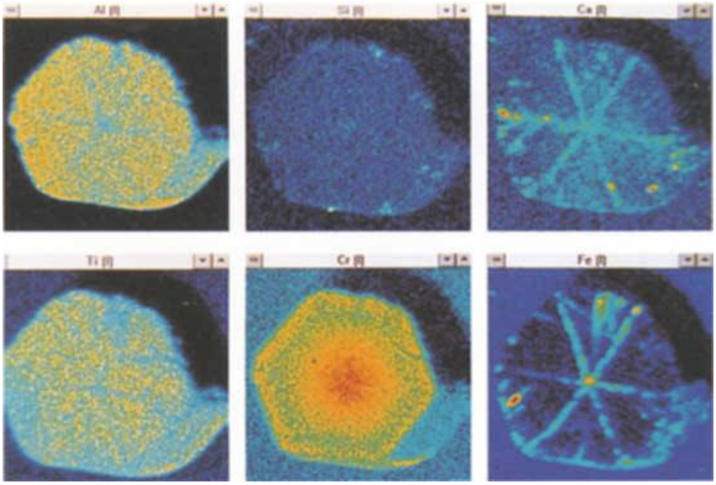


Figure 6: Element distribution maps for trapiche ruby, sample B, obtained by XRMF analysis; the six yellow arms of the sample intersect at one small central point.

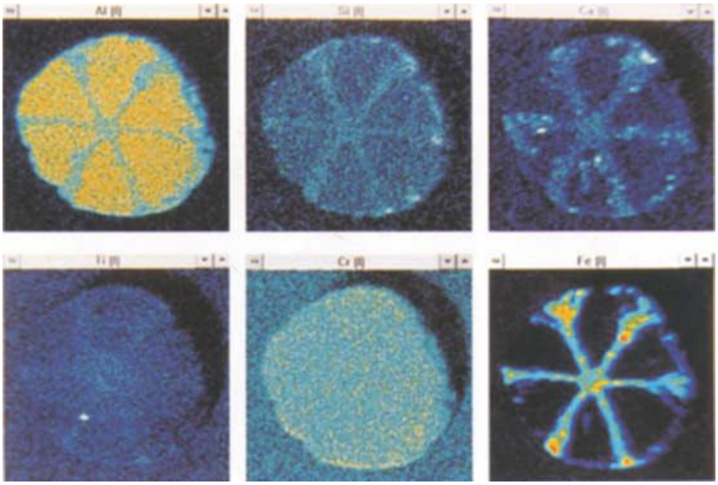
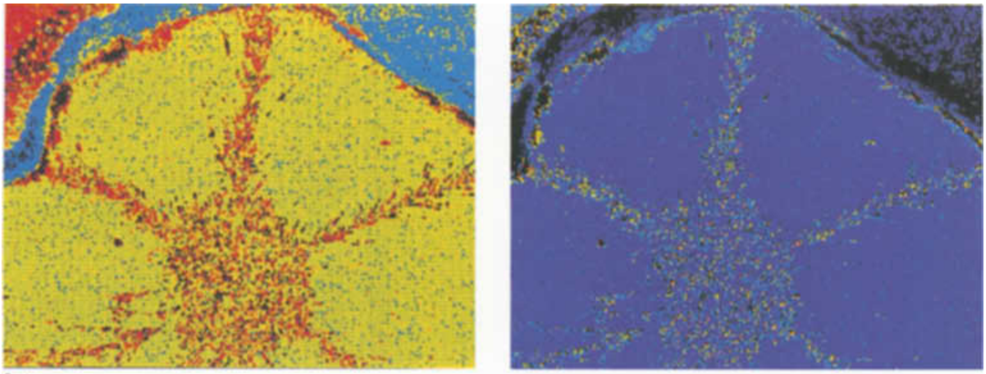


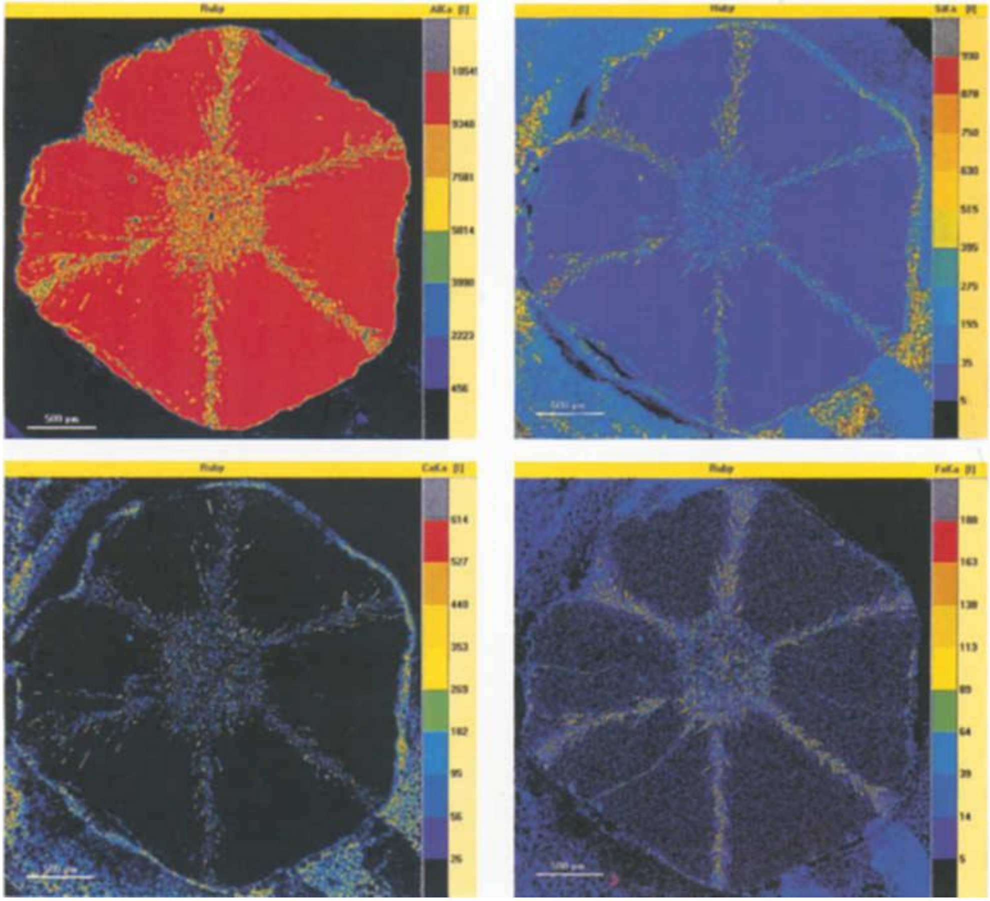
Figure 7: Element distribution maps for trapiche ruby, sample D, obtained by XRMF analysis; the six broad yellow arms of the sample extend outward from a hexagonal black core.



8a

Figure 8: *Element maps of Al, Si, Ca and Fe for trapiche ruby, sample C, obtained by EMPA. Different element concentrations are displayed pixel by pixel in the XRMF map; increasing concentrations are colour coded in the sequence violet → blue → green → yellow → red; (a) two element maps for Ca are given, which were obtained from data collected in a step-by-step measuring mode, different colour codes are applied for image forming according to the counting rates measured at each analysis point; (b) four element maps for Al, Si, Ca and Fe were obtained from a continuous raster mode.*

8b



Various calcium concentrations due to inclusions of calcite and dolomite (see Schmetzer *et al.*, 1996a) were found in the yellowish-white or yellow arms of all six samples and in the black cores of samples C, D and E. Any variation of magnesium concentration caused by the dolomite inclusions, on the other hand, was not resolved with the measuring conditions used. This result is consistent with decreasing sensitivity of the instrument towards lighter elements.

Iron was also observed in various concentrations in the arms of the six-rayed stars as well as in black cores. In general, yellowish-white arms (sample A, *Figure 5*) or yellowish-white inner parts of zoned arms (sample E) revealed smaller iron concentrations than the yellow outer parts of zoned arms (sample E) or completely yellow arms (samples B, C and D, *Figures 6 and 7*). No iron was found in the six triangular or trapezohedral ruby sectors of all six samples or in the red core of sample F.

A somewhat unexpected result was the observation of distinct concentrations of silicon in the yellowish-white arms of sample A (*Figure 5*) and of silicon and titanium in the yellow arms and black cores of samples C and D (*Figure 7*).

Electron microprobe analysis (EMPA)

The mapping of Al, Si, Ca and Fe in sample C by electron microprobe (*Figures 8a,b*) confirms the analytical results obtained by XRMF. According to the smaller diameter of the electron beam of the microprobe, a somewhat higher resolution is obtained for these element maps (compare *Figure 1c* and *Figures 4a,b*). In both analysis procedures applied, i.e. in a step-by-step (*Figure 8a*) and in a continuous raster mode (*Figure 8b*), no significant differences between the element images were observed. Iron contents were observed in the core and in the six arms of the star as well as in different small irregular fissures.

Characterization of inclusions

XRMF of trapiche rubies C and D revealed extraordinarily high concentrations of Si, Ti and Fe in the yellow arms and in the black cores of the samples. Semi-quantitative and quantitative chemical examination of several inclusions within these zones were performed by single-point analyses using the energy dispersive and wavelength dispersive analytical systems of the microprobe. These analyses of solid inclusions in orientated channels proved the presence of K–Al- and Fe–Al-silicates with or without titanium contents in addition to the previously identified calcite and dolomite fillings (see also Schmetzer *et al.*, 1996a). Quantitative chemical analyses, however, gave extremely variable results and proved compositions of the silicates in the channels to be inhomogeneous. From these results, it is concluded that the channels contain several extremely fine-grained silicate minerals.

Discussion

Chemical zoning in trapiche rubies has been proved by element mapping using XRMF and EMPA techniques. Three overlapping effects were observed in the samples (*Table I*):

(a) Chromium zoning within trigonal or trapezohedral ruby sectors (samples A, B, E and F) or between a red core and six trapezohedral ruby sectors (sample F) is due to growth zoning which is not related to inclusions in orientated channels.

(b) Calcite, dolomite and K–Al–Fe–Ti-silicate inclusions in the yellowish-white to yellow arms of all samples and in the black cores of samples C, D and E, cause aluminium and chromium deficiencies and variable concentrations of Si, Ca, Ti and Fe in these areas.

(c) A third mechanism contributing to the chemical inhomogeneity of trapiche rubies is caused by iron staining of primary tube-like cavities and secondary irregular fissures due to intense weathering of most samples. A distinct zoning with intensely weathered yellow arms in the outer parts and less weathered yellowish-white arms in the inner part of sample E (*Figure 1e*) is correlated with higher iron contents in the more weathered parts (*Table I*).

In summary, element mapping of trapiche rubies reveals a characteristic primary growth zoning, the presence of carbonate and some silicate mineral inclusions in orientated channels, and secondary weathering and iron-staining of the samples.

Conclusions

Element mapping by XRMF or EMPA is an extremely useful tool to understand various effects of chemical zoning within gem materials. Possible applications of element mapping to gemmological testing problems are the distinction of natural and synthetic gem materials due to variable chemical growth zoning as well as providing proof of diffusion treatments as recently demonstrated by Zhang *et al.* (1997).

Different diameters of incident X-ray or electron beams (70 or 3–4 µm respectively) were applied to excite characteristic X-ray fluorescence radiation in the samples and these give different spatial resolutions.

XRMF facilities include image-producing software packages which are nowadays routinely available (e.g. the OMICRON system by Kevex Instruments). The more time-consuming element mapping by electron microprobe requires extremely stable instrumental conditions and specially developed image-processing software applied to the data collection.

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Identification of B jade by FTIR spectrometer with near-IR fibre-optic probe accessory

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ABSTRACT: A FTIR spectrometer with a near-IR fibre-optic probe accessory has been found to be a useful and non-destructive tool for identification of bleached and polymer-impregnated jadeites (so-called B jade).

This method has the advantage of application to the testing of not only very thick or mounted stones, but also very large samples such as bracelets, which are difficult to test with other IR techniques. The important features of the technique are use of the fibre-optic probe and measurement of the near-IR frequency range. Therefore, clear near-IR absorption spectra from 7400 cm^{-1} to 4000 cm^{-1} could be obtained. The absorptions are caused mainly by the combination of stretching and bending vibrations and the harmonics of stretching vibration of C–H bonds.

Introduction

FTIR spectrometers have been successfully used to identify B jade for many years. The first report was by Hurwit (1989) when little was known about this kind of jade treatment and its detection. The methods developed to include the widely used FTIR transmission technique (Fritsch *et al.*, 1992), and the more recent DRIFT technique (Quek *et al.*, 1997). Although thick or mounted samples can be tested using the DRIFT method it cannot be used for testing very large samples.

The basic principle of the FTIR transmission and DRIFT techniques to identify B jade is to study and compare two groups of absorption peaks, one from 3200 cm^{-1} to 2800 cm^{-1}, caused mainly by the stretching vibration of C–H bonds in the treatment material and another centred at 3500 cm^{-1}, caused by the stretching vibration of O–H bonds in the host jade. In some specimens it is very hard to differentiate the two groups of peaks. For example, if a sample is too thick then a general absorption band from 3600–2800 cm^{-1} may form. When this occurs, the absorption peaks in the near-IR frequency range can be measured to determine the nature of the jade.

Because of the low near-IR energy distribution of normally used FTIR instruments and the low molecular absorption coefficients of C-H bonds in the near-IR frequency range, it can be hard to get good signal-to-noise ratio spectra of B jade in the near IR-range. This problem can be resolved by use of a near-IR fibre-optic technique.

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Figure 1: The near-IR fibre-optic probe accessory connected to the FTIR spectrometer.

Principle and experiment

Polymers show absorption peaks at about 4300 cm^{-1}, caused by the combination of C–H stretching and C–H bending vibrations and at about 5900 cm^{-1} caused by the first-grade multiple frequency vibration of C–H stretching.

In jade, except for absorption at 5230 cm^{-1} caused by water molecules in alteration of the pure jadeite, there are no other clear absorptions in the near-IR frequency range, thus the polymer absorptions in B jade in the near-IR range are clear and not affected by any jadeite absorption.

For measurement a Nicolet Magna-750 FTIR spectrometer and a 'sabIR' fibre-optic probe accessory were used for the first time. The accessory consists of integrated optics, fibre-optic cable, sampling probe, detector and probe mount. One end of the fibre-optic cable is connected with the stainless-steel probe and the other end is connected with the FTIR spectrometer by a special detector (*Figure 1*). White light (quartz-halogen) and a KBr beam-splitter were used. The wavenumber range scanned was from 6500 to 4200 cm^{-1} with a resolution of 8 cm^{-1}; the scan number was 10.

Figure 2: The sample can be tested by placing it on the mount of the fibre-optic probe.

A sample is exposed to near-IR radiation via the fibre optic and mainly diffuse reflectance light from the aggregate sample is collected. Thus, a diffuse reflectance spectrum can be obtained with the accessory; for the principle of diffuse reflectance, see Quek *et al.* (1997).

Except for cleaning the surface of a sample with a clean cloth, no sample preparation is necessary. The sample can be either placed on the probe mount (*Figure 2*), or touched directly with the probe by hand (*Figure 3*).

More than 50 pieces of A and B jade that had been tested by normal gemmological methods and by an FTIR transmission spectrometer were studied with the accessory. For conclusive results, a rough specimen of A jade was cut into two pieces by the authors (samples 1 and 2), and sample 2 was bleached and polymer-impregnated by a jade wholesale corporation.

Results and Discussion

Figure 4 (a,b) shows typical near IR spectra of two natural jadeites (samples 3

Figure 3: A large sample can be tested by bringing the probe adjacent to the sample by hand.

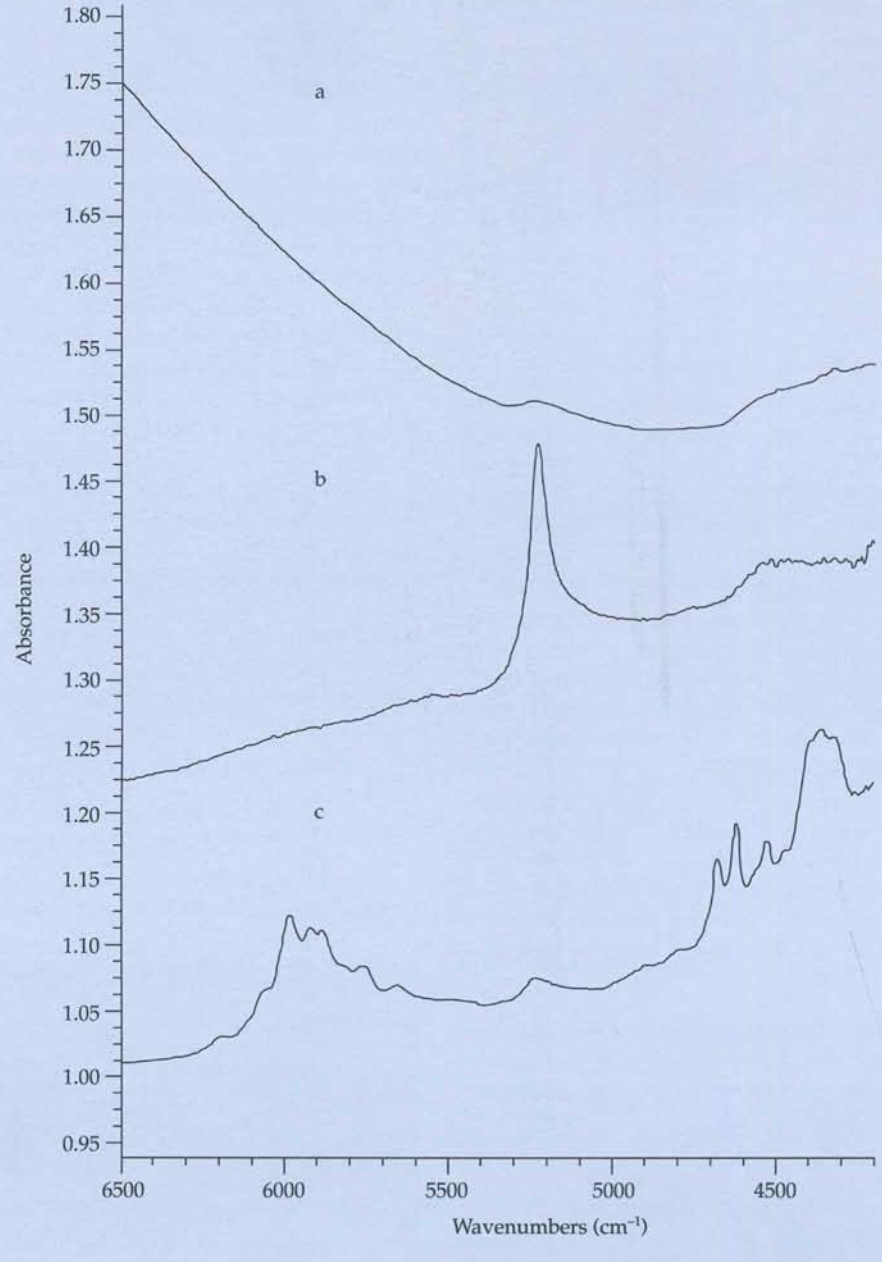

Figure 4: *Near-IR spectrum of (a) a high-quality, near-transparent, green natural jadeite (sample 3), (b) a poor-quality, opaque, green natural jadeite (sample 4), (c) a bleached and polymer-impregnated jadeite, tested using a 'sabIR' accessory.*

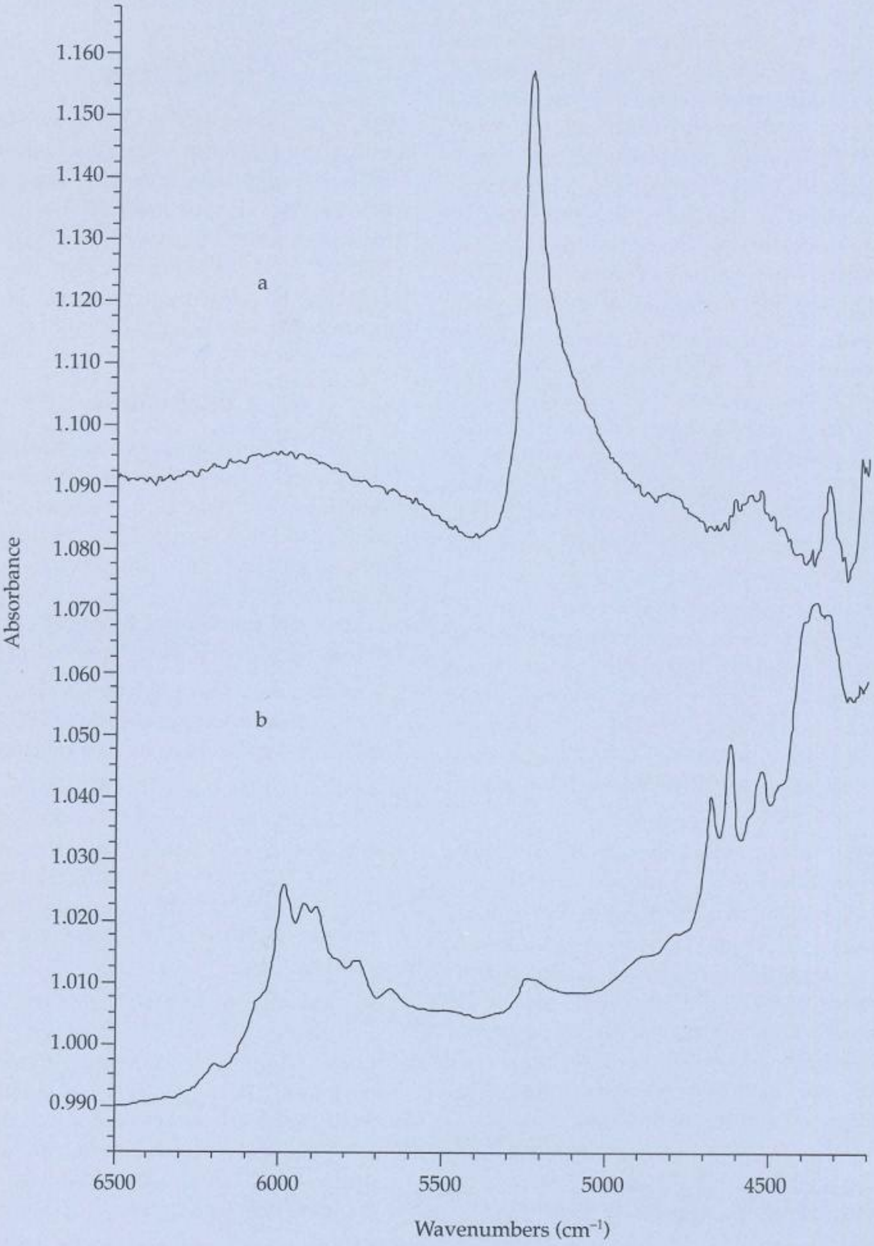

Figure 5: *Near-IR spectrum of (a) A jade before being bleached and polymer impregnated (sample 1), (b) B jade made from the material of sample 1 (sample 2), tested using a 'sabIR' accessory.*

and 4). Sample 3 is a high-quality, near-transparent, natural green jadeite. Sample 4 is a poor-quality, opaque, natural green jadeite.

It can be seen that the absorption peak occurring at 5230 cm^{-1} is the characteristic mark of natural jadeite, but the relative intensities of the absorption peak may vary significantly from specimen to specimen. Generally the better the quality of a jadeite, the lower relative intensity. So the relative intensity of the peak my be used as an indicator of the content of impurities in the jadeite, especially minerals that contain water.

Figure 4 (c) shows a typical near-IR spectrum of a bleached and polymer impregnated jadeite. The representative absorptions include four groups of peaks. The first group mainly contains peaks at 5985, 5922, 5885 and 5700 cm^{-1}, the second at 5230 cm^{-1}, the third at 4680, 4622 and 4530 cm^{-1} and the fourth at 4370, 4342 and 4324 cm^{-1}.

The first group of peaks near 6000 cm^{-1} are believed to be mainly related to the absorption caused by the C–H stretching vibration, the fourth group of peaks near 4300 cm^{-1} to the absorption of both stretching and bending vibrations of C–H. The cause(s) of the other two groups of peaks have not yet been explained.

Figure 5 (a,b) shows the spectra of sample 1 and sample 2.

It is evident that the relative intensity of the peak at 5230 cm^{-1} is lower after bleaching and polymer-impregnating treatment. It proves directly that impurities (especially minerals containing water) can be destroyed by bleaching. Although the absorption peak at 5230 cm^{-1} occurs in the two samples, the causes of formation are different.

The spectrum of jadeite which has been wax buffed is almost the same as that of the natural jadeite, the authors believe that the content of wax in such jadeite is too low to produce significant absorption peaks in the near-IR range.

The near-IR spectra of bleached and wax-impregnated jadeites have not yet been studied, but the authors believe that the spectrum of wax-impregnated jadeite could be characteristic and that identification of wax-impregnated jadeite could be as easy as that of polymer-impregnated jadeite.

Limitation

If a specimen of A jade is very thin and mounted in jewellery with glue, the near-IR radiation could penetrate the sample and reach the organic glue layer. Consequently a spectrum resembling that of B jade could be obtained and be misleading. In such instances, the measurements must be done carefully with this possibility in mind.

Conclusions

A near-IR fibre-optic accessory fitted to an IR spectrometer offers an effective and easy method for testing jade in various kinds of jewellery, and is particularly applicable to large samples. The sensitivity of the technique is good, and clear and characteristic spectra can be easily obtained. The following conclusions can be drawn:

1. Except for an absorption at 5230 cm^{-1}, there are no absorption peaks between 6500 cm^{-1} and 5000 cm^{-1} shown by natural jadeites.
2. The relative intensity of the peak at 5230 cm^{-1} can be used as an indicator of the quality of a natural jadeite specimen when compared with standard laboratory specimens. The better the quality of the jadeite, the lower the intensity of the 5230 cm^{-1} peak.
3. In jadeites examined after bleaching treatment, the relative intensity of the peak at 5230 cm^{-1} was smaller than before treatment, so a relatively high peak at 5230 cm^{-1} can be an indicator that the jade is A jade. This conclusion can also be applied to FTIR spectra obtained using a transmission technique.
4. The existence of absorption peaks at wavenumbers 5985, 5922, 5885, 5230, 4680, 4622, 4530, 4370, 4342 and 4324 cm^{-1} indicates that the jade being tested has been bleached and polymer impregnated. Ten scans of a sample are usually

sufficient to obtain a good spectrum, so the technique is very suitable for rapid testing of large batches of jewellery containing jade.

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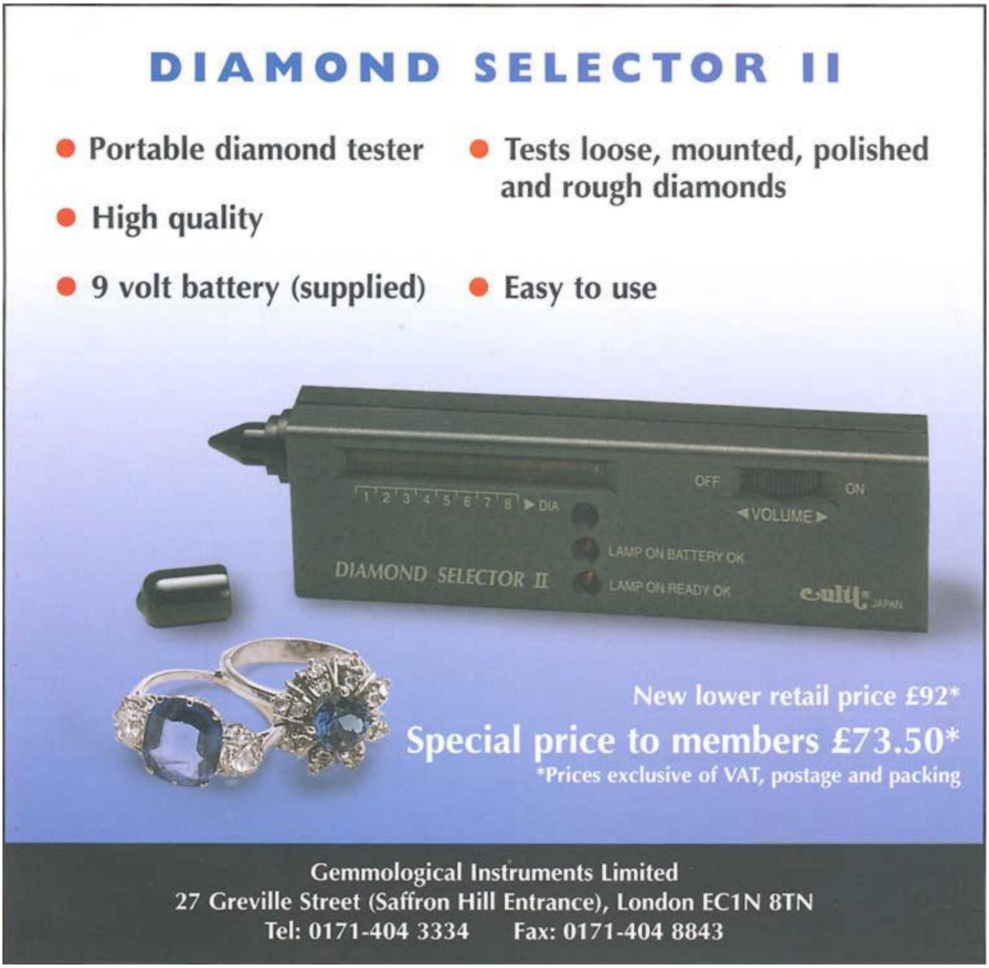

Natrolite from the Bela ophiolite, Pakistan

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ABSTRACT: The zeolite mineral natrolite was found as fracture filling in a slightly boudinaged dolerite dyke in serpentinized harzburgite WSW of Hazarganji, Khuzdar District, SW Pakistan. The mineral occurs as acicular, bundle-shaped aggregates up to 35 cm long and as prismatic milky-white or transparent idiomorphic crystals up to 12 cm long. Unusually large collectors' stones of up to 20.62 ct have been cut from this locality. The shape of idiomorphic crystals and mineral chemistry indicate a structurally highly (Si,Al)-ordered natrolite and this is consistent with the low temperature assemblage of associated minerals.

Keywords: Bela ophiolite, natrolite, Pakistan, rodingite, zeolite

Introduction

Natrolite (ideally $Na_2Al_2Si_3O_{10}.2H_2O$) is an orthorhombic zeolite mineral which is structurally closely related to mesolite ($Na_2Ca_2Al_2Si_3O_{10}.8H_2O$) and scolecite ($CaAl_2Si_3O_{10}.3H_2O$). The name derives from the Greek natron = soda and lithos = stone. Orthorhombic (pseudo-tetragonal) natrolite was first described by Klaproth (1803). The hardness is 5–5.5 on Mohs' scale, and its specific gravity is 2.20–2.25. Natrolite is biaxial positive and refractive indices are $\alpha = 1.473–1.480$, $\beta = 1.476–1.486$ and $\gamma = 1.485–1.496$ (Anthony *et al.*, 1990). The structure of the mineral was solved by Pauling (1930) and Taylor *et al.* (1933), and recently refined by Artioli *et al.* (1984). The basic structure of natrolite is an aluminosilicate framework composed of (Si, Al) tetrahedra. Each oxygen is shared between two tetrahedra and the negative charge is balanced mainly by Na situated in the cavities between; H_2O molecules also occupy the cavities. The structure of the natrolite-group zeolites contains a fundamental chain-like unit of edge-shared tetrahedra oriented parallel to the *c*-axis (*Figure 1*). This is the reason for the fibrous morphology common for this mineral group. Although natrolite is structurally related to mesolite and scolecite, it shows only limited solid solution with less than 0.5 Ca per unit cell present in natrolite. Other elements which may be present in small amounts are magnesium and potassium. Small impurities, order-disorder effects, and different hydration stages lead to the structurally, optically and chemically slightly different minerals of the natrolite group called gonnardite, tetranatrolite, ranite and paranatrolite (Chao, 1980; Chan and Chao, 1980; Mazzi *et al.*, 1986; Nawaz, 1988; Krogh Andersen *et al.*, 1969, 1990; Alberti *et al.*, 1995).

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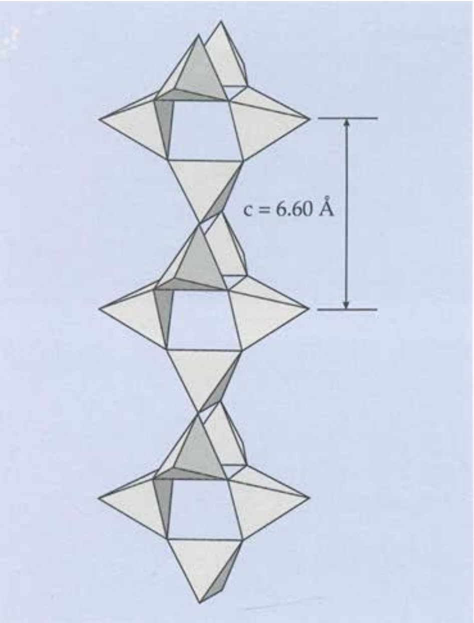

Figure 1: *Basic chain-like orientation of Si, Al-tetrahedra in natrolite structure, which explains its preferred fibrous growth.*

Natrolite occurrences are characteristically associated with basaltic rocks, alkaline intrusions, basic rocks in serpentinites and salt-lake environments (alkaline brines). In basaltic rocks well-developed crystals form in vugs (e.g. Hegau, Germany; Faeroe Islands; Auvergne; Bohemia) or in association with hydrothermal alteration (e.g. seafloor metamorphism). Natrolite associated with alkaline intrusions is, for example, described from Kola, USSR; Ilimaussaq, Greenland; San Benito County, California; the Langesundsfjord in Norway, and the Kimberley diamond mines in South Africa. Natrolite associated with basic rocks in serpentinites is reported from the Borus Mountains (Judin, 1963) and from the Johnston asbestos mine in Quebec, Canada (Poitevin, 1938). Natrolite formation in association with alkaline saline brines is reported from Tanzania, and from salt lakes in the USA (Hay, 1966).

Gem-quality natrolite is known from Bound Brook, New Jersey (Dunn, 1976) and Mont Saint-Hilaire, Quebec (Wight, 1996).

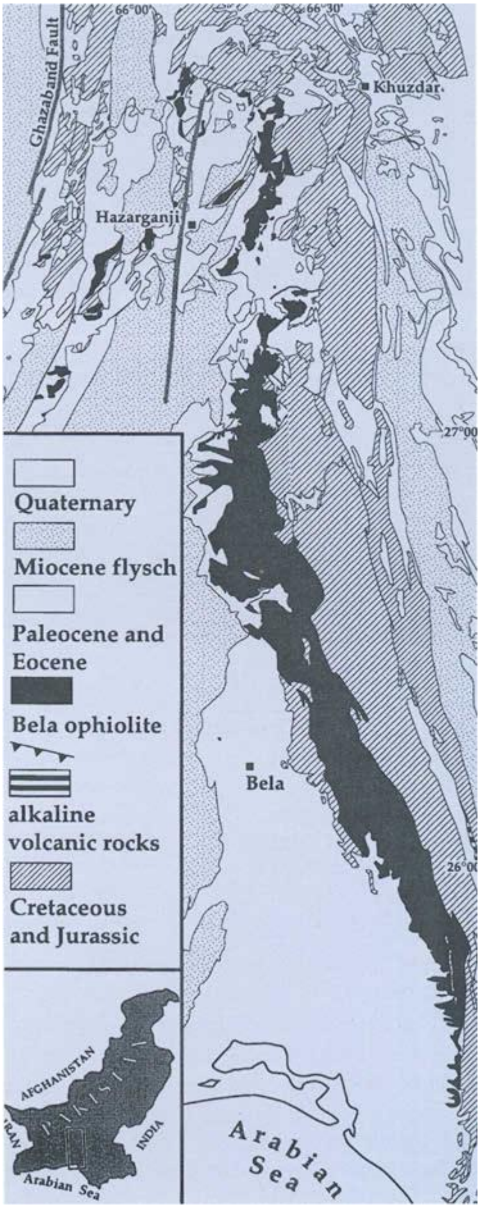

Figure 2: *Overview map of the Bela ophiolite and surrounding Mesozoic and Tertiary rocks. The map is based on Jones (1960).*

Regional geology

The natrolites of this study are from dolerite dykes, metasomatized towards rodingite, in serpentinite of the Bela ophiolite, Pakistan (*Figure 2*). The Bela

Figure 3: *(a) Typical outcrop of serpentinized harzburgite of the Bela ophiolite (Hazarganji area) containing white-weathering folded and boudinaged dolerite dykes.*
(b) Long prismatic, bundle-shaped aggregate of natrolite associated with prismatic white natrolite; size of specimen ca. *30 cm.*
(c) Long prismatic, idiomorphic gem-quality natrolite crystals, up to 12 cm in length, showing the morphology drawn in Figure 4.
(d) Cut and faceted natrolites from the Bela ophiolite. Back: left, modified scissors cut, 13.48 ct; centre, round brilliant-cut, 2.53 ct; right, modified scissors cut, 20.62 ct. Front: left, octagonal cut, 11.26 ct; right, rectangular cut, 5.08 ct. All stones are clean. Photo B. Schmied.

ophiolite is a fragment of ocean floor and forms part of the western ophiolite belt of Pakistan which was obducted onto the edge of the Indian continental plate during Palaeocene-Eocene times (Allemann, 1979; Mahmood *et al*., 1995). The specimens were collected from a nearly monomineralic crack filling, up to 10 cm across, in a several metre thick dolerite dyke WSW of Hazarganji (*Figure 3a*). Only calcite (< 2 vol.%) was associated with the natrolite in the crack. Most of the natrolite occurs in the form of milky-white long prismatic radiating crystals (*Figure 3b*) filling the cracks but a few cavities contained freely-grown white to transparent crystals (*Figure 3c*) which allowed a study of their morphology. The two thickest pure crystals were used for faceting and the results are displayed in *Figure 3d*.

Nearby, boudinaged dolerite dykes metasomatized towards rodingite and weathering white, contain small (< 1 mm) andradite (demantoid) and green vesuvianite crystals as coatings on fissures. Fibrous xonotlite, $Ca_6(Si_6O_{17})(OH)_2$, the hydrous low-temperature mineral related to wollastonite, also forms cross-fibre fracture fillings.

Mineralogy

The natrolite from the Bela ophiolite forms medium to long prismatic and fibrous radiating crystals which are morphologically simple, with dominant {110} prism and {111} pyramid, and smaller {100} prism and {101} pyramid forms (*Figure 4*). A few crystals have twinning on {110}. The samples are

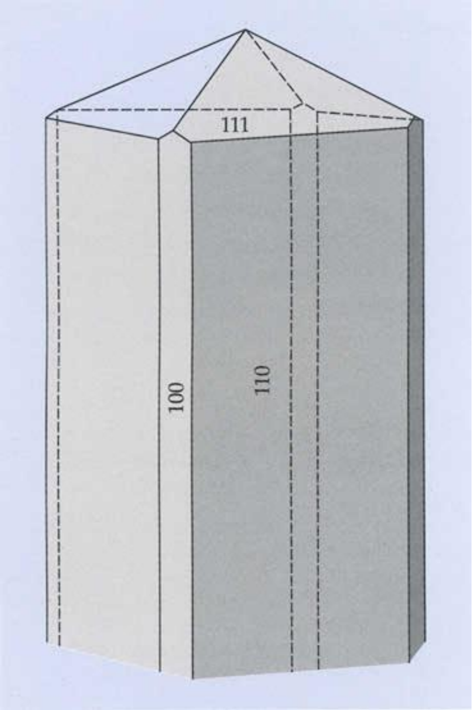

Figure 4: Morphology of natrolite from the Bela ophiolite. The {110} form may be absent; a second pyramidal form {311} was observed in some twinned crystals.

colourless and show no fluorescence in long- or short-wave ultraviolet light, although fluorescence has been described for samples from other localities (e.g. Laurent, 1941; Anthony *et al.*, 1990). Three different white and transparent natrolite crystals were analysed by powder X-ray diffraction, and the mineral was identified as natrolite.

A mean of four microprobe analyses of a gem-quality natrolite from the Bela ophiolite is listed in *Table I*. Data were collected with an enlarged beam diameter, and corrected online for H_2O absorption, assuming $2H_2O$ per formula unit. The chemical composition is close to endmember natrolite.

Gemmological characteristics

The refractive indices for the Bela material have been determined on a gemmological refractometer as $\alpha = 1.480$, and $\gamma = 1.485$. This gives a birefringence of 0.005 which is low and probably reflects the high Na and unusually low Ca, K and Mg contents. Spindle stage measurements yielded a $2V_z$ angle of $63.362 \pm 0.492°$. The natrolite gem material is free of inclusions and neither zoning nor luminescence were observed under the cathode luminescence microscope.

***Table I.** Electron microprobe analysis of Bela natrolite*

Wt. %		Cations on basis of 10 oxygens	
SiO_2	46.55	Si	2.983
TiO_2	0.08	Ti	0.001
Al_2O_3	26.74	Al	2.019
FeO	0.04	Fe	–
MnO	0.05	Mn	–
Cr_2O_3	0.07	Cr	–
MgO	0.07	Mg	–
CaO	0.00	Ca	–
Na_2O	16.34	Na	2.030
K_2O	0.06	K	–
Total	90.00	Total	7.033

Note: Mean of four analyses. H_2O was not determined and the total is low; absorption due to H_2O was taken into account in calculating the oxide percentages.
Microprobe analyses were performed on a Cameca SX-50 microprobe at Bern University by E. Gnos. Beam conditions were 15 kV and 10 nA, with a defocused beam size of approximately 30 microns. Natural and synthetic minerals were used as standards.

Formation conditions

The development of natrolite in cracks is related to post-obduction ophiolite deformation and to hydrothermal activity along faults (Sarwar, 1992; Bannert *et al.*, 1992). These caused deformation and serpentinization of the peridotites, and fracturing, boudinage and metasomatism towards rodingite of doleritic dykes. The faults are parallel to the large Chaman, Ornach-Nal, and Ghazaband fault systems (*Figure 2*) which are the result of extrusion of the Afghanistan continental blocks due to the Himalayan collision (e.g. Tapponnier *et al.*, 1981).

Heating experiments by Van Reeuwijk (1972) showed that natrolite dehydrates and transforms to metanatrolite at 285°C under atmospheric pressure. On the other hand, natrolite can grow under atmospheric conditions in saline lake basins. In natural hydrothermal assemblages fibrous zeolites generally occur in the highest temperature zone (Alberti *et al.*, 1995). Thus, comparison with similar occurrences and the presence of andradite garnet, vesuvianite and xonotlite suggest that formation of the Bela natrolites took place at 150–285°C. The proposed low-temperature hydrothermal origin of the natrolites is also consistent with a strongly ordered natrolite structure (Alberti *et al.*, 1995) which is indicated by its Si/Al ratio of *ca.* 1.5.

Conclusion

Natrolite is probably not an unusual mineral in Pakistan and can be expected in vugs in alkaline lavas or in hydrothermal veins associated with alkaline intrusions, as well as in alkaline lake deposits. The development of large idiomorphic gem-quality crystals at this locality is unusual and the occurrence is interesting for mineral collectors, but it is not of economic importance.

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Heat treatment of milky sapphires from the Mogok stone tract, Myanmar

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ABSTRACT: Heating experiments on Myanmar geuda sapphires indicate that the most beautiful blue stones are obtained by heating to temperatures about 1600°C.

Keywords: geuda, heat treatment, Myanmar, sapphire

There are numerous reports in the literature about heat treatment of geuda stones from Sri Lanka (e.g. Nassau, 1984; Ediriweera and Perera, 1989; Hughes, 1990; Hurlbut and Kammerling, 1991; Webster, 1994) and they are well known among gemmologists, but reports of heat treatment of geuda-like sapphires from the Mogok stone tract, Myanmar, are still scarce. Geuda-like sapphires from the Mogok stone tract generally appear milky or contain abundant silk, in a range of pale colours including waxy-white to colourless, yellowish, bluish, etc. (Themelis, 1992). Heat-treatment experiments of Upper Myanmar stones carried out under reducing atmospheres in the past have shown that

(i) translucent to opaque white/milky/bluish sapphires characterized by a dull blue appearance turned to lighter blue, opaque or translucent, suitable for cabochons (1800°C, 60 minutes),

(ii) translucent to semi-translucent, white to pale bluish sapphires characterized by a dull appearance turned medium to light bright beautiful blue, very transparent, suitable for faceting (1750°C, 30 minutes), and

(iii) some transparent to semi-translucent waxy whitish or colourless sapphires with intense silk turned into light to medium blue, suitable for faceting (1800°C, 120 minutes) (Themelis, 1992).

The authors recently had a chance to examine geuda-like sapphires from the Mogok stone tract and the opportunity to treat some of these stones (*Figure 1, A–D*). The stones were heated from room temperature using a supertherm high-temperature furnace model HT 08/17 in an oxidizing atmosphere and under atmospheric pressure in all experiments.

Heating started with a rise of 10°C per minute up to 1200°C. The temperature was held at 1200°C for two hours and then the furnace was cooled to room temperature over a period of eight to ten hours. The results were surprising: the milky sapphires turned to transparent or translucent colourless stones with the exception of a very light blue milky sapphire with zonal structure (*Figure 1D*), which turned white.

Next, the temperature was raised to 1300°C, also starting from room temperature with a rise of 10°C per minute and held for two hours, but the results were the same as

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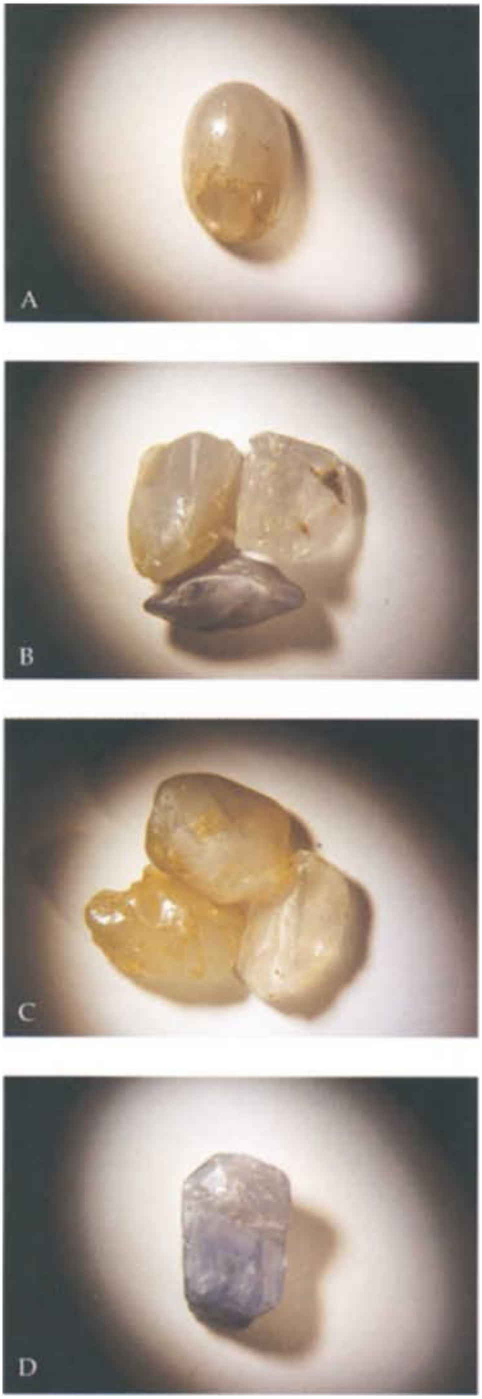

Figure 1 A–D: *Geuda-like, milky sapphires from the Mogok stone tract before heat treatment.*

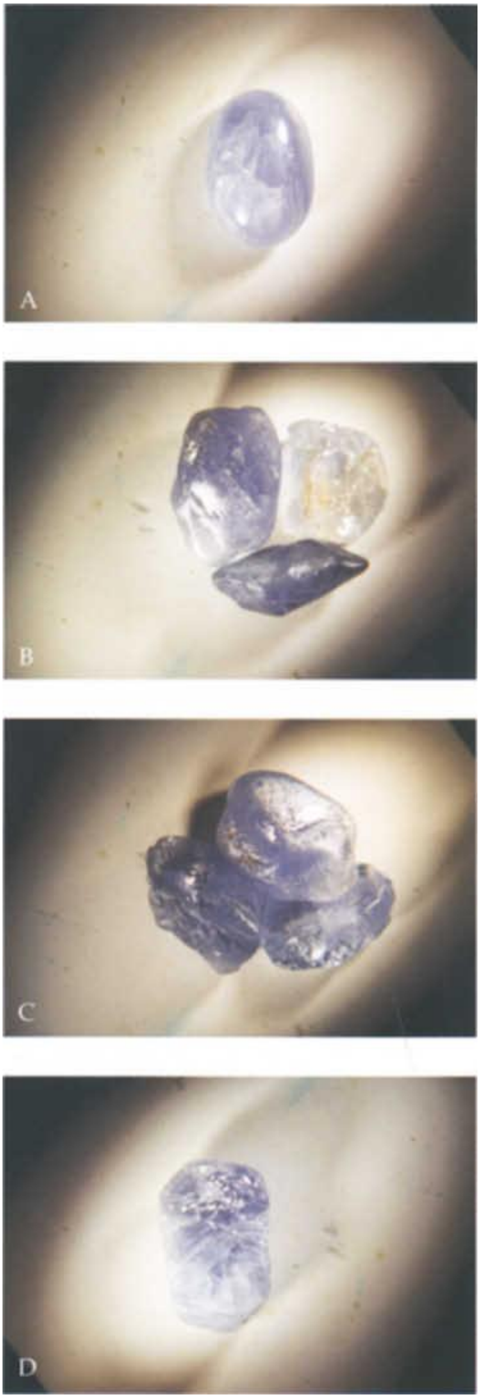

Figure 2 A–D: *Medium blue to beautiful blue sapphires from the Mogok stone tract after heat treatment at 1600°C.*

those obtained at 1200°C. Repetition of the experiment to a temperature of 1400°C caused no further dramatic changes in the sapphires.

At a temperature of 1500°C, the heating period was much longer than for the treatments described above, and this caused the colour of some milky sapphires to change to medium blue. The light-blue milky sapphire which had turned to white at 1200°C also changed to blue at 1500°C. When the temperature was raised to 1600°C and the heating period further extended, the colour dramatically changed from medium blue to a beautiful blue as shown in *Figure 2 A–D*. When the temperature was increased to 1700°C and the period of heating increased over that used at 1600°C, the beautiful blue sapphire turned to medium blue.

On the basis of these preliminary results on a small sample of geuda-like sapphires from Myanmar it would seem that the best results are obtained when the temperature range does not exceed 1600°C in an oxidizing atmosphere (cf. results obtained by Themelis, 1992). Further experimental details are available from the senior author.

Acknowledgements

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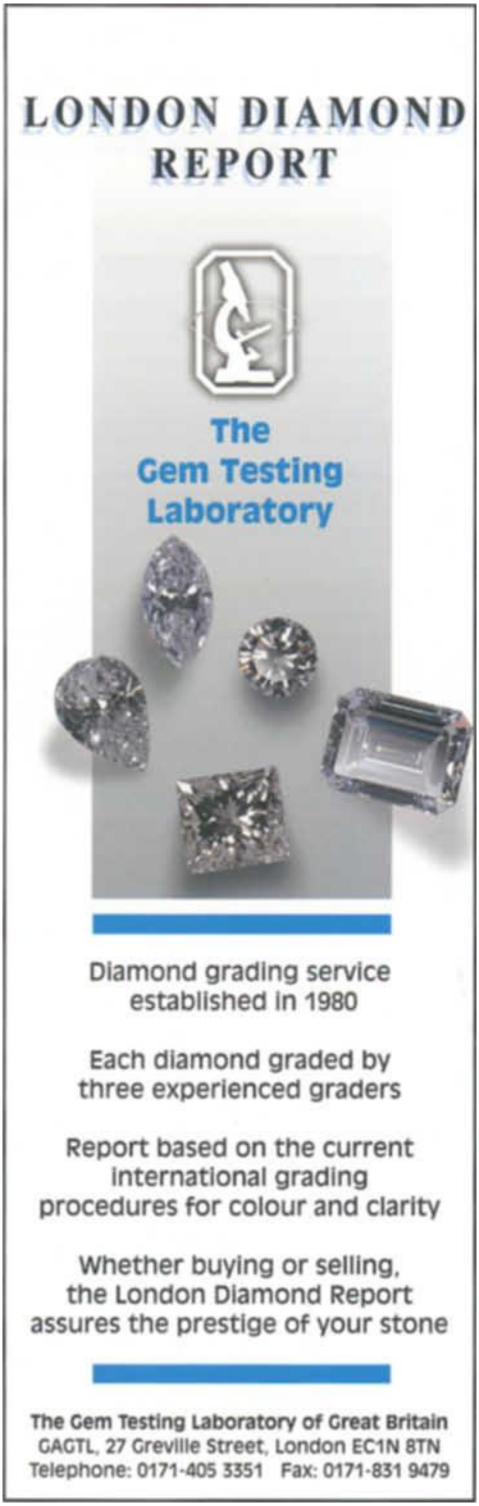

Laser-induced luminescence of emeralds from different sources

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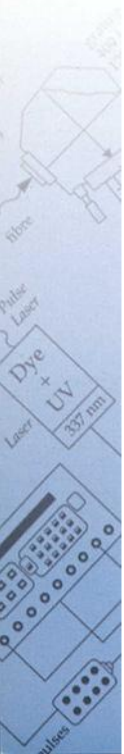
ABSTRACT: Preliminary spectroscopic analysis in the red range of the spectrum between 674 and 679 nm using the new laser-induced (time-resolved) photoluminescence (LPL) technique, has been carried out on six natural emeralds from Afghanistan, Brazil, Colombia, Nigeria, Russia and Zambia, and one hydrothermally grown synthetic emerald. Emeralds from different sources have distinctive luminescent spectra and the usefulness of the results is evaluated. Although the luminescence spectra of emeralds from Afghanistan, Russia and Zambia are similar to that of the synthetic emerald, they show an additional 'bulge' towards the longer wavelength. The artificial emerald displays about three times greater intensity of luminescence than that shown by the natural emeralds.

Keywords: emerald, laser, photoluminescence, spectrum



Introduction

A selection of emeralds from six gem-mining regions in Afghanistan (Panjshir), Brazil (Carnaiba), Colombia (Muzo), Nigeria (Jos), Russia (Malishevo), and Zambia (Kitwe), and one synthetic hydrothermally grown emerald were chemically analysed with the electron microprobe (Moroz and Eliezri, 1998). The emeralds are chemically not homogeneous for the most part and display colour zoning that correlates directly with variations in chromium content. Emerald occurrences in Afghanistan, Brazil, Russia and Zambia belong to 'schist-type' deposits (Beus and Mineev, 1974; Kiyevlenko *et al.*, 1974; Moroz, 1978; Sliwa and Nguluwe, 1984; Schwarz, 1991; Moroz, 1996). They are located in regions where acidic magmas have penetrated country rocks in the vicinity of basic and ultrabasic rocks, and formed phlogopite-bearing bodies of rock related to distinctive greisens which contain actinolite or tremolite and variable quantities of talc, chlorite, quartz, albite, chromite, ilmenite, magnetite, apatite, tourmaline, fluorite and so on (Moroz, 1978; 1996). Some of these minerals were identified as inclusions in our samples of emeralds from these deposits (Moroz, 1997). In contrast to the emeralds from the 'schist-type' deposits, which have relatively high magnesium and sodium contents, the Colombian and Nigerian emeralds are low in magnesium and sodium. This suggests that the rocks in the vicinity

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Apparatus

The principle characteristics of the luminescence equipment are as follows (*Figure 1*):

Pulsed UV radiation (337 nm) from a nitrogen laser beam of 20 µsec pulse duration focused on the test specimen is used to excite photoluminescence. The emitted light is directed from the specimen to the inlet slit of the monochromator. The luminescence spectra of the emerald samples were recorded in the Laboratoire de Physico-Chimie des Materiaux Luminescents, Lyon Université Claude Bernard, using an Instaspec V detector which combines the advantages of a new intensified CCD camera and an optical microscope. This detector, triggered by the laser, provides quick time-resolved spectra acquisition at a nanometre scale as well as selective separation of overlapping emission spectra from 200 nm up to 900 nm. An optical spectral analyser, based on the detector connected with a PC with INSTASPEC software, was used to produce the luminescence spectra. The method is non-destructive. All investigations were performed at room temperature in the air. The general data collection time is less than 20 µsec.

***Figure 1:** Schematic presentation of the time-resolved photoluminescence equipment.*

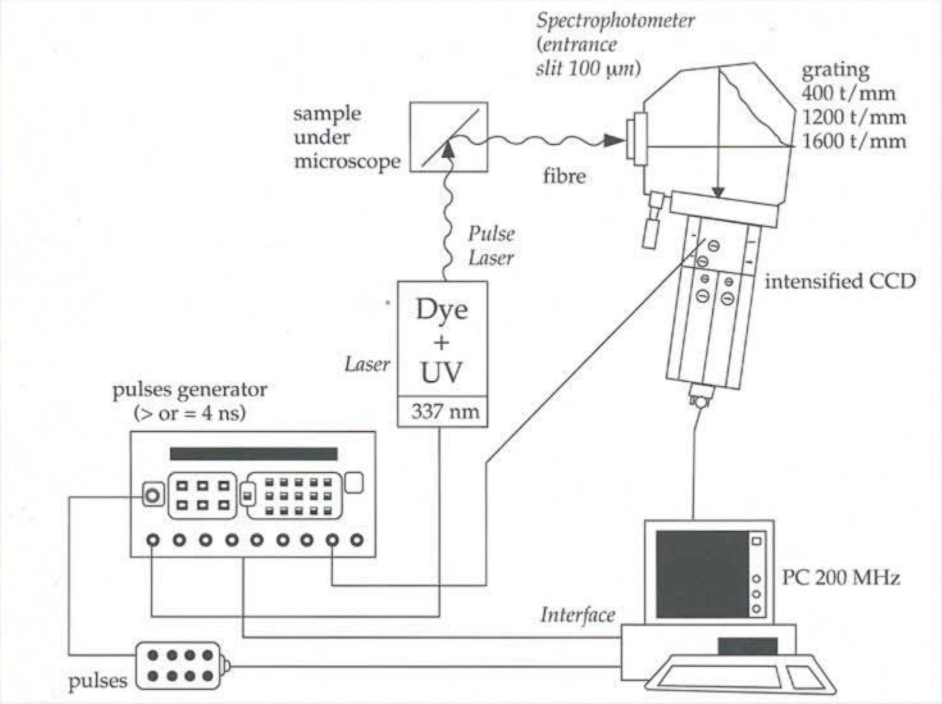

Table I. *Ranges of composition of emeralds from different sources*

Country	*Afghanistan*	*Russia*	*Zambia*	*Brazil*	*Colombia*	*Nigeria*	*Synthetic*
Deposit	*Panjshir*	*Malishevo*	*Kitwe*	*Carnaiba*	*Muzo*	*Jos*	*Hydrothermal*
No. of samples	3	2	3	2	2	3	3
No. of analyses	25	16	15	15	14	17	8
Wt%							
SiO_2	62.09–66.60	61.51–64.40	58.92–65.72	62.21–63.04	62.02–66.50	63.40–67.15	62.93–65.30
Al_2O_3	14.45–17.09	16.89–17.59	13.63–15.26	15.01–16.03	16.79–18.02	17.84–19.15	17.23-18.10
FeO	0.21–1.16	b.d.–0.52	0.47–0.97	0.52–0.85	b.d.–0.25	0.09–0.73	b.d.–0.30
MgO	0.95–1.89	0.60–1.29	1.84–2.34	1.51–2.26	0.7–0.76	b.d.–0.08	0.19–0.46
Na_2O	0.01–1.61	0.62–1.16	0.96–1.65	0.68–1.38	b.d.–0.65	0.10–0.67	0.01–0.58
Cr_2O_3	b.d.–0.16	b.d.–0.30	0.23–0.53	0.02–0.09	b.d.–0.29	b.d.–0.19	0.20–0.88

Note. Compositions were determined by electron probe microanalysis. BeO and H_2O were not measured. Contents of Ca, K, Ti, Mn, V, Cu, Ni, Co, Zn, Cs and S range from below detection to minor amounts less than 0.5% of oxide. b.d. = below detection level.

emerald, but vanadium also may contribute. Some samples from Colombia, Nigeria and Brazil (Carnaiba) have low chromium values, and some may contain up to 0.3% V_2O_3 (*Table I*).

The seven samples were studied by luminescence spectroscopy using a laser-induced (time-resolved) photoluminescence (LPL) technique. Conventional techniques currently used to obtain luminescence spectra of minerals are far from being perfect and are applicable only to a limited number of 'luminescent' gems. Emerald is usually considered a 'non-luminescent' gem (Smith, 1972; Samsonov and Turingue, 1984), but the luminescence intensity generated by the laser is significantly larger than the luminescence excited by conventional light sources and the LPL technique can be applied effectively in most minerals, especially those containing dopant ions. This technique is also attractive as it is non-destructive. In this contribution the preliminary results of the LPL technique carried out on a selected number of the chemically analysed emeralds are discussed and a possible application of the technique to characterize these gemstones is evaluated.

Results

The spectral range 675–679 nm is the most informative for analysing luminescence of the emeralds. The common spectrum of emeralds is a broad band in the 'red' part at 675 to 677 nm due to Cr^{3+}.

The emerald spectra (*Figure 2*) of the six samples of natural emerald and one synthetic hydrothermal emerald are characterized by the dominant role of Cr appearing at room temperature as a broad red band. The emeralds from Afghanistan, Russia and Zambia, which belong to 'schist-type' deposits, show an additional 'bulge' structure in the curves (*Figure 2*, curves 1–3). Apart from the broad red band there is a band at λ max ∼ 678 nm in these samples.

The artificial emerald displays about three times greater intensity of luminescence than that shown by each of the natural emeralds (*Figure 2*, curve 7). The luminescent spectra of the natural emerald specimens from Afghanistan, Russia and Zambia are similar in form if not intensity to the spectrum of the synthetic emerald.

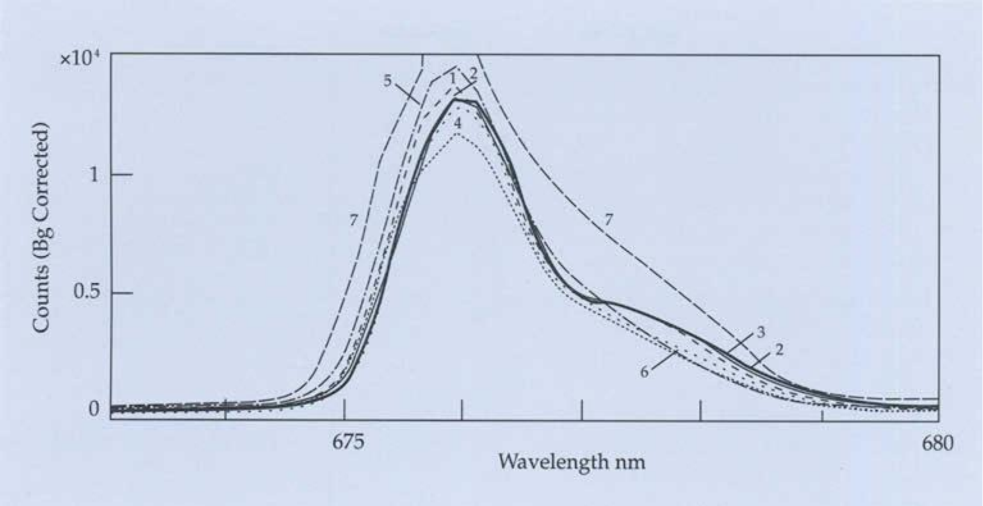

Figure 2: *LPL spectra of seven emeralds (the crystallographic c-axis is oriented parallel to the laser beam) from the following sources: 1 Afghanistan; 2 Russia; 3 Zambia; 4 Brazil; 5 Colombia; 6 Nigeria; 7 synthetic hydrothermal emerald.*

Discussion

The crystal structures of most minerals have defects which are usually present as dislocations or as 'dopant ions' and are, in essence, the luminescence centres (LC) in the visible spectral range. Every centre has its characteristic luminescence bands and lines (Ginzburg, 1985). The intensity of a specific spectral band or line is determined both by the number of centres contained in the mineral and by the concentration of luminescence absorption centres (LCA). Some dopant ions such as Fe^{2+} and Cu^{2+} may completely absorb or quench luminescence.

The most important dopant ion in emerald is Cr^{3+} in octahedral Al^{3+} sites (Wood and Nassau, 1968; Taraschan, 1978; Moroz *et al.*, in press). It is important that the wavelength of the major Cr-line in the red part of the spectrum is calibrated precisely. Along with the Cr^{3+} ions in natural emeralds, the presence of other dopants depends on their chemical nature and on their concentration in the geological and geochemical conditions of mineral formation. Differences in the chemical composition of emerald will show themselves either through the distinctiveness of the red band structure (*Figure 2*) or through other luminescence bands that may be typical for certain occurrences (Mesyats *et al.*, 1992). The stones from Afghanistan and Zambia contain appreciable iron concentrations (*Table I*). According to Platonov *et al.* (1984, p. 60), the colouring of emeralds may be influenced not only by iron, but also by other dopant ions, including 'non-chromophores' – for instance magnesium because they may change the proportions of the chromian polyhedrons in the beryl structure and shift the chromium bands towards longer wavelengths. We report elsewhere (Moroz and Eliezri, 1998) on heightened concentrations of magnesium in emerald samples from Zambia (to 2.34 wt%), Afghanistan (up to 1.73 wt%) and Russia (up to 1.3 wt%); which give rise to 'red shifts' of the Cr^{3+} absorption band in these samples (Moroz *et al.*, in press). Correspondingly, an additional 'bulge' structure appears as a long wavelength shoulder at λ max ≈ 678 nm in the luminescence spectra of the same samples reported here (*Figure 2*, curves 1–3). Such an influence on Cr^{3+} spectral bands position in emeralds may also be exerted by other impurities such as manganese, zinc and titanium when they enter octahedral positions in the emerald structure.

Conclusion

The luminescent spectra of emeralds from different sources are presented. The spectra of emeralds from Afghanistan, Russia and Zambia, which belong to 'schist-type' deposits, are less intense than the spectrum of the synthetic hydrothermally grown emerald and show an additional 'bulge' structure in the luminescence curves.

The investigation of luminescence spectra of emeralds through the laser-induced luminescence (LPL) technique opens up possibilities for obtaining fast and reliable solutions to a range of gemmological problems including gem identification, indication of the source of a gem, and characterization of synthetic gemstones.

Acknowledgements

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Obsidian from Chile with unusual inclusions

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ABSTRACT: A new type of transparent slightly yellowish obsidian from northern Chile is described and its chemical composition is given. The obsidian has a refractive index of 1.540 and a specific gravity of 2.36; it contains three types of distinct well-crystallized inclusions – hexagonal very strongly pleochroic columnar crystals thought to be indialite (high-temperature polymorph of cordierite), elongated striated rods of sillimanite and tiny parallelepipeds of probable feldspar.

Keywords: Chile, inclusions, indialite, obsidian, sillimanite

Introduction

Transparent natural glasses, with the composition of obsidian, are known from many places throughout the world but, unless they are of attractive colour and appearance, are not very interesting for the gemmologist or for the trade. The new material from northern Chile is a nice exception especially due to its wonderful interior with a variety of inclusions.

Description

Three cut stones between 7.13 and 12.90 ct and three rough pieces between 5 and 8 g were bought in Brazil in 1997 and 1998 respectively by the first author and they reputedly came from the Atacama desert in northern Chile (see *Figure 1*). The locality is probably correct, because similar obsidian comes from a nearby region in Peru and has been called 'macusanite' after the regional name (see later). Very little obsidian was found and only a few pieces were transparent enough to be cut according to the owner. One faceted obsidian is completely transparent and two are slightly milky, their colour being slightly yellowish. The refractive index of 1.540 is at the higher limit for natural obsidians, and the specific gravity is 2.36. All three pieces of rough show fine dark layers, rarely curved, indicating fluidal structure. Their surfaces are dull, probably as a result of wind erosion. All stones stay bright during rotation in the polariscope due to the abundant anisotropic inclusions; obsidian itself is isotropic. The chemical

Figure 1: *Faceted obsidians, 17 mm and 14 mm long. Photograph by J. Hyrsl.*

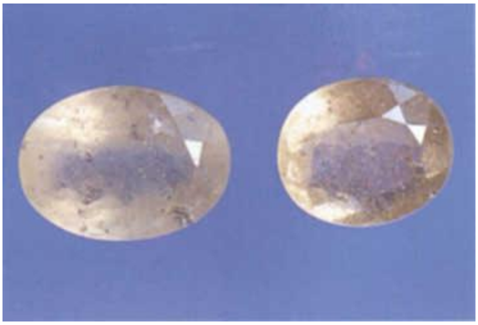

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Table I. *Chemical composition of obsidian from Chile compared with macusanite from Peru, marekanite from Arizona and an indialite inclusion from Chile.*

Wt.%	1. *Obsidian, Chile*	2. *Macusanite, Peru*	3. *Marekanite, USA*	4. *Indialite inclusion*
SiO_2	74.20	77.98	74.64	47.87
TiO_2	0.09	–	0.12	–
Al_2O_3	14.26	13.16	12.48	32.39
CaO	0.33	0.54	2.25	0.05
FeO	0.46	1.34	0.82	7.83
MgO	0.08	–	0.44	7.51
MnO	0.27	–	0.06	1.53
Na_2O	3.82	–	2.46	0.36
K_2O	4.48	6.98	5.66	–
P_2O_5	–	–	0.24	–
SO_3^-	–	–	0.58	–
Cl^-	–	–	0.25	–
Total	97.99	100.00	100.00	97.54
RI	1.540	1.489	1.480	
SG	2.36	2.36	2.33	

NB: Total iron is given as FeO; – means below detection; macusanite analysis from Henn, 1995; marekanite analysis from Holzhey, 1996; obsidian and indialite compositions from microprobe analyses by I. Vavrin.

composition of the Chilean obsidian was studied using an EDX microprobe fitted with a LINK-eXL system. The results are given in *Table I* together with the chemical compositions of two recently described obsidians, marekanite from Arizona (Holzhey, 1996) and 'macusanite' from Peru (Henn, 1995). The analysis shows high silica and alkali contents and confirms an origin connected with rhyolitic volcanism.

Inclusions

All three cut stones contain easily visible inclusions which diminish their transparency (see *Figure 2*). The most striking inclusions are blue columnar hexagonal crystals with very strong pleochroism, deep bluish-violet along *c*-axes and colourless perpendicular to the elongation. They show only two crystallographic forms, the hexagonal prism and basal pinacoid, and the longest crystals reach 1 mm. They show high relief with pale interference colours even in plane polarised light.

The second type of inclusion consists of colourless long rods striated parallel to the *c*-axes. The rarest inclusions are tiny colourless parallelepipeds with monoclinic or triclinic symmetry. All three types of inclusions are anisotropic, have a higher refractive index than obsidian (measured by a Becke line) and show a straight extinction in cross polars.

The blue columnar inclusions were initially interpreted as cordierite from their shape and pleochroism, and this was confirmed by a microprobe analysis which indicated a compositional formula of $(Mg_{1.17}\ Fe_{0.68}\ Mn_{0.14}\ Na_{0.07}\ Ca_{0.01})_{2.07}\ (Al_{3.98}\ Si_{5.00})O_{18}$. Cordierite is very rare as an inclusion, having been reported by Gübelin and Koivula (1992) only as an inclusion in beryl. In this Chilean

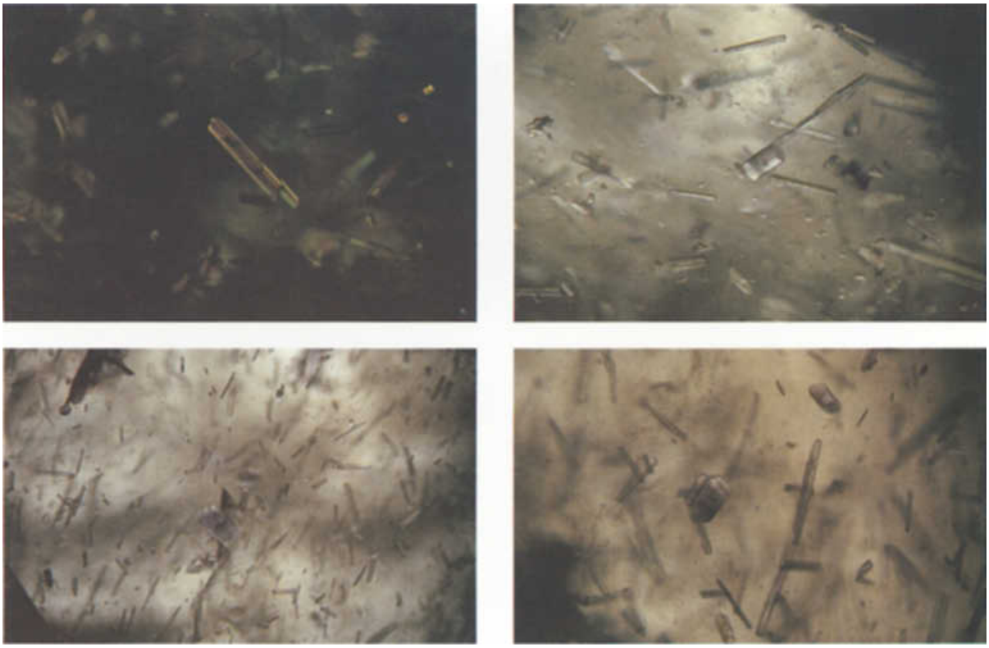

Figure 2: Inclusions in the faceted obsidians (in crossed polarized light). Photographs by J. Hyrsl.

obsidian the inclusions are probably not orthorhombic cordierite, but its high-temperature hexagonal polymorph, indialite. Distinction between these polymorphs would only be possible by X-ray methods.

Although the long rod-like inclusions are very similar to andalusite inclusions in Peruvian obsidian (macusanite) described by Gübelin and Koivula (1992) and Henn (1995), who analysed them chemically, they have been identified as sillimanite by laser Raman methods (Koivula, pers.comm.). Some rods were found to be broken, signifying crystallization in a plastic medium rather than formation from recrystallization of the solid obsidian. Sillimanite is a high-temperature polymorph of Al_2SiO_5 which is consistent with presence of indialite postulated above. The crystal shape of the third kind of inclusion corresponds with feldspar, and tiny feldspars are mentioned as common inclusions in many obsidians (Bouska *et al.*, 1994). Due to its RI of more than 1.54, sanidine and albite can be excluded as possibilities, but it could be a basic plagioclase.

Acknowledgements

We would like to thank Dr I. Vavrin at the Czech Geological Survey, Prague, for microprobe analysis, and J.I. Koivula at the GIA, Carlsbad, U.S.A., for identification of inclusions in the obsidian.

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Johachidolite – a new gem

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ABSTRACT: A pale yellow mixed-cut gemstone of 14.02 ct has been identified as the rare borate, johachidolite ($CaAlB_3O_7$) and is the first recorded gem of this species. Its gemmological properties are described and are broadly consistent with the data published for the original mineral from Korea except that the birefringence of the gem (0.007) is smaller and its fluorescent properties may differ. The Raman spectrum of johachidolite is presented.

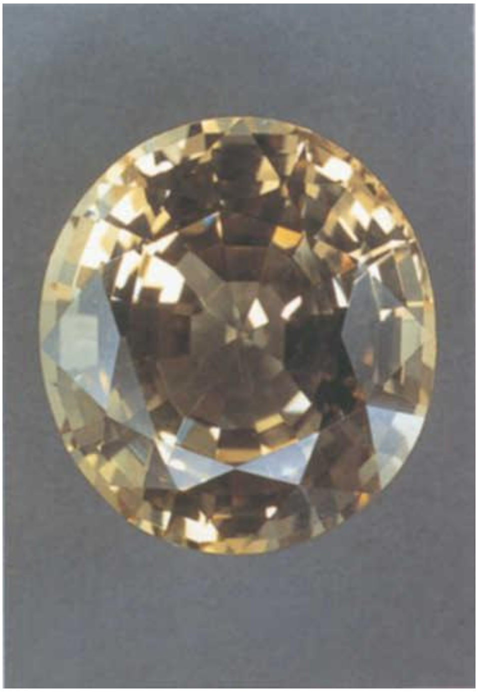
Keywords: borate, johachidolite, new gem variety, Raman spectrum

Introduction

On the advice of C.R. Cavey, the owner of a pale yellow cut gemstone came to the GAGTL in Spring 1998 to have the stone identified (*Figure 1*). The results from RI and SG measurements and from spectrum, fluorescence and filter examination were inconclusive and an electron probe microanalysis (EPMA) at the Natural History Museum was suggested.

The analysis at the Museum indicated the presence of Ca and Al but significantly the total was low, which suggested the presence of an element or elements of low atomic number (less than sodium). The most promising line of enquiry was then investigation by X-ray diffraction and since this meant scraping a minute amount of powder from the girdle of the stone, permission had to be obtained from the owner. This was duly granted; an X-ray powder diffraction pattern was then obtained and this proved to be a clear and convincing match with the standard pattern of the rare borate mineral, johachidolite (Powder Diffraction File number 29-280).

Figure 1: *Johachidolite, 14.02 ct. Photograph by F. Greenaway.*



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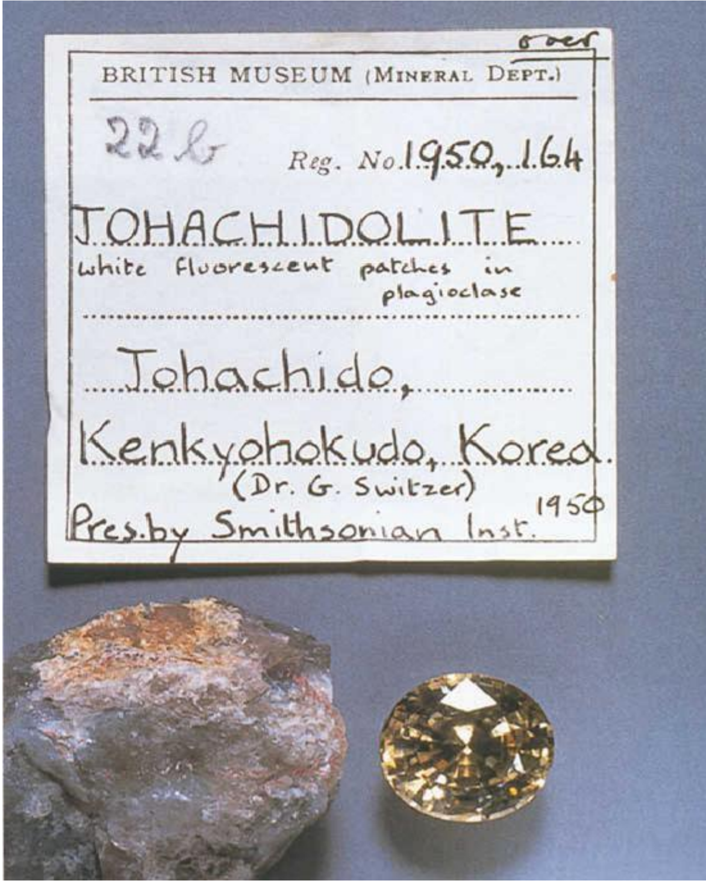

Figure 2: Johachidolite occurs as tiny grains in a small vein crossing the centre of the specimen which was presented to the Natural History Museum by Dr G. Switzer of the Smithsonian Institution in 1950. Details of the specimen are on the museum label and the gem johachidolite is shown for comparison. Photograph by F. Greenaway.

Johachidolite – the mineral

Johachidolite was first described by Iwase and Saito (1942) from the type locality in the Johachido District, Kisshu County, Kankyo Hodu Prefecture, North Korea (*Figure 2*). Moore and Araki (1972) solved the structure of a crystal (in the National Museum of Natural History, Washington) from the same locality and this led them to assign a formula of $CaAlB_3O_7$ to johachidolite, i.e. without the components H, F and Na of the original formula of Iwase and Saito (1942) which Moore and Araki (1972) attributed to impurities. Aristarain and Erd (1977) reviewed the history of investigation into johachidolite, further refined the data on its crystallographic properties and, with the approval of the IMA Commission on New Minerals and Mineral Names, confirmed its composition as $CaAlB_3O_7$. Until now, the only reported occurrence of johachidolite is in North Korea where it is found in nepheline veins cutting metamorphosed limestone. In specimen 105479 in the National Museum of Natural History (Washington), johachidolite is associated with scapolite, diopside, albite and phlogopite (in addition to nepheline) as equant anhedral grains up to 1 mm across. It is colourless and transparent or whitish and semi-transparent; under short-wave ultraviolet radiation it shows pale-blue fluorescence and weak phosphorescence.

The rock specimen shown in *Figure 2* was presented to the British Museum (Natural History) by Dr G. Switzer of the Smithsonian Institution, Washington, and is presumably comparable with the material originally examined. Recent electron microprobe work on this specimen has confirmed the presence of a vein of small grains of johachidolite in a matrix of feldspathoid, plagioclase feldspar and other minerals.

Properties of gem-quality johachidolite

The gem johachidolite has a modified brilliant-cut crown and a step-cut pavilion, measuring approximately 15.83 mm (long diameter) by 14.36 mm (short diameter) by 8.99 mm (depth), and weighing 14.02 ct. It is pale yellow with no detectable pleochroism and displays strong whitish-blue fluorescence under long-wave ultraviolet, weak blue fluorescence under short wave, and no phosphorescence. Under the Chelsea Colour Filter it appears yellowish-green.

Refractive index readings taken from the table facet on Rayner Dialdex and Kruss refractometers give the following results: α 1.717, β 1.720 γ 1.724, giving a birefringence of 0.007. Specific gravity measurements were carried out using the hydrostatic method in demineralized water and yielded a mean SG of 3.45.

Examination of the stone through a hand-held spectroscope revealed no

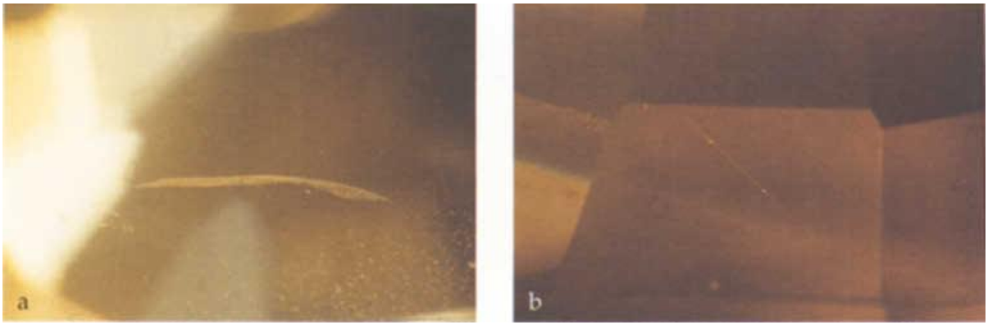

Figure 3: (a) One of two curved planes showing dense pattern of tubular cavities, just beneath the table facet.
(b) Needle inclusion angled into the stone from a pavilion facet, with reflecting crystals or discs along the length (about 2 mm). Photographs by R.R. Harding.

distinctive absorption or fluorescence bands; a UV-visible spectrum of the johachidolite from the Pye Unicam PU8800 spectrophotometer showed complete absorption at wavelengths shorter than 350 nm, a shoulder at 380 nm and transmission with no significant absorption bands up to 750 nm.

Under 10x magnification, two feathers are visible just under the table (see *Figure 3a*) and two needles occur deep in the pavilion. Under the higher magnifications of a microscope, more needles are visible and some are accompanied by a tiny disc or tabular crystal at a high angle to the needle (*Figure 3b*).

Some properties of johachidolite reported by Aristarain and Erd (1977) are compared with results obtained from the gem in *Table I*. Two differences worth noting are the birefringence values and the possible differences in behaviour under ultraviolet radiation. The measured birefringence of the gem johachidolite is half that reported by both Iwase and Saito (1942) and Aristarain and Erd (1977). In the paper by Aristarain and Erd (1977) it is not clear if the mineral they tested fluoresced under long-wave ultraviolet; the gem johachidolite is strongly fluorescent under long-wave ultraviolet, shows weak

		1	2
Refractive indices	α	1.712	1.717
	β	1.717	1.720
	γ	1.726	1.724
Birefringence		0.014	0.007
Optic sign		positive	positive
Specific gravity		3.37 (meas.) 3.43 (calc.)	3.45
Colour		colourless	pale yellow
Fluorescence:	LWUV	not reported	strong whitish-blue
	SWUV	pale blue	weak blue
Phosphorescence		weak	none

1. from Aristarain and Erd (1977)
2. this work

Table I. *Properties of johachidolite derived from 1, the mineral from North Korea, and 2, the gem*

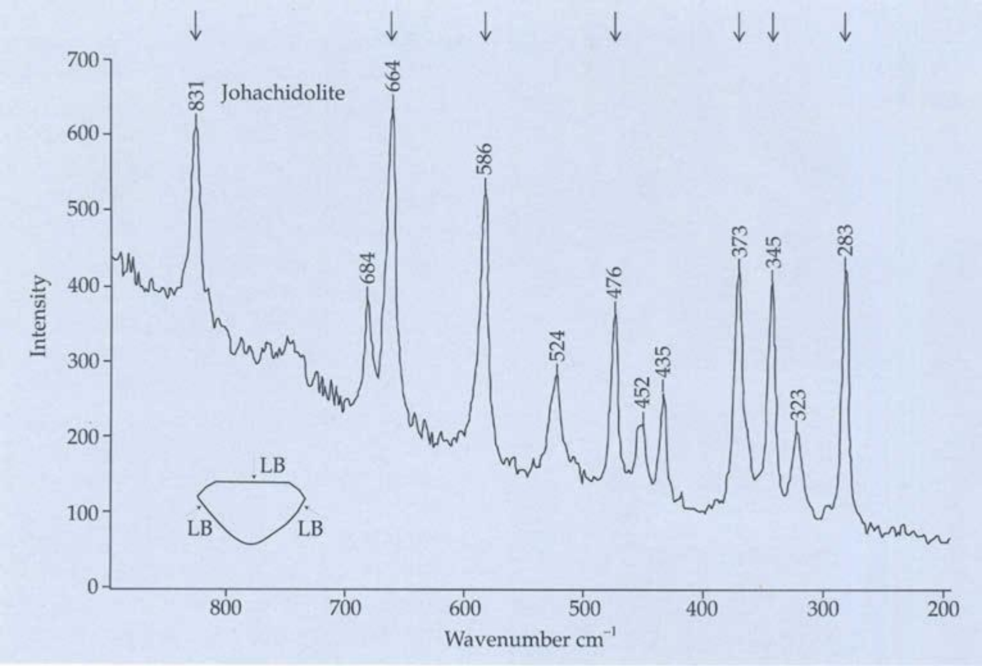

Figure 4: ***Raman spectrum of johachidolite; table facet*** *perpendicular to the laser beam. Sketch of stone shows three directions of laser beam (LB) used to obtain spectra. The spectra from all three directions contained the seven peaks arrowed.*

fluorescence in SWUV (in agreement with that of the mineral), and shows no phosphorescence – unlike the mineral.

Raman spectra were obtained using a Renishaw micro-Raman 1000 system coupled to an Ar ion laser (514 nm) and a petrological microscope. The system was operated in confocal mode with the laser beam focused about 50 μm below the surface of the stone and operated at full power (20 mW). Scanning times of 60 seconds were used for each of three spectra obtained from different orientations of the crystal. Characteristic Raman shifts in wavenumbers (cm^{-1}) are shown in *Figure 4*.

The spectrum with the most peaks was obtained with the laser beam perpendicular to the table facet. Spectra obtained from pavilion facets near the girdle at each end of the stone contained fewer peaks, but all spectra contained the seven peaks arrowed in *Figure 4*, i.e. at 831, 664, 586, 476, 373, 345 and 283 cm^{-1}, all ± 2 cm^{-1}.

Discussion

The appearance of a 14 ct cut gemstone of a species only known in nature as colourless transparent grains less than 1 mm across was a considerable surprise, and immediately led to questions about its origin; in particular initially as to whether it was natural or synthetic.

The stone was bought in Myanmar as a natural gem but the species is so rare that the possibility that it had been introduced into the gem trade after having been grown in a laboratory had to be investigated. Natural and synthetic substances containing boron were recently described in an encyclopaedic volume edited by Grew and Anovitz and published by the Mineralogical Society of America (1996). In this volume, Werding and Schreyer (1996) set out to present existing data on experimental studies of borosilicates and selected borates and made no reference to johachidolite, presumably reflecting the absence of any significant work. Anovitz and Hemingway (1996) also presented a

Figure 5: Johachidolite (centre right, 14.02 ct) with two sinhalites (centre left, brown, 9.84 ct; and top right, yellow, 6.25 ct) and two danburites (bottom right, table cut, 18.85 ct; and top left, round, 13.10 ct). The danburites are from Mogok, Myanmar, and the sinhalites are probably from Sri Lanka. Photograph by F. Greenaway.

summary (in their Table 6) listing references to known experimental data for minerals containing boron, and although johachidolite is in the list, the adjacent column for references to any experimental work on johachidolite is blank.

Crystal growing activities are extensive and varied in the former USSR, Thailand, the P.R. of China and other countries. So searches were made for references to johachidolite and to CaAl borates in the indexes of the *Journal of Crystal Growth* and of *Chemical Abstracts* from 1990–97. These also proved fruitless, and provisionally one must conclude that CaAl borate is either of little interest to the materials researchers or, if it is of interest, the results are not being published. Anyway, no source for synthetic johachidolite was indicated.

If the stone is of natural origin and possible sources are being considered, it might be useful to compare it with other borates. Gem-quality examples of natural borates include hambergite [$Be_2(OH, F)BO_3$], rhodizite [$(K, Cs)Al_4Be_4(B, Be)_{12}O_{28}$] and jeremejevite [$Al_6B_5O_{15}(OH, F)_3$], but the best known is sinhalite [$MgAlBO_4$] (see *Figure 5*).

Sinhalite of gem quality comes largely if not exclusively from Sri Lanka, but one crystal (rough) was found in Burma and brought to London by A.C.D. Pain (Payne, 1958). Non-gem-quality sinhalite has been found in both Warren County, New York (Schaller and Hildebrand, 1955), and Handeni District, Tanzania (Bowden *et al.*, 1969); both occurrences are in metamorphosed limestones, geological contexts very similar to that described for johachidolite. The occurrence of the borosilicates tourmaline, kornerupine and danburite in or near the Mogok gem gravels (*Figure 5*) together with the admittedly rare occurrence of sinhalite suggests that other borates may also be present at Mogok. In this context, painite, the most famous rare mineral of all from Burma, has a small content of boron in an essentially aluminate structure. This area therefore could be a possible source of natural gem johachidolite.

In a historical context, the present investigation into johachidolite has many similarities with the discovery of a borate, already cut as a gem, some fifty years ago when collaboration between Anderson and Payne of the Gem Testing Laboratory and Claringbull and Hey of the Natural History Museum led to the recognition and description of the new mineral sinhalite (Claringbull and Hey, 1952).

Conclusion

This is the first reported occurrence of gem-quality johachidolite. No evidence of any sources of synthetic CaAl borates could be found in current literature and the stone is probably natural, with a possible source in the Mogok area of Myanmar.

Acknowledgements

We would like to thank F. Greenaway for photographs of the gems and Museum specimen, and J. Spratt for the electron microprobe analyses. A.I. Castro, S.J. Kennedy and T. Lodge at the GAGTL Gem Testing Laboratory are thanked for their work on the gem, and M.J. O'Donoghue and Dr Chen Changkang (Clarendon Laboratory, Oxford) provided useful advice in searching the literature. Finally we would like to thank the owner of the stone for permission to examine it in detail.

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Abstracts

Diamonds

Gems and Minerals

Synthetics and Simulants

Diamonds

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **34**(1), 1998, 50–62, 23 coloured illus.

Diamond crystals in various shapes from Russia and China were on display at the 1998 Tucson Trade Fair. J.J.

Zur Vulkanologie von diamantführenden Kimberlit- und Lamproit-Diatremen.

V. Lorenz. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, **47**(1), 1998, 5–30, 11 photographs, 2 diagrams, bibl.

The vulcanology of diamondiferous kimberlite and lamproite diatremes and dykes is considered in the light of a detailed model of phreatomagmatic formation of maar-diatreme volcanoes. Maars and the underlying diatremes form when magma rises in dykes and contacts groundwater resulting in thermohydraulic explosions. The magma with the surrounding country rocks is fragmented, the groundwater vaporized and then, because of the expansion of the steam, the fragmented materials are ejected at the surface and cause the collapse of the surrounding rocks; at the earth's surface it forms a collapse crater, a maar. The article explains the hydrogeological conditions necessary for the formation of kimberlite and lamproite diatremes. E.S.

The rise to prominence of the modern diamond cutting industry in India.

M. Sevdermish, A.R. Miciak and A.A. Levinson. *Gems & Gemology*, **34**(1), 1998, 4–23, 15 illus. in colour and 2 tables.

Over the last thirty to forty years India has become one of the major centres for the cutting of diamonds, and is the sixth most important diamond market in the world. India specializes in cutting low quality small diamonds often less than 7 points and these are mostly exported to foreign jewellery manufacturers; 70 per cent by weight and 35 per cent (wholesale) value of diamonds in the world are cut there. From the late sixties the market has expanded by 82 fold by polished weight and 249 fold by polished (wholesale) value. This expansion has been due to the exploitation of the large diamond deposits in Russia, Botswana and Australia, especially the Argyle mine in Western Australia, which produces large quantities of small low quality material. In the future India will have difficulties maintaining its position as the largest supplier of polished stones in the world due to the diminishing availability of small stones. There are no new major mines in an advanced stage of development that could produce the volume of gem rough needed to replace the Argyle mine when it becomes exhausted within the next six years. The implications for India are of unemployment but this might be alleviated by the cutting and polishing of synthetic diamonds. J.J.

Diamond prospecting in Finland – a review.

M. Tyni. In *Mineral Deposits*, ed. H. Papunen (Balkema, Rotterdam), 1997, 789–91.

To date, 24 kimberlites and related deposits have been discovered in Finland, of which 16 are diamondiferous. R.A.H.

[Examination on colouring of diamonds by proton beam irradiation.]
(Japanese with English abstract.)

I. Umeda and K. Iida. *Journal of the Gemmological Society of Japan*, **21**, 1996, 15–19.

A 2.378 ct colourless diamond was first irradiated by high energy electron beam using a linear accelerator, which produced homogeneous green colour, and subsequently annealed. The stone became homogeneously yellow, which was then irradiated by 18 MeV proton beam using a cyclotron to the culet through a ϕ 3 mm metallic collimeter. The stone became bi-colour; surrounding the culet is green, the table and the girdle are yellow. The stone exhibits an umbrella mark around the culet, whereas green diamonds produced by irradiation by high energy electron beam do not show such a mark. I.S.

Abstractors

R.A. Howie	R.A.H.	M. O'Donoghue	M.O'D.	I. Sunagawa	I.S.
J. Johnson	J.J.	E. Stern	E.S.		

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

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Gems and Minerals

Iridescent andradite garnet from the Sierra Madre Mountains, Sonora, Mexico.

M.A. Badar and M. Akizuki. *Neues Jahrbuch für Mineralogie Monatschefte*, **12**, 1998, 529–39.

Iridescence in andradite from the Sierra Madre Mountains, Sonora, Mexico, was examined by optical microscopy, electron microprobe analysis, back-scattered electron image and single-crystal X-ray diffraction. The iridescence is caused by cyclically stratified growth lamellae in the {211} and {110} sectors with chemical content And_{79}–And_{94}. A marked contrast between adjacent lamellae arises from differing refractive indices and gives a source of iridescence. The garnet was found to contain isotropic and anisotropic (triclinic) zones. M.O'D.

A corundum-quartz assemblage in altered volcanic rocks, Bond Range, Tasmania.

R.S. Bottrill. *Mineralogical Magazine*, 62(3), 1998, 325–32.

This unusual assemblage occurs in a hydrothermally altered Cambrian quartz porphyry; the quartz and corundum are in mutual contact, in association with andalusite, pyrophyllite, diaspore, etc. This metastable assemblage apparently resulted from advanced argillic alteration at moderate *T* and *P*, followed by rapid depressurization accompanying boiling of hydrothermal granite-derived fluids. This corundum appears to be unrelated to the sapphires found in placer deposits in Tasmania. R.A.H.

A re-examination of the turquoise group: the mineral aheylite, phanerite (redefined), turquoise and coeruleolactite.

E.E. Foord and J.E. Taggart, Jr. *Mineralogical Magazine*, 62(1), 1998, 91–111.

The turquoise group has the general formula $A_{0-1}B_6(PO_4)_{4-x}(PO_3OH)_x(OH)_8\cdot 4H_2O$, where $x = 0$–2, and has six members: planerite, turquoise, faustite, aheylite, chalcosiderite and an unnamed Fe^{2+}–Fe^{3+} analogue. The existence of 'coeruleolactite' is doubtful; planerite is revalidated as a species characterized by a dominant *A*-site vacancy; aheylite is established as a new member of the group characterized by having Fe^{2+} dominant in the *A*-site. Chemical analyses of 15 pure samples of microcrystalline planerite, turquoise and aheylite show that $\leq$ two of the (PO_4) groups are protonated (PO_3OH) in planerite; complete solid solution exists between planerite and turquoise. Most samples of 'turquoise' are cation-deficient or are planerite. There are four molecules of water. Planerite, ideally $\square Al_6(PO_4)_2(PO_3OH)_2(OH)_8\cdot 4H_2O$, is white, pale blue or pale green, and occurs as mamillary botryoidal crusts as much as several mm thick; it may also occur massive, microcrystalline, typically with crystals 2–4 µm, lustre chalky to earthy, H 5, D 2.68 g/cm³, mean RI ~ 1.60. Aheylite, ideally $Fe^{2+}Al_6(PO_4)_4(OH)_8\cdot 4H_2O$, is pale blue or green, and occurs as isolated crystals and hemispherical aggregate of crystals that average 3 µm in maximum dimension; porcellanous-subvitreous lustre, mean RI ~ 1.63, biaxial (+), D 2.84 g/cm³. R.A.H.

Feueropal von Opal Butte, Oregon, USA.

G. Holzhey. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, **46**, 1997, 161–8, 10 photographs, 3 tables, 1 graph, bibl.

This occurrence has been known as Peter's Butte in the Blue Mountains north east of Oregon since 1889, but has only been worked intensively since 1986. The specimens occur within concretion-like spherical masses, which carry fillings of fire and other opals. The fire opal is an arrangement of silica spheres of different diameter up to 250 nm with a high calcium content. RI 1.431, SG 2.05. Some inclusions seem to be of organic (vegetable?) matter. E.S.

[Study on the mechanism of formation of 'circle pearls' – an approach from the nacreous structure.] (Japanese with English abstract.)

E. Ito. *Journal of the Gemmological Society of Japan*, **21**, 1996, 33–44.

Pearls showing circumferential ditches or depressions are called circle pearls, and are often encountered among cultured black pearls. Optical and SEM observations were made on the internal structures of the nacreous layer of circle pearls of various types, as well as flat pearls formed on flat shape nucleus, twin pearls formed on two nuclei. Sectional colour distribution, stage of initiation of circles, deviation of circles from symmetry, the degree of continuation of aragonite layers, thickness and number of aragonite layers at depressed and elevated portions, comparison of nacreous structures between twin and flat pearls, and circle twin and flat pearls were investigated. Two possible mechanisms are proposed for the origin of circle pearls; one assumes wrinkles formed on pearl sac due to illness of mother pearls or external stress, and the other assumes rotation of the nucleus in the pearl sac. I.S.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **34**(1), 1998, 50—62, 23 illus. in colour.

Chiastolite spheres from China were on offer at the 1998 Tucson Trade Fair. Coral with a blue sheen and horn like appearance has been found in the ocean of Alaska at depths of 300 m or more. A faceted corundum, reportedly from Vietnam, gave rise to a nomenclature problem as it was ruby one end and blue sapphire at the other end. Samples of emerald from a new deposit in Tocantins State, Brazil, were darker than most Colombian emeralds and showed evidence of clarity enhancement. Yellowish to reddish-orange spessartine garnets from northern Madagascar are of a large size and unusual cuts. A new deposit from Northern Madagascar is producing yellowish-brown sphenes, with some crystals up to 29 ct, much of the material possibly contains chromium and is red when viewed through a Chelsea filter. Spinel from the Luc Yen area in Vietnam is now available and is mined as a bi-product of ruby mining. Parti-coloured faceted liddicoatite tourmaline from Madagascar has limited use in jewellery as they tend to have a muddy appearance in the finished stone. Transparent and uniform coloured green tourmalines from Namibia were on show. J.J.

Diopside inclusions in Arizona pyrope identified by Raman analysis.

J.I. Koivula. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, 47(1), 1998, 39–44, 4 photographs, 2 graphs, bibl.

The author describes the identification of bright green diopside inclusions in pyrope garnets from Arizona by means of Raman laser microspectrometry. The Raman spectrum of a completely enclosed inclusion was compared to some obtained from surface-exposed inclusions in both pyrope and diamonds; the latter were previously identified by X-ray powder diffraction and served as a chrome diopside standard. E.S.

Die dicken Brunner aus St Egidien.

W. Leonhardt. *Mineralien Welt*, 8(5), 1997, 28–31, 2 maps.

Fine ornamental agates are described from St Egidien, Saxony, Germany. Details of the occurrence are given. M.O'D.

Dendritenachat: 'kristalline Pflanzenwelt'.

W. Lergier. *Lapis*, 22(11), 1997, 25–8, illus. in colour.

Illustrations and discussion of notable examples, mostly from Minas Gerais, Brazil, of dendritic agate. M.O'D.

Teaching gemology at the undergraduate university level.

A.A. Levinson. *Mineralogical Association of Canada Newsletter*, 57, 4–12, 1998.

University courses in gemmology held at the undergraduate level are thought to benefit both gemmology students and geology/mineralogy students who are able to share the classes. Canadian experience in more than one institution is outlined. M.O'D.

Vergleichende Untersuchungen an Rhodolithen verschiedener Provenienz.

Th. Lind, U. Henn and C.C. Milisenda. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, 47(1), 1998, 53–9, 4 photographs, 2 graphs, 2 tables, bibl.

The examined rhodolites came from Tanzania, Orissa (India), Sri Lanka, Malawi, Brazil and Madagascar and could be subdivided into three types on the basis of their visible absorption spectra. Type 1 was found only seldom, with the exception of the find in Siali in Orissa; most rhodolite belonged to type 2 (landaban); type 3 came mainly from Tanzania. All types have typical mineral inclusions such as zircon, apatite and rutile. The origin of the stones could not be determined by microscopic examination. E.S.

Texture and structure of opal-CT and opal-C in volcanic rocks.

T. Magase and M. Akizuki. *Canadian Mineralogist*, **35(4)**, 1997, 947–58.

For opal in volcanic rocks from the Hosaka and Akase opal mines in Japan, textures of opal-CT are optically classified into anisotropic columnar and isotropic massive (opal-CT$_M$) types; both textures consist of thin and platy crystals showing two wide {101} faces of low cristobalite. Images from HRTEM show that the cristobalite structure is the fundamental component of volcanic-type opal-CT, and that many stacking faults occur at random in the structure. Columns are produced by parallel growth of platy crystals; opal-CT$_M$ and lepispheres consist of criss-crossing aggregates of blades; each blade consists of ~ parallel aggregates of platy crystals. The variation of d_{101} values with textural and structural changes of the opal-CT was measured by an XRD powder method; with decreasing d_{101}, highly ordered cristobalite domains develop surrounding the domains of disordered cristobalite. This considerable difference in degree of order of stacking between the two types of domain implies changes in the growth process of the crystal. R.A.H.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure. *Gems & Gemology*, 34(1), 1998, 44–9, 12 illus. in colour.

Colombian emeralds with three-phase inclusions were found with a solid inclusion of triangular shape and not cubic; this is possibly due to space restrictions during formation. The triangular platinum inclusions seen in synthetic emeralds should not be confused with natural inclusions. A large greenish-blue fibrous rough and a cabochon of the same colour were found to be hemimorphite, the first time this material had been seen at the GIA Lab since 1971. A Raman Imaging Microscope System was used to identify some small crystal inclusions, which reached the surface of a green cabochon jadeite, as zircon. A cabochon-cut yellow cat's-eye was found to be opal with the chatoyancy caused by fine and coarse needles, possibly pseudomorphous after goethite. Two reddish-brown scapolites from Tanzania both exhibited chatoyancy and one also had six additional weaker rays. A rare bluish-green oval brilliant-cut topaz was found to be natural, the stone had marked colour zoning and displayed no radioactivity. Spherical blue clouds surrounding dark blue crystal inclusions were seen in sapphires that have been heat-treated to a temperature approaching the melting point of sapphires. J.J.

The color of minerals.

N.V. Putivtseva and E.V. Pryakhina. *World of Stones*, **12**, 1997, 34–7, illus. in colour.

Drawing from exhibits forming part of an exhibition held at the Mineralogical Museum of the Moscow State Geological Prospecting Academy, notes on mineral coloration are summarized with a number of examples, some of ornamental species. M.O'D.

Grosser Rauchquarzfund am Piz Giuf, Bündner Oberland.

V. Sialm-Bossard. *Lapis*, **23**(1), 1998, 42–5, illus. in colour.

Exceptional crystals of smoky quartz have been recovered in a cavity at about 2800 m on Piz Giuf in the

Bündner Oberland of eastern Switzerland. Specimens up to 1.2 m have been found as crystal groups and some of the finest examples are displayed at the Museum 'La Truaisch', CH-7188 Sedrun. M.O'D.

La géologie des gisements de saphirs.

C. Simonet. *Revue de gemmologie*, **132**, 1997, 21–3.

A short study of sapphire occurrence submitted for the Diploma of the Université de Gemmologie, Nantes, France. Sedimentary, volcanic and metamorphic types of deposit are considered. M.O'D.

Imperfections and inhomogeneities in single crystals as a basis to distinguish natural from synthetic gemstones.

I. Sunagawa. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, **47**(1), 1998, 45–52, 3 diagrams, bibl.

The author discusses physical imperfections and chemical inhomogeneities in single crystal gemstones. They are a record of growth and post-growth history of the stone and show the differences between natural and synthetic stones as well as differences in origin. Thus they serve as diagnostic features. Methods of application of these features are briefly explained. E.S.

Tessiner Rauchquarze: die grössten Kristalle vom Cavagnoli-Gletscher.

S. Weiss. *Lapis*, **23**(2), 1998, 36–7, illus. in colour.

Very fine large crystals of smoky quartz are reported from the Cavagnoli glacier, Ticino, Switzerland. The largest crystal found measures 60 x 75 cm in thickness and length, weighing 114 kg. M.O'D.

Cultured pearls from Indonesia.

P.C. Zwaan. *Gemmologie (Zeitschrift der Deutschen Gemmologischen Gesellschaft)*, 47(1), 1998, 31–8, 8photographs, 2 maps, 2 tables, bibl.

Cultured pearls from different localities in Indonesia, produced by *Pinctada maxima*, were examined. Dobo pearls come from the Aru Islands; there is, however, now a pearling project by an Australian company near Kupang in West Timor; this is supposed to reach a maximum capacity by the year 2000 of 200–400 thousand pearls. Dobo pearls are silvery white and have a nacre thickness of 1.0 to 2.0 mm, they are rarely round, often egg- or pear-shaped. Lambok Mabe pearls have a hemi-spherical nucleus consisting of artificial resin; the nacre has a thickness of 0.4–1.1 mm. Kuta pearls are blister pearls with a nucleus of artificial resin plus a plug of an echinoid; they are round, button-shaped and resemble imitation pearls because of their sheen. It is not known where these are grown. E.S.

Synthetics and Simulants

Russian synthetic pink quartz.

V.S. Balitsky, I.B. Makhina, V.I. Prygov, A.A. Mar'in, A.G. Emel'chenko, E. Fritsch, S.F. McClure, Lu Taijing, D. DeGhionno, J.I. Koivula and J.E. Shigley. *Gems & Gemology*, **34**(1), 1998, 34–43, 16 illus. in colour.

The first reported production of transparent synthetic pink quartz was in 1992 manufactured by Russian laboratories, and the first material was commercially available in 1994. It is currently produced near Moscow under the name of 'Flamingo quartz'. The synthetic material is grown in a solution containing ammonium fluoride (NH_4F) and silica at temperatures between 220°C and 350°C. The pink colour is produced by subsequent irradiation and heating together with a concentration of phosporus in the fluoride solution. Although natural massive rose quartz is relatively common, natural transparent single crystal pink quartz is very uncommon and only found in Madagascar and Brazil. The authors, both from Russia and the GIA, examined synthetic material and natural quartz from Brazil. Although they found many similarities between the stones, advanced testing techniques helped to distinguish the natural quartz from the synthetic. In synthetic material the colour banding was found to be always parallel to the basal faces and often uneven, while in the natural stones the banding was oblique to the axis with feathery edges, which was not seen in the synthetic stones. All synthetic material lacked twinning. The infrared absorption spectrum of the synthetic quartz contained a diagnostic band at 3420 cm^{-1} and weak bands at 3500 and 3650 cm^{-1}. J.J.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **34**(1), 1998, 50–62, 23 illus. in colour.

A new synthetic amethyst from China has been grown on dome-shaped seed crystals. They were all deep purple and showed natural quartz faces, but FTIR spectroscopy showed a peak at 3545 cm^{-1} in the infrared spectrum, which confirmed they were synthetic. Glass cabochons and beads to imitate agate are now being made. A brown and nearly opaque faceted synthetic moissanite originated from a new source in Russia, which is producing material using a vapour deposition technique. Synthetic bi-coloured amethyst and citrine, which resembles ametrine from Bolivia is now being manufactured in Russia. J.J.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure. *Gems & Gemology*, 34(1), 1998, 44–9, 12 illus. in colour.

Repolished heat-treated rubies have been seen recently with surface pits that have been partially repolished and showed semi-circular grooves. When viewed under magnification an orangey-pink cabochon was found to be an assemblage of a plastic top and an aragonite base. J.J.

BOOK REVIEWS

Recovery and refining of precious metals. [Third edition]

C. W. Ammen, 1997. Chapman and Hall, New York. pp xi, 441, softcover. £37.00. ISBN 0 412 72060 4.

The first edition has become known as the 'Precious metal bible' and anyone connected with the manufacture, testing or evaluation of jewellery should read this text which approximates to a metal testing manual with copious explanations of how the testing results are obtained. The book opens with a very useful section on general chemistry before proceeding to the chemistry of the precious (and other) metals. Recovery and refining methods are described at considerable length, and the whole text is presented lucidly in such a way that the reader can assimilate a good deal of serious metallurgy and at the same time find out how to regard the precious metals that may turn up needing to be tested. Appendices give a list of the naturally-occurring chemical elements with their atomic weights and numbers, a list of some of the metallic salts and their contents and one of the best glossaries I have seen for some time.

While intended for a wide readership, students beginning a course in metallurgy in particular will find many uses for the book and the price is very reasonable for so comprehensive a coverage of the field. M.O'D.

Handbook of mineralogy. Vol III: halides, hydroxides, oxides.

J.W. Anthony, R.A. Bideaux, K.W. Bladh and M.C. Nichols, 1997. Mineral Data Publishing, Tucson. pp ix, 628 Hardcover. Price on application. ISBN 0 9622097 2 4.

Three down and two to go! I refer of course to the progress of this magnificent series which gives single page coverage to each validated mineral species and which has been exceptionally well-received by the mineralogical community. The first volume covered elements, sulphides, sulphosalts and some less important classes and the second, in two volumes gave (at last!) an up-to-date survey of the silicates. The remaining two volumes are scheduled to cover arsenates, phosphates, uranates and vanadates (one volume) and borates, carbonates, sulphates and small groups which have not been dealt with already.

Gemmologists will find the present volume interesting for the information given on oxides alone. A complete set of the *Handbook* should last a long time even though new species are arriving at the rate of around one a week. M.O'D.

Führer durch das Deutsche Edelsteinmuseum.

H. Bank, 1996. The Museum, Idar-Oberstein, Germany. pp 128, illustrated in colour, softcover. Price on application.

Beautifully produced and illustrated guide to the 'new' [i.e., relocated] Deutsche Edelsteinmuseum at Idar-Oberstein. Much of the text and illustrative matter is close to that used for a description of the museum published in *Der Aufschluss* fairly recently and an advertisement for the publishers of Aufschluss appears on the back cover. However, an insert gives a plan of the new building and arrangement of its exhibits and this is dated 1996.

After a history of the museum and of the gemstone industry in the Idar-Oberstein area, the book goes on to describe the nature and testing of gem specimens before covering the major species in chemical order, the customary arrangement for a cabinet of minerals. Both major and uncommon species are introduced and a great many are illustrated by top class colour photographs. Organic and man-made materials are reviewed before accounts of gemstone fashioning, naming and use. There is a very short bibliography, a table of synthetic materials and growers with the date of their first appearance and a table of recently discovered gem species and varieties. An index concludes the book. M.O'D.

Gem minerals of Victoria.

W. D. Birch and D. A. Henry, 1997. (Mineralogical Society of Victoria: Special Publication No. 4), Melbourne. pp 121. A$29.95 (plus A$14.00 economy air post). ISBN 0 959 4573 3 X.

Although the State of Victoria is not the richest in Australia for gemstones, nevertheless it contains a considerable range of collectable gems. The aim of this well-illustrated book is not to be a locality guidebook (though each of the more important localities for each species is listed and discussed), but rather to provide assistance with the identification of the gem minerals.

After an introductory chapter outlining the discovery of gem deposits, those such as diamonds, sapphires, zircons and olivine which are typically associated with basic volcanic rocks are described. Small diamonds have been found in alluvial deposits, most being discovered by accident during treatment of wash dirt for gold and tin recovery; no commercial deposits have been found and the primary source of the diamonds remains unknown. Sapphires are of widespread occurrence as waterworn crystals in present-day streams and older gravels; blue is the dominant colour, but purple, yellow and brown varieties are found. Pale rubies also occur but are rarer and smaller than sapphires. Rounded grains of reddish brown to near colourless zicon are also found in stream gravels at numerous localities. The primary sources of the sapphires and zircons are thought to be basalts and volcani-sedimentary rocks. Olivines and anorthoclase occur in xenoliths and megacrysts in lava flows of the Newer Volcanics in the W of the state; scoria cones have yielded olivine fashioned to give peridot < 8 mm in size.

J. Gemm., 1998, 26, 5, 334–339

In the areas of granitic rocks and pegmatites, tourmaline is common but mainly as schorl; elbaite is extremely rare. Topaz has been found *in situ* in granites at only a few localities, but waterworn colourless to blue fragments are widespread in alluvial deposits. In Victoria, the garnet species almandine, spessartine, pyrope, grossular and andradite have been found, mainly in stream gravels, but few have been large or transparent enough to facet. Quartz is the most common gem mineral, with the varieties rock crystal, amethyst, smoky quartz and citrine all recorded; agate, chalcedony, jasper and common opal also occur.

The book is extremely well illustrated, both by numerous sketch maps showing most of the localities mentioned in the text and by an abundance of excellent colour photographs of rough and faceted stones for each of the principal localities. It ends with a list of some 180 references, a localities index and a glossary, together with tabulated mineral data for Victorian occurrences, and clearly fulfils the author's intentions of providing a book to assist with the identification of many of the gem minerals through the use of colour photographs. R.A.H.

Gemme del Vicentino.

M. Boscardin and O. V. Tescari, 1996. Montecchio Maggiore, Vicenza, Italy (Museo Civico 'G. Zannato'). pp 114.

Descriptions (often accompanied by colour photographs) are given of gem materials which occur in the Vicenza area of NE Italy. These range from alabaster to amber, aragonite/calcite, beryl, brucite, celestine, feldspars, garnet, hematite, ilmenite, obsidian, rhodochrosite, rhodonite, serpentine, silica minerals (agate, amethyst, carnelian, chalcedony, jasper, quartz, rose quartz) and zeolites (analcite, mordenite and natrolite). Johannsenite occurs with rhodonite at Mte Civillina, and has been fashioned into cabochons. Olivine (peridot) is well represented in the area around Salcedo and cut stones of 0.36–3.68 ct are reported. Xonotlite is found at the contact between a monzonite and dolomitic limestone near Molini di Laghi and yields translucent cut stones (including a 12.19 ct oval showing the characteristic pinkish white appearance of this mineral). Gemmy golden brown zircons occur in stream gravels and have yielded cut stones up to 4.11 ct. R.A.H.

Calcit: das formenreichste Mineral der Erde.

1998. Christian Weise Verlag, München. pp 96, illustrated in colour, softcover. ISBN 3 921656 44 3.

With the greatest number of recorded forms, calcite is a worthy subject for the latest number of the beautifully-produced and informative *extraLapis* series. While gemmologists will particularly welcome the exposition of the use of calcite in obtaining interference figures and of its varied fluorescent effects, mineralogists and collectors will find equal pleasure in the details of classic occurrences. M.O'D.

The Amber book.

A. Dahlström and L. Brost, 1996. Geoscience Press, Tucson AZ. pp 134, illustrated in colour, hardcover. US$27.00. ISBN 0 945005 23 7.

A translation of *Stenen som flyter och brinner*, first published in 1995 by Norsteds Forlag Stockholm, the book is pleasingly produced and is intended as an uncomplicated guide to amber, its composition, mode of occurence, lore and use with particular emphasis on material from the Baltic area. Photographs in colour are found in almost every opening and maps are provided for major amber-producing areas: the maps are, however, insufficiently detailed for serious use. A 35-item bibliography leads the reader to further sources of information: I was surprised by the omission of Fraquet (1987) and by the inclusion of the poor book by Hunger (1977) to which an incorrect publication date is ascribed. As a stimulus to readers with an interest in amber, with good illustrations and at a reasonable price the book is worth buying. M.O'D.

Gemstones of Brazil: geology and occurrences.

P.J.V. Delaney, 1996. Revista Escola de Minas, Ouro Preto. pp 125, illustrated in colour, softcover. US$5.00. ISBN 85 86112 02 X.

The apparently impossible does happen sometimes! A geological survey of the major gem-fields of Brazil, with notes for those wishing to visit some of the locations, an excellent bibliography, maps of the deposits and all at a very modest price. This is one of the most useful books I have seen for a long time and it is particularly welcome for its geological basis.

The text opens with a short history, followed by a description, of the diamond deposits of Brazil. Eleven major deposits are shown on a sketch-map and all are described. Short notes on modes of occurrence are given: these include presently-held theories on how the deposits formed. Notes on present-day status and workings are provided where appropriate. The beryl minerals are treated in the same way, with notes on early discoveries and on the currently-worked deposits at Carnaíba and Socoto (Bahia), Itabira and Capoeirana (Minas Gerais), Santa Terezinha de Goias, Pirenópolis and Porangatu (Goiás), Tauá, (Ceará). Aquamarine deposits are described under southeastern pegmatite province and northeastern pegmatite province and there are brief notes on other Brazilian beryl deposits. Chrysoberyl, topaz, tourmaline, opal and quartz are dealt with in similar fashion while brazilianite, amazonite, andalusite, kunzite and garnet are described in a section on other gemstones.

Briefer details on other species are given in the first of three appendices: species name, location and state are the only facts provided: ruby and sapphire can be found in this list, together wih peridot, green spodumene, spinel, zircon and others. The second appendix gives suggestions on how to organize field trips to Brazilian gem deposits and the 10-page bibliography follows a glossary in the third appendix.

The book is lucidly written and a pleasure to read. I should welcome similar treatment for other major gem-producing countries. M.O'D.

Franklin and Sterling Hill, New Jersey: the world's most magnificent mineral deposits.

P.J. Dunn, 1995. Franklin-Ogdensburg Mineralogical Society, Franklin NJ. pp 978, illustrated in black-and-white, paper cover. £150.00.

Since the area of Franklin, New Jersey, has attracted so many mineral collectors who also have an interest in gem species, this highly individual presentation deserves as much publicity outside the United States as it can get. First of all, the absence of any colour is not a disadvantage since the black-and-white reproductions are of excellent quality (and in any case the cost of colour used on so large a scale would have been prohibitive). Secondly, opening the first section to find a bibliography heading the text would perhaps surprise and disconcert some readers: I felt that this was the place to put it and since it covers 63 pages (approximately 3000 entries) the scale of the whole undertaking is apparent at once.

This area does merit a survey of this size and quality: mining operations carried out by the New Jersey Zinc Company and many other bodies are fully described and a most useful chronology can be found at the end of the first part. Collectors and many gemmologists will know that the area has produced something like 10 per cent of all validated mineral species and that 69 of them were first described from this locality (this is a record). Something like 10 per cent of the species are found nowhere else. While some specimens can be fashioned in one way or another, by far the most presentable ones fluoresce and it is this property which places Franklin very high on the list of sites from which ornamental minerals can be recovered.

Everything is here and the whole work is a model which I hope will be followed by others: this author's dedication is universally known and admired and we must hope for echoes from other writers about other major sites, including some gemstone-producing ones.
M.O'D.

The world of opals.

A. W. Eckert, 1997. John Wiley & Sons, Inc., New York and Chichester. pp xiv, 448. £60.00. ISBN 0 471 13397 3.

This is the first comprehensive book on opals for over thirty years and claims to give a complete guide to the science and history of this gem material. After a definition of exactly what constitutes an opal, the author provides a new look at opal formation, and this is followed by chapters describing opalized fossils and pseudomorphs, the mythology of opals (the 'bad luck' popular image being blamed on the one of Sir Walter Scott's *Waverly Novels 'Anne of Geierstein'*), famous and otherwise noteworthy opals, types of opals, the World's major opal occurrences, and a glossary of opal-related terms; there is also an extensive bibliography and an index.

The chapter on the mode of formation of opals is based largely on the thesis that most of what has been taught about opals has been based on theories now proven, in part at least, to be incorrect. The author's style is distinctly idiosyncratic, and it is difficult to unravel the use of such terms as atom migration [metasomatism?] and the definition of an electrolyte as 'a liquid carrying a chemical that generates an electrical pathway through anything'. The work of Sanders and Darragh in 1965 using electron microscopy to demonstrate that precious opal consists of aligned lepispheres and voids giving rise to a three-dimensional diffraction grating is acknowledged, but we are told that the refutation of part of if not all of the other theories on the basic formation of opal must take place because of experiments carried out by a man from Lightning Ridge, New South Wales, who has succeeded in growing opals from 'opal dirt' in a liquid in glass jars in an incredibly short time (a few days to six months, followed by the secret electrolyte being siphoned off through a small hole in the container's cover, allowing air contact to dry the stone). These opals are said to be indistinguishable by sight from natural opal, but have not yet been scientifically analysed; a lot of work has been done, but the experimenter quite reasonably wants to publish the results himself. We are thus left with various statements, but a lot of the author's work reminds one of a current British advertising campaign on the lines of '... I don't know the answer but I know a man who does'. Nevertheless, the evidence of fossil pseudomorphs leads one to the conclusion that opalization does not neccessarily require a geological time-scale in which to operate.

Putting aside these reservations, this book does succeed in giving an overall account of the occurrence of opals, not only in Australia, the United States and Mexico, but also in British Columbia, Honduras, Austria, the Czech Republic, Slovakia and Hungary. The descriptions of opal deposits in Opal Butte, Oregon, and the Virgin Valley area of Humboldt County, Nevada, are described in detail , and in the section on noteworthy opals details are given of the Roebling opal (2560 ct) and the Bonanza opal (25 586 ct) both from Virgin Valley. Opal being what it is, many of the black-and-white photographs in the text are uninspiring, but 22 colour plates demonstrate the amazing variability in play of colour to be seen in opals even from the same mine. A book that manages to be both provoking and informative, while we await the promised definitive work on the geology and chemistry of opal by the 'man who does'.
R.A.H.

Jean-Pierre Bertrand de Lom (1799-1878), prospecteur-minéralogiste vellave, et son oeuvre gemmologique.

F. H. Forestier, 1995. Cahiers du Haute-Loire. pp 66 illustrated in black-and-white, softcover. FF80.00.

Jean-Pierre Bertrand de Lom (1799–1878) was occupied with geological and mineralogical studies for most of his life, as a child obtaining specimens of sapphires and zircons occurring in the vicinity of Espaly, the town of his birth. This small book sheds light on the activities of a pioneer French mineralogist with an interest in ornamental minerals. By 1840 Bertrand de Lom (the second element of the surname arriving through marriage) was contributing to mineralogical reports, including items on garnets and corundum from Haute-Loire and on both jade minerals. The area of Riou-Pezouillou, in Haute-Loire, was extensively described, with its gem minerals, in a paper published in 1844, subsequent years up to 1878 producing more studies of this and other areas. The book is a very well-constructed study of the way in which different hands contributed to French determinative general and gemmological mineralogy through most of the last century: there are many useful footnotes and references while all Bertrand de Lom's papers are fully abstracted. There are also notes on the disposition of his property after his death. M.O'D.

Dana's new mineralogy: the system of mineralogy of J.D. Dana and E.S. Dana. [8th edition, entirely rewritten and greatly enlarged]

R.V. Gaines, H. C. W. Skinner, E. E. Foord, B. Mason and A. Rosenzweig, 1997. John Wiley & Sons Inc., New York. pp x1v, 1819, hardcover. £191.00. ISBN 0 471 19310 0.

For mineralogists this has to be the most important new publication of the last few years. Even a continuation of Dana 7th edition [D7] had rapidly been lost to sight and the last complete edition of the *System* was published late in the last century. For those new to taxonomic mineralogy, the *System*, first privately published in 1837, was the first large-scale attempt in English to classify mineral species using data provided from earlier workers and leaving behind medical and magical properties as a basis for systematization. The second edition followed in 1844 and the third in 1850. Today's reader of these (very rare) early editions (and gemmology students) would find the Berzelian (chemical) notation used hard to understand and today's formulae are much simpler in this respect as strange symbols have been banished!

Following the sixth edition serious attempts were being made to establish a seventh as far back as 1915 but no volume appeared until 1944 when the first volume was published. A second volume and a third (on silica alone) followed but by then it was 1960 and the number of new species, established by many new laboratory techniques was outstripping the production capacity of editors and publishers.

Thus the concept of a single-volume eighth edition, this time with five co-authors was a bold one but it has succeeded brilliantly: even though many crystal drawings, references and locality information have not found a place this time, such data can easily be obtained from journals and thus via the Internet. The authors tell us that even during the years of compilation the number of species to be covered nearly doubled.

Prefatory material is short though there is a useful index of the symbols used for the main bibliographic sources. The main text is arranged in chemical order (and includes a number of anthropogenic and synthetic minerals). A hierarchical numbering system (updating that used in the incomplete seventh edition) is useful and the profuse and complex silicate species are here classified according to a structural-chemical system developed by two of the co-authors. Name, chemical formula, isostructural substitutions, vacancies or voids in structures, name derivations, groups, dimorphs and polymorphs, synonyms, varieties and polytypes are all indicated. The notation used to describe crystals is explained and referred to the authorities from which it was derived: a useful section on crystallographic principles [adopted from this work] explains the use of systems, classes, Miller indices and zone symbols, forms and space groups, choice of settings [i.e. assignment of unit cell edges to the axes a, b and c], twinning and epitaxy. The choice and arrangement of physical and optical property data is also explained , followed by notes on phase relationships and occurrences. Finally the structure used for locality citation is explained: the exclamation mark (!) is used to indicate specimens of exceptional museum quality – this reminds me of the nineteenth and early twentieth-century British county floras, when the same symbol indicated that the author had found the specimen described!

Having read the prefatory matter the reader is already expecting a highly compressed text and this is what is presented. I found it, together with an excellently-chosen typeface and good-quality [acid-free] paper, particularly pleasing to read. I noted one or two small misprints and no doubt there are others but several samples chosen to identify small errors were amazingly free from them (there seems to be slight confusion between occurrence of the Yogo and Missouri River sapphire deposits – this is perhaps undue compression of the text) – but the book is intended only to lead to more detailed descriptions elsewhere and small omissions and errors are too trivial to mention. Species described up to the end of 1995 are included - at the time the review was written there were approximately 3,700 validated species.

This is a magnificent effort: the price is high but it is worth every cent of it. M.O'D.

Geological Survey and Mines Bureau of Sri Lanka.

Colombo, 1997

The seven sheets under review are 8 10 11 13 14 16 and 17 and while 16, covering the Colombo-Ratnapura area, will be of the highest interest, gemstones feature on some of the other sheets. Each sheet carries identical notes on the geology of Sri Lanka as a whole and then gives a useful summary of the local conditions and the economic minerals found. Sheet 8 (Anuradhapura-Polonnaruwa) includes major apatite deposits: sheet 10 covers the coastal region of Battulu Oya-Kurunegala: sheet 11 (Dambulla-Pallegama) includes the major Elahera gem field: sheet 13 covers Kochchikade-Attanagalla: sheet 14 (Kandy-Hanguranketa) includes gem deposits hosting spinel, sapphirine and ornamental feldspar minerals among others: sheet 17 (Nuwara Eliya-Haputale) also includes major gem deposits (Ratnapura, Pelmadulla and Balangoda in particular). It is very rare for maps to be available from gem-producing countries and these beautifully-produced examples are greatly welcomed. M.O'D.

Dana's minerals and how to study them (after Edward Salisbury Dana). [Fourth edition]

C. S. Hurlbut and W. E. Sharp Jr, 1998. John Wiley & Sons, Inc., New York. pp v, 328, illustrated in colour, softcover. £32.50. ISBN 0 471 15677 9.

The bibliographic history of this small simple manual is almost as interesting as its contents! The first edition was published nearly 100 years ago and the edition preceding the current one is about 50 years old. It is pleasing to see an old friend received with what is admittedly the same general form. The book is directed mainly at the amateur and the collector but there is enough solid material for the gemmologist who will be able to view some areas of the subject in a different light. Some of the old sections, including the use of the blowpipe (not so easy as it sounds!) have been retained but more up-to-date techniques of mineral testing are here too, together with a new chapter on mineral genesis. About 150 of the major species are described and there is a pleasant central colour section. M.O'D.

Cultured Pearls: the first hundred years.

A. MÜLLER, 1997. Golay Buchel Group. pp 142, illustrated in colour, hardcover. US$60.00. ISBN 4 9900624 1 8.

This well presented and richly illustrated book starts with a brief description of pearls in history then continues in some depth on the story of the cultured pearl, how it came about and who was instrumental in its development over the past one hundred years. The latter part of the book describes today's cultured pearls.

It is not a definitive work and the gemmologist could wish for much more detail, but that can be found elsewhere. The author himself states in the foreword that he has targeted a wide audience and tried to fill a specific gap in the literature on cultured pearls. He writes factually, but his love of the subject is very obvious, and the result is an interesting and pleasing book which would be a good addition to any collection. M.C-P.

Crystallization. [Third edition]

J. W. MULLIN, 1997. Butterworth Heinemann, Oxford. Softcover. £35.00. ISBN 0 7506 3759 5.

The softcover issue of the third edition of Mullin appears just at a time when many of the standard crystallization and crystal growth texts are about due for update. While the emphasis has always been on industrial crystallization, there is much for the mineralogist and the gemmologist to work upon and the earlier chapters give a valuable introduction to the crystalline state, viewed from a position which may be unfamiliar to earth science-based students.

It would be hard to over-praise the lucidity of much of the material. The section on solutions and melts will help the reader to understand something of the processes which take place on a larger scale in the Earth and the same can be said for the exposition of phase equilibria, nucleation and crystal growth. There is a 32-page bibliography with the emphasis on industrial crystallization and while much of the treatment of the subject is inevitably mathematical the general level is such that the careful reader with an interest in gem crystal growth will find the book well worth buying. M.O'D.

Color for science, art and technology.

K. NASSAU, 1998. Elsevier, Amsterdam. pp xvii, 491 illustrated in colour, hardcover. US$132.00. ISBN 0 444 89846 8.

Making the point that there is still much more to be learnt about colour, its production, uses, measurement and perception, the authors combine to produce a broad coverage of colour science with many features of interest to the gemmologist. Such readers will at once turn to the editor's own chapter (there are three) dealing with the fifteen causes of colour: the text is understandably based on the editor's monograph *The Physics and chemistry of colour* (Wiley, 1983). In case this book is now hard to obtain, readers will find the present one worth obtaining for this chapter alone, since the colour of gem materials is discussed there along with a good deal of background information on colour causes.

This coverage apart, the editor has also contributed chapters on fundamentals of colour science: on a double-blind test for biological and therapeutic effects of colour and on colour preservation, this section being of special interest to the curator and archivist. Other chapters of the book deal with colour vision and measurement, colour in anthropology and folklore, in plants, animals and man, with the therapeutic effects of light and with colour imaging and photography.

Though a substantial book, no section of it can hope to serve as an exhaustive treatment of its subject. For this reason the possible readership must have been hard to define and in such a case the publisher must ensure the most authoritative standards from contributors. This has certainly been achieved in those chapters on which this reviewer has some knowledge and a reading of the remainder of the text suggests that a uniformly high standard prevails. The rather small number of colour illustrations, placed together at the back this time, achieves a fair standard but with some loss of definition in the Nassau pictures, in my copy at least. This is a very small matter when set against the excellence and interest of the text and the careful citations. M.O'D.

A Fossicker's guide to gemstones in Australia.

N. PERRY AND R. PERRY, 1997. Reed Books, Kew, Victoria. pp viii, 160, illustrated in colour, softcover. £16.50. ISBN 0 7301 000 8.

Updated edition of a book first published in 1982 under the title *A prospector's guide to gemstones*, this guide intended for the amateur gem collector in Australia describes the basic techniques of fossicking [mine dump searching], the evaluation of and collecting possibilities of alluvial deposits, gemstone recognition in the field, details of Australian gem materials and an all-states summary of gemstone locations. These introductory sections precede a detailed state-by-state survey of the major gem deposits: there is a glossary and a short list of references. The book is clearly written and well illustrated with both black-and-white and coloured photographs: legal notes are given and sketch maps are plentiful and certainly needed. All Australian gem hunters will welcome this accurate and handy guide. M.O'D.

The National Gem Collection, Smithsonian Institution.

J. E. POST, 1997. Smithsonian Institution in association with Harry N. Adams, Inc, New York, Washington DC. pp 144, landscape format, hardcover (softcover available), illustrated in colour. £29.00. ISBN 0 8109 3690 9.

After a short introduction in which the nature of gemstones and minerals, fashioning, colour and the history of the collection are introduced, the book introduces historical jewels; not only the Hope diamond but also the Napoleon diamond necklace, the Marie-Antionette earrings and the Spanish Inquisition necklace, with the Portugese Diamond and the Hooker emerald (75.47 ct and set together with diamonds).

Diamond, corundum and beryl have the next chapter to themselves, the following section dealing with quartz, topaz, garnet, tourmaline, peridot, zircon, spinel, chrysoberyl, spodumene and tanzanite. Phenomenal gemstones (star stones and cat's-eyes) have their own chapter: the ornamental species jade, lapis lazuli, turquoise and malachite are treated individually. Appendices cover rare and unusual gemstones, birthstones, a glossary of fashioning terms, hardness values for the more important species, diamond grading and a list of some of the more important specimens in the collection. This list appears in previous guides but it has of course been updated. Entries, alphabetically arranged, give weight, source, donor (where important) and museum accession number.

Quality of the photographs is all-important in this kind of book and for the very reasonable price the quality is good, though variable, Particularly attractive are the pictures of kunzite (in which pleochroic colours are shown), peridot, topaz, variously-coloured sapphires and the red phosphorescence of the Hope diamond. The collection is well-served by this excellent guide. M.O'D.

A field guide to rocks and minerals. [5th edition]

F. H. Pough, 1996. Houghton Mifflin Company, Boston. pp xv, 396, illustrated in colour, softcover. £10.99. ISBN 0 395 72777 4.

According to the preface this excellent guide was first published 46 years ago but while it has always been one of the best field guides and long familiar to all serious collectors, this edition is worth particular mention on account of the fresh colour photographs supplied by Jeffrey Scovil. They are grouped together in a single section at the centre of the book and are of very high quality. Otherwise the text is similar in arrangement to past editions and so is the genial and sometimes combative style. M.O'D.

Antiker Schmuck vom Klassizismus bis zur Moderne.

E. Strack, 1998. Rühle-Diebener Verlag, Stuttgart. pp 112, illustrated in colour, softcover. DM42.89 including postage and packaging. ISSN 0175-565-X.

The 118 coloured photographs of jewellery very pleasingly illustrate a short survey of European jewellery from 1789 to Art Deco and modern styles. A good deal of gemmological information appears within a text devoted in the main to jewellery for German speakers. Incidentally the book has no ISBN number as it is not available through bookshops; it can be obtained only from the publisher who has been allocated an ISSN number. M.O'D.

The Theodore Horovitz Library.

[Catalogue of a sale held at Christie's Geneva] 1997. pp 46, illustrated in colour, softcover.

Theodore Horovitz, born in Romania, eventually became one of Geneva's best known jewellers. During his life he collected a number of fine and rare books on jewellery and gemstones summarized in the catalogue descriptions and supported with several excellent illustrations. M.O'D.

Jadeite.

Lee Ying Ho, 1996. Asiapac, Singapore. pp 126, illustrated in colour, softcover. £17.95. ISBN 981 3029 87 0.

Short but beautifully illustrated survey of jadeite and jadeite jewellery first published in 1991, the Chinese text now translated and accompanied by illustrations taken largely from Sotheby's jadeite sales. Notes on buying jadeite, on it's simulants and treatments are particularly useful but other sections, dealing with jadeite carving and styles of ornament are also valuable. I can strongly recommend this book to all classes of reader. M.O'D.

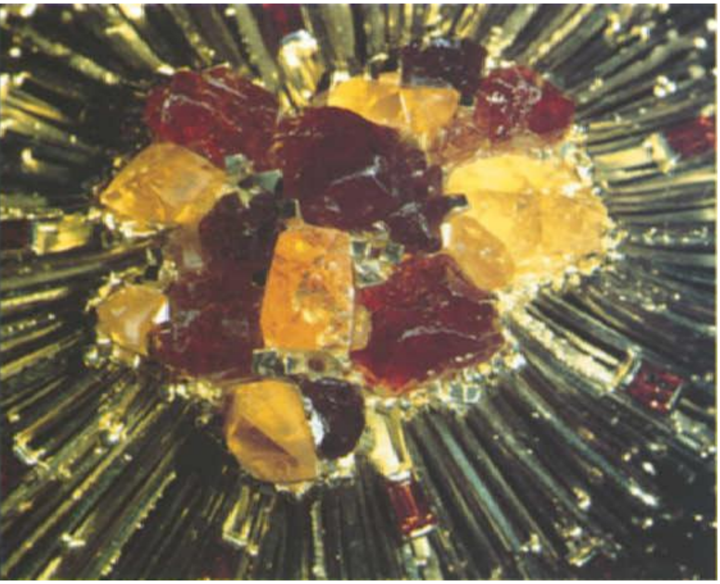
Proceedings of the Gemmological Association and Gem Testing Laboratory of Great Britain and Notices

NEWS OF FELLOWS

We are very pleased to report that our President, Professor R.A. Howie, has recently been awarded the Distinguished Public Service Award for 1999 by the Mineralogical Society of America. This is one of their three highest awards, and is for Professor Howie's services to mineralogy – particularly his enormous contribution to *Mineralogical Abstracts*.

Michael O'Donoghue gave a paper on *Synthetic gemstones at the end of the twentieth century* to the Gemmological Association of Hong Kong on 21 September 1998 and the same paper to the Shanghai Gem and Jade Association on 30 September.

1960s brooch with gem garnets by David Thomas. Photograph by Bob Maurer, FGA DGA, London.



OBITUARY

Alan Bridgewood (D.1988), Bramhope, Leeds, West Yorkshire, died suddenly on 10 May 1998.

1999 CALENDAR

The brooch illustrated for January and February in the GAGTL 1999 calendar (see below left) was by David Thomas and not Stephen Webster. We apologize for the error and any embarrassment caused.

MEMBERS' MEETINGS

London

On 9 October 1998 at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8TN, Kreg Skully from Virginia Beach, USA, gave a talk on *Contemporary Gem Art in America*. Kreg creates crafted carvings of stone enclosing gold-bezelled opal freeforms, and he spoke about his own work and that of other contemporary gem artists in North America.

On 1 November at the Barbican Centre, London EC2, the GAGTL Conference was held on the theme *Gems in Jewellery*. This was followed on Monday 2 November by visits to the Victoria and Albert and the Natural History Museums, South Kensington. A full report of the Conference was published in the December issue of *Gem and Jewellery News*.

On 4 November at Imperial College, South Kensington, Dr Kurt Nassau gave a lecture entitled *F.F.H. Moissan, Polytypes and Synthetic moissanite*. Samples of the new diamond simulant were available for examination.

Midlands Branch

On 30 October 1998 at the Earth Sciences Building, University of Birmingham, Edgbaston, Clive Burch gave an illustrated talk on *The amazing*

ISSN: 1355–4565

GIFTS TO THE ASSOCIATION

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

Richard Burton for an apatite (aqua blue) from Mogok, Myanmar.

Daniel Dower, London, for a smoky quartz and 32 pieces of amber.

Luella Dykhuis, Tucson, Arizona, USA, for a various gem materials including quartz, calcite, peridot and bone.

Arthur Flewelling, Arthur Ontario, Canada, for a collection of quartz crystals from Herkimer, New York.

John R. Führbach, Amarillo, Texas, U.S.A., for a specimen of smithsonite, a superb Herkimer quartz crystal with interesting inclusions, a halite from a little-known source in Mexico and a topaz from the new mine in Colorado.

Elizabeth Gage, London, for 50 specimens including tanzanite, quartz, fire opal, tourmaline and glass.

Sonja Glaser, Galle, Sri Lanka, for 15 cut specimens including aquamarine, natural and synthetic spinels and hessonite garnets.

Marcia Lanyon, London, for a CD-writer for the new CD-ROM archiving and production system.

Jean Smith (the late Robert Webster's daughter), West Wimbledon, London, for *Gemme* (in Italian) by Robert Webster.

Yasukazu Suwa, Tokyo, Japan, for *Gemstones quality and value* volumes 1 and 2, with English translations.

Paul Thurlby, Birmingham Institute of Art and Design, for a large collection of coloured glass.

Wilma van der Giessen, Voorburg, The Netherlands, for a Gilson mosaic opal triplet.

Pierre Vuillet, Villards d'Héria, France, for nine specimens of emerald replacing fossil snails.

Robert Wood, Stamford, Lincolnshire, for a quantity of mineral specimens, a selection of rough beryls, and cut stones including garnet, ruby, sapphire, synthetic spinel and fire opal.

Yumi Yoshitake, London, for a report on Japanese cultured pearl with samples of oyster shell and cultured pearls of various qualities.

and informative world of gemstone inclusions. The accent was on geological signatures of inclusions and the data available indicating formation and provenance of the gem inclusions observed.

On 27 November at the Earth Sciences Building Alan Jobbins gave a talk on his *Gemmological journeys in Brazil*, covering the pegmatite gems of Minas Gerais and the opals and diamonds of Piauí.

On 5 December the 46th Annual Dinner was held.

North West Branch

On 21 October 1998 at Church House, Hanover Street, Liverpool 1, Martin Connard gave a presentation entitled *Silversmith of Williamsburg 1780*.

On 18 November at Church House the Branch AGM was held at which Irene Knight, Deanna Brady and Dr John Franks were re-elected Chairman, Secretary and Treasurer respectively.

Scottish Branch

On 12 October 1998 at the British Geological Survey, Murchison House, West Mains Road, Edinburgh, David Lancaster gave a talk entitled *Pointers for valuation*.

On 11 November at the British Geological Survey Dr Kurt Nassau gave a talk entitled *Gemstones: science, synthesis, beauty, deception*.

PRESENTATION OF AWARDS

The Presentation of Awards gained in the 1998 examinations was held at Goldsmiths' Hall, Foster Lane, London EC2, on Monday 2 November. The President, Professor R.A. Howie, presided and welcomed those present. He announced that in January and June 1998 a total of 972 students entered the Preliminary, Diploma and Gem Diamond Examinations. A total of 149 students passed the Diploma examination and they came from 18 countries. 106 students passed the Gem Diamond examination and there were successful candidates this year from nine countries.

'Here tonight,' continued Professor Howie, 'we have successful candidates from the U.K. and Europe as well as those from Canada, Japan, New Zealand, Sri Lanka and the U.S.A.'

Professor Howie recalled that at previous Presentation ceremonies he had talked about hardness and its importance to mineralogists and gemmologists. 'Tonight', he said, 'I want to spend a few moments talking about carborundum. Having been brought up on a farm, I became acquainted with all manner of devices used for sharpening scythe blades, and the blades or "knives" of mowing machines and harvesting machines. Such sharpening stones, or whetstones, ranged from sandstone to fine-grained metamorphic rocks or hornstones, but these were mostly supplanted by bonded carborundum. Carborundum was first manufactured in 1893 and was so named because it was originally believed to be a compound of carbon and aluminium. It is commonly bluish grey when bonded, but material produced as slag from electric furnaces has bright blue to greenish colours with a very high lustre. Indeed if one talks to museum curators, they will tell you that one of the most frequent "unknowns" brought in by the general public for identification is coarse-grained lustrous carborundum.

Tully Medal and Anderson Bank Prize winner Laurent Kellerson from London, receiving his awards from Robin Buchanan-Dunlop.

Diploma Trade Prize winner Tina Notaro from Madison, U.S.A., receiving her prize.

'It was found later that carborundum was in fact a compound of carbon and silicon, SiC, and as such material had been described in 1904 from the Canyon Diablo meteorite in Arizona, the mineral SiC was named moissanite after the Frenchman who first described it. It is, however, extremely rare, and is not represented in most museum collections. Indeed in the decade around 1960, many scientific papers were produced arguing that the identification of the occasional grains may have been correct but that in fact they represented contamination from grinding materials used to prepare the thin sections for microscopic examination. The 1997 edition of *Dana's New Mineralogy,* the mineralogist's bible, for example observes that moissanite was "originally described from the Canyon Diablo meteorite, but is probably a contaminant". However, moissanite is now accepted as a very rare natural mineral species found in some meteorites and in kimberlites and as even as inclusions in diamonds. But it is still extremely rare, occurring in amounts of around 0.001 per cent in rocks that are themselves rare.

'With the brilliant lustre and bright colours shown by carborundum, I must confess that for some years I have been expecting a new synthetic gem to be produced from silicon carbide – however, I was thinking in terms of an attractive, lustrous, greenish-blue or blue stone to simulate some of the corundum family of gems. But this new material currently called synthetic moissanite is virtually colourless and water-clear, with hardness 9¼ and high dispersion. Its manufacturers (C3 Inc.) claim that it is not meant to simulate diamond, but merely to offer a reasonably cheap stone for incorporation into jewellery at an attractive price. We shall see. Certainly the "synthetic" part of the name must never be dropped but must be used for each and every mention of this material. However, the gem trade has got used to the term CZ as a shorthand name for cubic zirconia (to distinguish this material from natural zirconia, baddeleyite, which is monoclinic). So why not call this material simply SiC – or even C3 as opposed to CZ. I will leave you to think on these things!

'You may not have yet seen this newest "fashionable" stone but, as trained gemmologists, you should find that your training in observation with a lens and in the measurement of specific gravity leaves you amply equipped to deal with it; it is doubly refractive and floats in methylene iodide (as I still call it; perhaps diodomethane or just CH_2I_2 to you). Your training in fundamentals will stand you in good stead and hopefully will provide you with the means to deal with whatever the trade comes up with in the future – and even to make new discoveries.'

Professor Howie then introduced Robin Buchanan-Dunlop, Clerk of the Worshipful Company of Goldsmiths, who presented the awards. Mr Buchanan-Dunlop delivered his address (see below) and a vote of thanks was given by Vivian Watson.

Professor Howie concluded the proceedings by thanking the Goldsmiths' Company for kindly permitting the GAGTL to hold the ceremony at the Hall.

Robin Buchanan-Dunlop's address

'I am delighted to be here tonight to present these awards, but I do so with a little trepidation, because although I am lucky enough to work surrounded by gold and silver and jewels, I know very little about gemmology. A little knowledge is a dangerous thing, and I learnt sometime ago that it is even more dangerous to display one's ignorance in the company of experts. So if you are expecting a learned dissertation on heat treatment or radiation or analysis by proton-induced X-ray emission – I am afraid you are going to be disappointed! Instead I want to talk briefly about the history and romance of precious stones. Part of the fascination of precious stones is not just that they are beautiful, rare and expensive, but behind them lies an age-old history of myth, love, hate and intrigue. If you are exploring the history of precious stones as jewels, then it is possible with a little imagination to reach out and touch that history.

Preliminary Trade Prize winner Linda Rythen from Stockholm, Sweden, receiving her award.

'Let us start with my grandfather (well, one has to start somewhere). He fought in the Boer War and First World War, which is of little consequence. But he was born in 1876. You may find nothing remarkable about that date. But if I were to tell you that that was the year in which Alexander Bell submitted a patent for a telephone; that it was the year in which the Otto engine, the first practical internal combustion engine in general use, was introduced; that it was the year in which electric light started to be used as a public utility; then you might change your mind. The motor car and the airplane had still to be invented, not to mention the silicon chip, but arguably it was the dawn of modern civilization as we are accustomed to it today.

'Forty-one years before he was born you could have been sitting here for the grand dinner to celebrate the opening of Goldsmiths' Hall in 1835.

Robin Buchanan-Dunlop speaking at Goldsmiths' Hall

The room would have been lit by candlelight, but from the four chandeliers only because the central chandelier was a later addition, being one of the first gas chandeliers in the country. The colour scheme would have been in the chaste colours of white and cream and buff picked out in gold. The colours you see today were a late Victorian concoction. There would have been no royal portraits. Queen Victoria had yet to ascend the throne, and she did not meet Prince Albert for the first time until the following year in 1836. Queen Adelaide in the centre was certainly William IV's consort at the time, but she had yet to present her portrait to the Company. And up here at the top table giving a speech, instead of me, you would have seen the Duke of Wellington, a great national hero from the Battle of Waterloo exactly twenty years earlier.

'This was the third Hall on this site. When the first Hall which was acquired shortly after the Goldsmiths' Company received its first charter in 1327, England was in the grip of the 100 Years War with France, and the Black Death had yet to sweep away a third of the population.

'One hundred years earlier in 1227, that great warlord Genghis Khan who drove his armies across Asia to the gates of Vienna died. By now you may be wondering where I am taking you. Have patience! We are now at the limit of so-called modern history, so let us leap back 1500 years to the Sinai Desert where the children of Israel having escaped from Egypt are journeying to the Promised Land. And you will recall that God commanded Moses to build a tabernacle, and there was to be a High Priest, Aaron, and he was to have a breastplate of beaten gold, and set into that breastplate in mountings of gold were to be four rows of precious stones: the first row: a sardius, a topaz and a carbuncle; second row: an emerald, a sapphire and a diamond; third row: a ligure, an agate and an amethyst; fourth row: a beryl, an onyx and a jasper. They present an interesting mixture on what the early recorders of history regarded as important precious stones.

'Come forward again in time just over 1500 years and we have the first record of the Koh-i-Noor Diamond, the Mountain of Light, which was acquired in 1304 by the Sultan Ala-ed-din. Eventually it was to be presented to Queen Victoria and displayed in the Great Exhibition of 1851.

'The fascination of precious stones has provided many an author with inspiration. It was believed at one time to have been the eye of an idol in a temple in an island in Mysore. This may have given Wilkie Collins the idea for his book *The Moonstone,* published in 1868 which is widely regarded as the first detective story. If you are a fan of James Bond you will remember Ian Fleming's *Diamonds are Forever,* now immortalized by De Beers' famous slogan.

'The romance of the past is still with us today, but so is ignorance, deception and greed. And just as we here at Goldsmiths' Hall believe that hallmarking protects both the consumer and the honest trader, so knowledge and expertise in gemmology has never been more important in our trade.

'The part which the Gemmological Association and Gem Testing Laboratory of Great Britain plays in making this happen is significant, not only in our domestic trade but as tonight's awards have demonstrated throughout the international avenues as well. When I visited the Gem Testing Laboratory the other day I was told that 60 per cent of the students came from overseas, and that is a remarkable figure.

'Finally, I should like to congratulate the awards winners once again. I hope whatever you do next and wherever it is, you will enjoy being an important part of this great jewellery trade. Someone once said that there are four essential

FORTHCOMING EVENTS

29 January	**Midlands Branch.** Bring and Buy followed by Quiz.
21 February	**Scottish Branch.** Gemstone photography course. Clive Burch and John Harris
26 February	**Midlands Branch.** Cameos and gemstones carvings. David Callaghan
11 March	**London.** Some current problems in diamond research. Dr H. Judith Milledge.
17 March	**Scottish Branch.** Diamonds from the crust to the core. Dr Jeff Harris
17 March	**North West Branch.** Exotic diamonds. Keith Mason
26 March	**Midlands Branch.** Jewels in the hand. James Gosling
30 April	**Midlands Branch.** ID challenge and AGM
30 April to 2 May	**Scottish Branch.** Annual Conference and AGM. Guest speaker Dr W.W. Hanneman
14 May	**London.** Shining examples – the teaching potential of a gemmologist's jewel box. Cecilia Pople
19 May	**North West.** Pearls – romance and fact. Rosamond Clayton
23 May	**Midlands Branch.** Gem Club – Jet. Peggy Hayden
26 June	**Midlands Branch**. Summer supper
28 June	**London.** Annual General Meeting, Reunion of Members and Bring and Buy Sale
14 July	**London.** Demantoid garnet and other new gems and minerals from Namibia. Professor Peter R. Simpson

For further information on the above events contact:

London:	Mary Burland on 0171 404 3334
Midlands Branch:	Gwyn Green on 0121 445 5359
North West Branch:	Deanna Brady on 0151 648 4266
Scottish Branch:	Catriona McInnes on 0131 667 2199

GAGTL WEB SITE

For up-to-the-minute information on GAGTL events visit our web site on www.gagtl.ac.uk/gagtl

ingredients to a happy life: to work with nice people, to eat with nice people, to drink with nice people, and to go to bed with a clear conscience! I wish you every one of those ingredients.'

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8TN on 28 October 1998 the business transacted included the election of the following:

Fellowship(FGA)

Amor, Miranda E., Taunton, Somerset. 1998
Cho Ka Wah, New Territories, Hong Kong. 1998
French, Thomas, Knaphill, Woking, Surrey. 1998
Gao, Peng, Guangdong, P.R. China. 1998
Gudmundson, Inger, Lit, Sweden. 1998
Ikebe, Emi, London . 1998
Lam Lai Chun, Kowloon, Hong Kong. 1998
Lee Chun Man, Central, Hong Kong. 1998
Lee Yin Wa, Kowloon, Hong Kong. 1998
Liang Weizhang, Guangzhou, P.R. China. 1998
Liying Fan, Shanghai, P.R. China. 1998
Maddison, Steven J., Benfleet, Essex. 1998
Nunn-Weinberg, Danielle, Toronto, Ont., Canada. 1998
Okamoto, Chizuko, Kochi, Japan. 1998
Ono, Shiho, Tama-City, Tokyo, Japan. 1998
Plitsi, Catherine, Larissa, Greece. 1998
Segelken, Christine, North Vancouver, BC, Canada. 1998

GEM TUTORIAL CENTRE

27 Greville Street, London EC1N 8TN

17 February

RUBY AND SAPPHIRE – THE INSIDE STORY

A day looking at all aspects of ruby and sapphire: natural, treated, synthetic and imitation.

Price £104 + VAT (£122.20) – Includes a sandwich lunch

24 February

EMERALDS TODAY

A day looking at all aspects of emerald: natural, treated, synthetic and imitation.

Price £104 + VAT (£122.20) – Includes a sandwich lunch

3 March

ORGANICS – AMBER, IVORY, JET, PEARL AND SHELL

An opportunity to look at these organic materials, the best way to identify them and their most common imitations.

Price £104 + VAT (£122.20) – Includes a sandwich lunch

17 March

DIAMONDS TODAY

A valuable and concentrated look at all aspects of diamonds: rough and cut stones, treated (laser drilled and filled), synthetic and imitation materials.

Price £104 + VAT (£122.20) – Includes a sandwich lunch

24 March

EVERYDAY LIFE – TREATMENTS AND SYNTHETICS

A look at the synthetic, imitation and treated materials encountered in the jewellery trade today. The course will concentrate on emerald, ruby, sapphire and diamond, emphasizing observation techniques.

Price £80 + VAT (£94.00) – Includes a sandwich lunch

STUDENT WORKSHOPS

Preliminary Theory Review	26 April
Three-day Preliminary Workshop	26 to 28 April
Diploma Theory Review	17 May
Four-day Diploma Workshop	17 to 20 May
Weekend Diamond Grading Revision	5 and 6 June
Two-day Diploma Practical Workshop	5 and 6 June

For further details contact the GAGTL Education Department

Tel: +44 (0)171 404 3334 Fax: +44 (0)171 404 8843

Smits, Cyntha A.N., Alphen a/d Rijn, The Netherlands. 1998
Song, Ruohan, Shanghai, P.R. China. 1998
Stratton, Claire, London. 1998
Wang Shu-Ying, Taipei, Taiwan, R.O. China. 1998
Watson Mendis, Alexandra E., Toronto, Ontario, Canada. 1998
Yahampath, Hirosha, Maharagama, Sri Lanka. 1998
Yeung, Michelle, Toronto, Ont., Canada. 1998
Yip Liana Ching Ying, North York, Ontario, Canada. 1998
Zou Hon Wah Coral, Hong Kong. 1998

Diamond Membership (DGA)

Chan Yuk Yee May, Kowloon, Hong Kong. 1998
Clancy, Jo, London. 1998
De Souza, Suzanne P., Walton-on-Thames, Surrey. 1998
Howard, Christine, Sevenoaks, Kent. 1998
Uhlin, Christophe R., Leytonstone, London. 1998
Yam Yau Shun, Hong Kong. 1998

Ordinary Membership

Audretsch, Evelyn A., Aberdeen, Scotland
Burton, Mark G., Guildford, Surrey
Candengue, Domingos M., Streatham, London
Choi, Sun Young Chun, Yangon, Myanmar
Delamater, Laurel, Chesterton, Cambridge
Jonson, Catalina C., St John's Wood, London
Lee, Poh Heong, St John's Wood, London
Mossuto Mori, E. Maria, Yangon, Myanmar
Patel, Virendra T., Norbury, London
Roberts, Kenneth H., London
Shahdadpuri, Neeta D., St John's Wood, London
Soe, Myint, Yangon, Myanmar
Walters, Belinda, Horsham, Sussex

Laboratory Membership

Lawrence (Hatton Garden) Ltd., 63-66 Hatton Garden, London EC1N 8LE
M.G. Welch, Taunton, Somerset. TA1 4AJ

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8TN on 25 November 1998 the business transacted included the election of the following:

Fellowship (FGA)

Darcy, John P, Dublin, Ireland. 1979
Rowe, Leonard James, Croydon, Surrey. 1974
van der Giessen, Wilma, Voorburg, The Netherlands. 1985

Diamond Membership (DGA)

Smith, Colin, Teddington, Middlesex. 1998

Ordinary Membership

Kilian, Angela Maria C., Leidschendam, The Netherlands
Sullivan, Brenda, London

Transfer from FGA to FGA DGA

Deer, Georgina, Salford, Lancashire. 1998

Transfer from Ordinary Membership to FGA

Kellerson, Laurent P., London. 1998

Pearls Coral Amber Bead Necklaces Carvings Cameos Mineral Specimens

Opal Precious Topaz Ruby Star Ruby Sapphire Star Sapphire Tourmaline

Gemstones Aquamarine Alexandrite Amethyst Emerald Jade Lapis-Lazuli

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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.

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

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

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

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

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

A **This is a first level heading**

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

B *This is a second level heading*

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

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

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

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

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

Notes and References Authors may choose one of two systems:

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

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

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

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

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

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

Volume 26 No. 5

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Cover Picture

Johachidolite in a rock specimen from the original locality in Korea shown next to a cut stone of 14.02 ct recently acquired in Myanmar (see 'Johachidolite – a new gem', pp. 324–9)

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