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## Cover Picture

The Hope Pearl in its crown setting. *Photograph: Mikimoto.*  
(See The Hope Pearl p. 235)

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## Editorial

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The first two papers in this issue of the *Journal* concern pearls. The Hope Pearl is famous through a connection with Tavernier in 1669 and derives its name from being part of the Hope collection of gems in the 1830s.

Over time this collection has been dispersed but parts are still identifiable notably in the Smithsonian Institution and in the Natural History Museum, London. This is the first modern professional gemmological description of the Hope Pearl to appear in print.

The roots of gemmology lie in the application of mineralogical, physical or chemical techniques to the solution of gem problems and the second pearl paper extends this concept to the discipline of biomineralization. There is considerable research today into how organic tissues secrete and deposit solid matter and the application of some of these ideas has led the authors to conclusions of importance to the future of the cultured pearl industry.

The third paper takes us from sea level (or below) to high in the western Himalayas where the gems of Afghanistan are the subject of renewed exploration and

development. To date, however, their historical background has been the result of much speculation and a thorough summary of the known records, long overdue, is published in this issue. Some famous gems in the world's regalia may well have their origins in northern Afghanistan and the evidence is assessed.

Papers on Burmese gems have been increasing in frequency in the past few years and here the first of two accounts of the jades of Myanmar by two authors on the spot in Yangon deals with their composition. The constituent minerals and chemistry of a representative range of different coloured jades are described and related to an extensive set of illustrations.

Two short papers complete the contents of this issue: new dendritic opals are described from Zambia and a new appearance in the trade of a star ruby imitation is reported by Dr Schmetzer. The latter material is dyed star corundum and is plainly being produced to tempt the unwary public; however, advice on how to recognize these treated stones is clearly outlined.

R.R.H.

# The Hope Pearl

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## Abstract

The Hope Pearl and its crown setting is described and the history of the item is reviewed. The pearl was examined by fluorescence emission spectrometry, reflection spectrophotometry, X-ray fluorescence analysis and X-ray radiography. Surface features and the X-ray radiograph proved it to be a natural blister pearl. A peak at 620nm in the fluorescence emission spectrum indicates the presence of porphyrin in the coloured base of the pearl. The reflection spectrum confirms the presence of porphyrin as well as displaying a trough at 700nm characteristic for a black pigment found in Black-lip pearls from the *Pinctada margaritifera* oyster.

## Introduction

In 1993 the London Laboratory was privileged to examine one of the larger pearls known to exist. The Hope Pearl was purchased by H.E. Mohammed Mahdi Al-Tajir in 1974 from Gerards, the Paris jewellers (personal communication). The pearl formed part of the Christie's exhibition in 1989 called *The glory of the goldsmith - magnificent gold and silver from the Al-Tajir collection*. Last year, under a loan agreement, the pearl was to be taken from London to Tokyo to be the centrepiece of an exhibition arranged by K. Mikimoto & Company. The pearl was examined by X-ray radiography and its surface was closely inspected before departure, and the laboratory was asked to assess whether any



Fig. 1. The Hope Pearl, viewed from the front (left), from the right-hand side (centre) and from the back (right). Photos: Mikimoto.

damage had been suffered by the pearl when it was returned to London. Once in Japan much more extensive research was carried out at the Mikimoto Pearl Research Laboratory at Toba, Toba-shi, Mie-ken.

### Description and History

The Hope Pearl (Figure 1 and cover picture) is roughly drop-shaped with irregular channels on the surface around the base. The narrower top of the pearl is white in colour with a bright orient whereas the broader base graduates to an iridescent greyish-purple. The narrow top end of the pearl is capped with a gem-set, red-enamelled, gold-coloured metal arched crown pendant fitting. The item measures approximately 9cm in length from the top of the crown fitting to the base of the pearl. The broader base of the pearl varies in width between approximately 3cm to 4cm (Figure 2). The whole item of jewellery weighs 134.6 grams.

The crown fitting has been set with 70 diamonds in the arches and the pendant ring part of the fitting, and three rectangular natural emeralds, four round natural rubies and two blue lozenge-shaped pastes are set in the front part of the band of the crown fitting. The blue, orange, and green 'gem-shapes' on the reverse part of the crown band (Figure 3) are small enamelled geometric shapes giving an appearance of set gems. In addition to these small areas of enamel there is also a large area of red enamel on the cap underneath the arches of the crown.

The pearl itself is reputed to weigh 450ct or 1800 grains. As its name implies, the pearl formed part of the famed collection of the London banker Henry Philip Hope, which was assembled in the early 1800s. The collection, which was catalogued by Bram Hertz in 1839, is probably best known for the 45.52ct deep-blue Hope Diamond. The previous history of the pearl is sketchy but reference (Dickinson, 1968) is made to it having been purchased in India by Jean Baptiste Tavernier, the

jewel merchant, in the mid-seventeenth century. The pearl is believed to have been sold to Louis XIV, possibly when the two met in 1669 (Tavernier, J.B., English translation 1889).

Henry Philip Hope died in 1839 and the pearl was passed down through the family. Mr A.J. Beresford-Hope loaned the pearl to the South Kensington Museum (Streeter, 1886) at some stage subsequent to its opening in 1881. The pearl was sold with other gemstones from the Hope collection in 1886 by the auctioneers Christie & Manson. Garrard & Co. of London purchased the pearl and it is known that it was being offered for sale in 1908 at £9000 (Kunz and Stevenson, 1908). As mentioned above the pearl was purchased in 1974 for a figure that has been quoted at \$200,000 (Newman, 1981). At some time prior to this the pearl had been exhibited at the Smithsonian Institution in Washington (Taburiaux, 1985).

### Investigation methods

In addition to microscopic and fibre-scope examination the following techniques were also used in examining the pearl:

#### Ultra-violet fluorescence

The fluorescent colours emitted by a pearl when irradiated by ultra-violet light may yield information concerning the species of the mother oyster (Sawada, 1958; Miyoshi *et al.*, 1987 a and b).

#### Fluorescence emission spectrometry

The different fluorescent colours emitted by pearls originating from certain oysters can produce characteristic fluorescence emission spectra. Black pearls from the black-lipped *Pinctada margaritifera* (Miyoshi *et al.*, 1987 a and b) and pearls from the Mabe *Pteria penguin* can be distinguished from other pearls by the presence of a peak at 620nm in their fluorescence emission spectra (Figure 4), which is due to the presence of porphyrin. The fluorescent

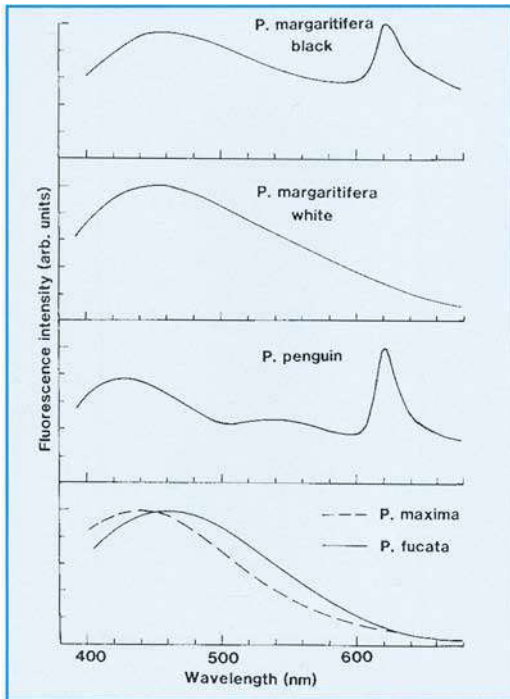


Fig. 4. Fluorescence emission spectra of the nacre from different types of oysters, showing how the nacre from *Pteria penguin* and the black nacre *Pinctada margaritifera* differ from the nacre of other oysters by the presence of a peak at 620nm.

emission characteristics of the coloured base of the Hope Pearl were measured with a Nihon Bunko spectrofluorophotometer Model FP770 at an excitation wavelength of 400 nanometres.

### Reflection spectrophotometry

The pigmentation of coloured pearls can also give rise to specific reflection spectra in the visible region for particular pearl-producing oysters (Wada, 1983). The reflection spectra for grey *Pinctada margaritifera* pearls display a trough at 700nm whereas the spectra for *Pteria penguin* pearls do not show the trough (Figure 5). A reflection spectrum was obtained from the iridescent greyish-purple base of the Hope Pearl using a CMS-35sp spectrophotometer from the Murakami Color Research Laboratory.

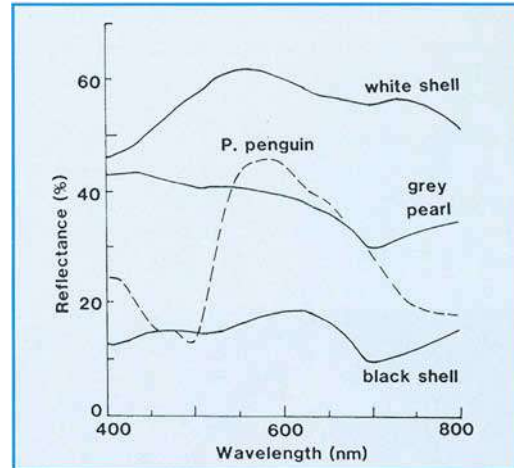


Fig. 5. Optical reflection spectra of a pearl and the shells of *Pinctada margaritifera* (solid curves) and the reddish-brown shell of *Pteria penguin* (dashed curve), which can be differentiated on the basis of a trough at 700nm in the spectra for *Pinctada margaritifera*.

### X-ray fluorescence analysis

The main inorganic component of pearl is calcium carbonate. The chemical composition also includes some minor elements, of which the relative amounts of manganese and strontium have been found to be an important indicator of the species of the pearl-producing mother oyster.

Freshwater pearls can be differentiated from marine oyster pearls on the basis that the latter have lower concentrations of manganese and higher concentrations of strontium (Wada and Fujinuki, 1988). Amongst seawater pearls strontium is found in slightly greater concentrations in Black-lip (*Pinctada margaritifera*) and White-lip (*Pinctada maxima*) pearls than in Akoya (*Pinctada fucata*) pearls. The Hope Pearl was analysed for calcium, manganese and strontium by Energy Dispersive X-ray spectrometry using Seiko Model SEA 2001.

### X-ray radiography

The internal structure of the Hope Pearl was revealed by X-ray radiography. In Japan the radiographs were obtained using a SOFTEX CMB-2 set. In London the spe-

cially designed X-ray set uses a Machlett fine focus diffraction tube with a molybdenum anode target.

### Results and discussion

Visual examination of the reverse side of the Hope Pearl reveals the growth lines that prove the pearl was attached to the shell (Figure 6) and should therefore be



Fig. 6. Surface growth lines on the back of the Hope Pearl indicating its blister origin. 5x.

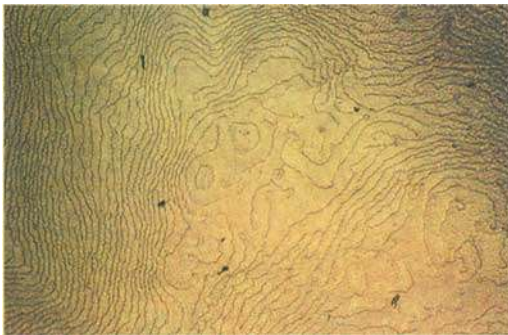


Fig. 7. Overlapping platy crystal structure on the surface of the Hope Pearl typical of pearls from nacreous bivalves. 25x.

described as a natural blister pearl. At higher magnification the striped pattern of overlapping platelets (Figure 7) characteristic of nacreous bivalves can be seen. The fact that light from the fibroscope could not penetrate very far through the surface of the pearl indicates that it consists mainly of solid calcium carbonate, and this was confirmed by the X-ray radiographs (Figure 8).

The presence of the organic component



Fig. 8. Positive photograph of the X-radiograph taken of the Hope Pearl.

conchiolin is recorded on the radiograph negative (not shown) by a series of faint growth lines sweeping across the body of the pearl to its edge; this pattern is typical for a natural blister pearl which has grown away from the inner surface of the shell.

The coloured base of the pearl fluoresces a reddish colour under ultra-violet light, and this suggests the presence of porphyrin pigment known to exist in Black-lip (Iwahashi and Akamatsu, 1994) and Mabe pearls (Comfort, 1949).

The fluorescence emission spectra recorded under 400nm radiation contain a peak at 620nm (Figure 9), confirming that the pigment is porphyrin, which can be found in both Black-lip and Mabe pearls.

Porphyrin also gives rise to the troughs at 400nm and 500nm in the reflection spectra (Figure 10a and b). More importantly the trough at 700nm (Figure 10c) is characteristic for a black pigment contained in the Black-lip pearl.

The X-ray fluorescence analysis reveals concentrations (cation %) of 99.54% for



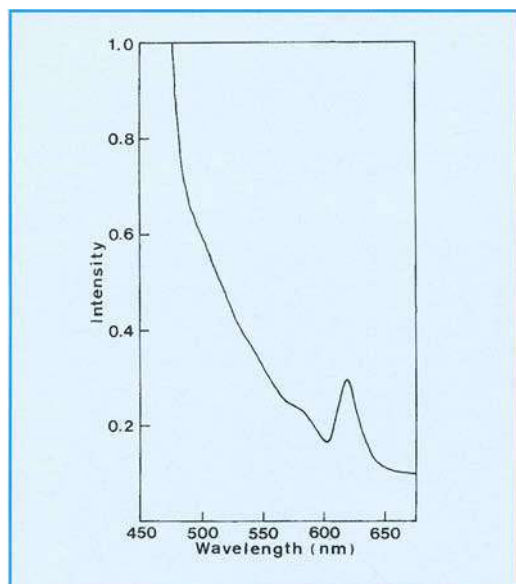


Fig. 9. Fluorescence emission spectrum of the Hope Pearl showing the presence of the peak at 620nm.

calcium, 0.42% for strontium, and 0.04% for manganese. The relatively low concentration of manganese and high concentration of strontium point to a marine origin for the Hope Pearl.

### Conclusions

The Hope Pearl is a natural blister pearl of solid nacre. The pigments present in the bronzed area indicate that the Black-lip oyster (*Pinctada margaritifera*) is the most likely source of the pearl.

### Acknowledgements

The authors wish to convey their thanks to the owner, H.E. Mahdi Mohammed Al-Tajir, for his permission to publish this article.

SJK would like to thank his colleague Ana Isabel Castro who examined the pearl with him. He would also like to acknowledge all the assistance given by Mr Ryo Yamaguchi. Further thanks from the London author go to Nick Silver, who arranged for the London Laboratory's involvement in the project.

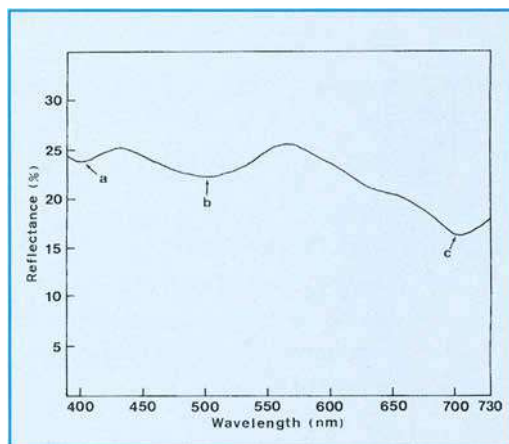


Fig. 10. Optical reflection spectrum of the Hope Pearl. The troughs at (a) and (b) relate to porphyrin, the trough (c) at 700nm is typical for a black pigment contained in *Pinctada margaritifera*.

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Pair of pearl and diamond drop earrings. Pearls, 20mm in length, recently identified as natural by the Gem Testing Laboratory.

*Photograph courtesy of Christie's, London.*

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# Structural and chemical investigations on shells and pearls of nacre forming salt- and fresh-water bivalve molluscs

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## Abstract

To investigate the shell structure of some pearl-forming bivalve molluscs the following techniques were used: light microscopy, scanning electron microscopy (SEM), X-ray diffraction (XRD), texture goniometry, scanning force microscopy (SFM), energy dispersive X-ray fluorescence (EDXRF) and fourier transform infrared spectroscopy (FT-IR).

X-ray diffractograms were taken to determine the identity of the minerals forming the shell. They were identified as aragonite in the mother-of-pearl layer and as calcite in the prismatic layer.

The X-ray diffractograms also showed that the orientation of the crystallites forming the nacreous layer of freshwater mussels is different from those of saltwater oysters. In pictures taken by SEM the aragonite crystals of all the investigated mussels except *Hyriopsis schlegeli* show a pseudo-hexagonal shape. Investigations by texture goniometry indicate the crystals to be single crystals, so they are not twins like their inorganically grown counterparts.

A theory of nacre growth is proposed and its application would help to decrease the amount of waste pearls. It was found to be possible to influence the colour of the pearls without using artificial treatment.

Attempts were made to explain the crystal growth by means of high resolution scanning force microscopy (SFM) which enables examination of the surface of the aragonite microcrystals. The observed structures on top of these crystals could be the so-called organic matrix that strongly influences nacre growth.

The chemical investigations showed that there is little difference in the amount of minor and trace elements in the nacre and pearls from different localities. However, it is possible to distinguish between the origins of freshwater mussels due to their contents of manganese and potassium. The strontium contents of some saltwater oysters are presented but are not a diagnostic feature.

## Introduction

Investigating the shell and shell growth of nacre forming molluscs (e.g. bivalvia (mussels)) is not only of gemmological interest because of their capability to form pearls. The shell growth is a biomineral-

ization process which is related to similar processes in the human body (skeleton) (Handschin and Stern, 1992). Compared to human bones, the shell of a mussel is a simple model where mineralization processes can easily be studied (see also

Caseiro, 1993). The aim of this study was to perform a structural and chemical comparison of shells and pearls from different origins. In order that one may understand the observed structures it is important to know how the mussel grows and to recognize the main parts of the shell.

Because the growth process is essentially the same in shells and pearls, the results of the shell investigations can be used to supplement the knowledge of the process of pearl formation, but this work does not attempt to explain the initiation of pearl growth.

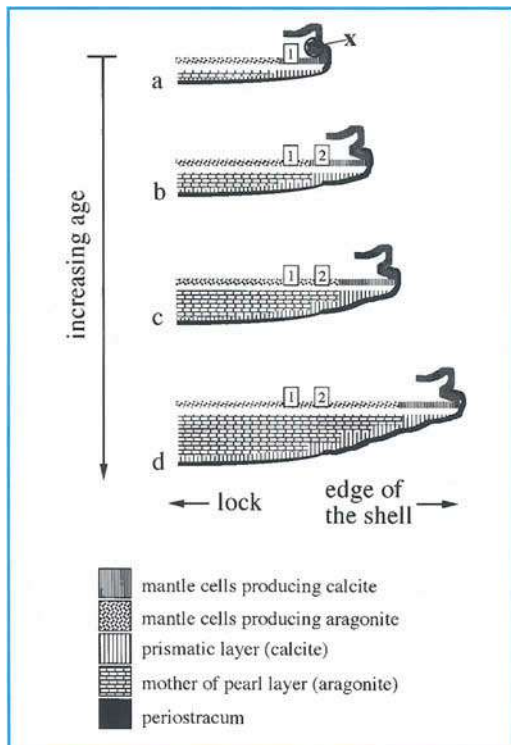


Fig. 1. Schematic cross-section through the shell, showing the mineral components of the shell and the soft parts of the animal (mantle tissue, periostracum) that produces them. From a to d the cross-sections represent increasing ages.

## Background

This section includes not only the results of earlier work but also some of our own

new results which should enable the reader to understand the following text.

Figure 1d shows a schematic cross-section through the type of shell used in this study. The bottom of the sketch represents the outer surface of the shell. This is a hydrophobic organic skin called the periostracum. It covers the hard parts of the shell and serves as a defence against erosion and enemies. On the inside of the periostracum is the prismatic layer, the first inorganic part of the shell. It is formed by small prisms of calcite crystals ( $\text{CaCO}_3$ , trigonal). The prismatic layer is followed by the mother-of-pearl layer, or nacreous layer, which is formed from tabular aragonite crystals ( $\text{CaCO}_3$ , orthorhombic).

All these components of the shell are produced by a soft part called the mantle (Figure 1), the part of the animal next to the shell. On the opposite side of the hinge (that is where the two shells are connected) the mantle forms a fold (x in Figure 1a). The cells in this fold produce molecules which grow to form the periostracum (Lowenstam and Weiner, 1989) which is the first part of the shell that is formed. It builds the substrate on which the prismatic and mother-of-pearl layers grow. There is also evidence for another organic phase besides the periostracum playing an important role in the formation of the shell. It is called an organic matrix (Weiner and Traub, 1984) and may influence strongly the crystallization of the calcite and aragonite crystals. More details follow in the section 'Morphological structures'.

Figure 1 shows the growth stages of the type of shell investigated. The shell always grows from the centre towards the edge. At the hinge the shell does not spread but thickens with increasing age. The growth of the shell is a consequence of the growth of the inner soft parts, in other words of the animal itself whose growth centre is the mantle. There are two types of mantle cell that secrete the  $\text{Ca}^{2+}$  and  $\text{CO}_3^{2-}$  ions (1 and 2 in Figure 1). The formation of the crystals as calcite or aragonite is determined by the

age of the cells. Young cells (1) near the border of the shell produce calcite and older cells (2) towards the inner part of the shell form aragonite.

This means that young cells situated on the inner side of the shell always produce calcite (type 1 cells). These young cells are followed by older cells (type 2 cells), which were former type 1 cells. Because the cells do not change their places relative to the shell, but change the mineral phase they produce, there will be a certain time when they deposit aragonite over calcite (Gutmannsbauer, 1992). This growth behaviour is summarized in Figure 1.

The knowledge of this theory could be of great importance for the cultured pearl industry. The production of large amounts of reject cultured pearls, e.g. – pearls that consist of, or are partly overgrown by, calcite – could be prevented. Since cultured pearls will have the same colour as the mother-of-pearl grown by the original mantle cells, pearl culturers can influence the colour of the end product by carefully

choosing the mantle cells from the right location in the bivalve sacrificed for its mantle tissue.

#### Material and methods

In this study the shells and pearls of the main pearl-forming oysters and mussels were of interest. Cultured as well as natural pearls were investigated and a main point for our sample acquisition was that the shells and pearls were not treated in any way, so that there could be no falsification of the chemical and structural data. The examined shells and pearls are listed with their origins in Table I.

The following techniques were used to investigate the structures of the shells: light microscopy (LM), scanning electron microscopy (SEM), X-ray diffraction (XRD), texture goniometry and scanning force microscopy (SFM).

Chemical analyses were carried out by energy dispersive X-ray fluorescence (ED-XRF). Fourier transform infrared spectroscopy (FT-IR) was used for struc-

Table I. Shells and pearls examined in the present study.

<i>Saltwater oysters</i>	<i>Quantity</i>	<i>Origin</i>	<i>Pearls</i>
<i>Pinctada margaritifera</i>	10	Tahiti	yes
<i>Pinctada martensii</i>	8	Japan	yes
<i>Pinctada maxima goldlipped</i>	3	Philippines	no
<i>Pinctada maxima goldlipped</i>	4	Australia	no
<i>Pinctada maxima goldlipped</i>	1	Thailand	no
<i>Pinctada maxima silverlipped</i>	1	Burma	no
<i>Pinctada maxima silverlipped</i>	12	Australia	no
<i>Pteria penguin</i>	2	Okinawa	yes
<i>Pteria penguin</i>	2	Philippines	yes
<i>Pteria penguin</i>	3	Australia	yes
<i>Pteria penguin</i>	3	Thailand	yes
<i>Freshwater mussels</i>	<i>Quantity</i>	<i>Origin</i>	<i>Pearls</i>
<i>Anodonta plicata</i>	5	China	yes
<i>Hyriopsis schlegeli</i>	6	Japan	yes
<i>Unio margaritifera</i>	1	USA	yes



Fig. 2. Cross-section through the shell of the saltwater oyster *Pinctada margaritifera* (Tahiti). The components from the bottom to the top are: prismatic layer (calcite), mother-of-pearl layer (black-and-white, aragonite). 27x

tural as well as chemical investigations.

We will not give any technical details of the well-established methods such as SEM, FT-IR, XRD and texture goniometry, (a further development of XRD), but a short introduction is given to the less well-known method of energy dispersive X-ray fluorescence (EDXRF) and to scanning force microscopy (SFM), which is relatively new.

### Morphological structures

#### Light microscopy (LM)

The essential observations were made with normal light microscopy, which led

us to the theory of shell growth outlined above in the 'Background'. The pictures were taken on polished cross-sections of shells and pearls, both natural and cultured. Figure 2 shows a cross-section through the shell of the saltwater oyster *Pinctada margaritifera* from Tahiti. The layers seen compare favourably with those in Figure 1d. The black colour is due to the organic phases, conchiolin and porphyrin (Miyoshi *et al.*, 1987, 1989). The difference of colour in the aragonite layer may be caused by either a seasonal change or variation in food availability.

The influence of the age of the tissue causing the growth of a pearl is shown in Figure 3 (cf. Figure 1). The bead of the cultivated Japanese saltwater pearl (the oyster *Pinctada martensii*) in Figure 3a is the nucleus for a deposit of a thin layer of calcite prisms. Figure 3b shows a large core of calcite prisms in a natural saltwater pearl. In both cases, the calcite layers are followed by aragonite layers. The identity of the calcite prisms was checked by FT-IR (Farmer, 1974).

What do we learn from the structures of these pearls?

The piece of mantle that was inserted with the bead, to build up the tabular aragonite crystals (nacre) around it, was cut from a little too near the edge of the victim bivalve. It was not old enough to produce aragonite from the beginning. After producing calcite prisms for a while, it switched to aragonite. This explains the calcite rim around the bead followed by the aragonite layer.

Initial growth of the natural pearl also took place near the edge of the shell in very young mantle cells which deposited calcite for a long time before changing to aragonite production. Like others (e.g. Scarratt, 1987), we also have observed both natural and cultivated pearls built totally out of calcite prisms. These pearls show none of the desired optical iridescence effects and most are of no commercial value.

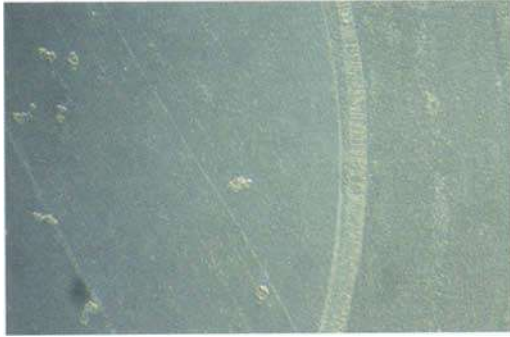


Fig. 3a. Cross-section through a Japanese bead-nucleated pearl cultured in saltwater (Akoya). The bead (left) is followed by a small layer of calcite prisms that is followed by the mother-of-pearl layers (aragonite). 40x

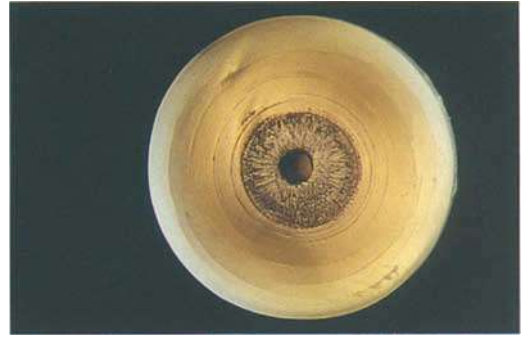


Fig. 3b. Cross-section through a natural saltwater pearl with a large core formed of calcite prisms. The prismatic layer is followed by the mother-of-pearl layers. 30x

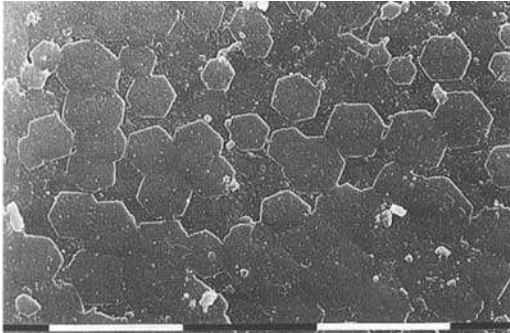


Fig. 4. SEM micrograph of the pseudo-hexagonal aragonite crystals forming the mother-of-pearl layer in the shell of the saltwater oyster *Pinctada maxima* (Australia). Length of one white line segment:  $d = 10\mu\text{m}$ .

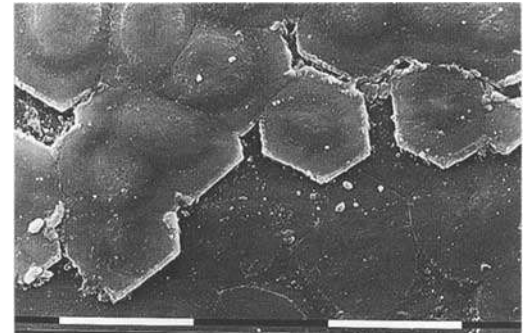


Fig. 5. SEM micrograph of the aragonite crystals forming the mother-of-pearl layer in the shell of the freshwater mussel *Hyriopsis schlegeli* (Japan, Lake Biwa). Nearly all crystals show screw dislocations. Length of one white line segment:  $d = 10\mu\text{m}$ .

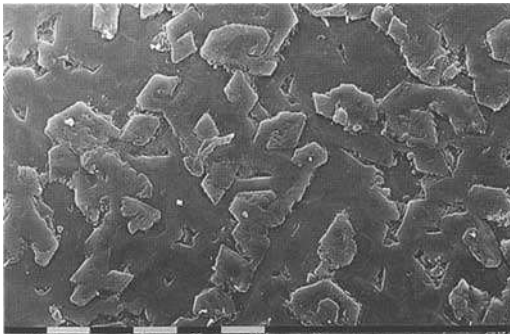


Fig. 6. SEM micrograph of the pseudo-hexagonal aragonite crystals forming the mother-of-pearl layer in the shell of the saltwater oyster *Pinctada margaritifera*. The crystals show hillocks on their surfaces. Length of one white line segment:  $d = 10\mu\text{m}$

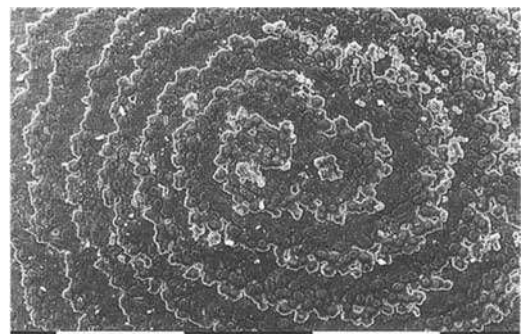


Fig. 7. SEM micrograph of a spiral formed by many aragonite crystals in the mother-of-pearl layer of the saltwater oyster *Pinctada margaritifera* (Tahiti). Length of one white line segment:  $d = 0.1\text{mm}$

### Scanning electron microscopy (SEM)

The aim of the SEM investigation was to characterize the aragonite and calcite crystals and perhaps some organic relics such as the organic matrix mentioned in the introduction (for a short review of SEM see Postek *et al.*, 1980).

For the SEM investigations three specimens of each species were chosen. At least three samples were taken from every single shell. In this way, we hoped to gain an overview of the internal diversity of the shell. Indeed, we observed that the habits of the aragonite crystals vary between the different species and in the shells themselves. However, there is one particular habit of the aragonite crystals that can be found in every species. These are tabular crystals with a thickness of 400 nm to 1500 nm that have a pseudo-hexagonal shape (see also Mutvei, 1980, and Erben, 1970). Figure 4 shows a top view on the mother-of-pearl layer which is built of these pseudo-hexagonal aragonite crystals, from the shell of the saltwater oyster *Pinctada maxima* (Australia).

The nacreous layers from the shell of the freshwater mussel *Hyriopsis schlegeli* (Biwa pearls, Japan) and the saltwater oyster *Pinctada margaritifera* (Polynesian black pearls, Tahiti) show some features that distinguish them from the other shells. Figures 5 and 6 show SEM micrographs which exhibit two totally different kinds of growth. The *Hyriopsis schlegeli* grows by adding carbonate in spirals initiated by structural dislocations. The term dislocations describes changes in the symmetry of the array of atoms as they adhere to a crystal at its growing surface. Nearly every aragonite crystal in the nacreous layer shows this phenomenon. In contrast, the aragonite crystals of the *Pinctada margaritifera* (Figure 6) exhibit a kind of hillock on every crystal. We think that these 'growth hills' could be the initial stages of the crystals forming the next nacreous layer.

Screw dislocations can be observed in

nearly all shells, but to a much lesser extent than in the *Hyriopsis schlegeli*. Only a few crystals in the whole of the *Pinctada margaritifera* (Tahiti) shell have such dislocations, but these are transmitted to the overlying crystals, giving rise to a large spiral involving many single aragonite crystals without dislocations (Figure 7). The reason why the aragonite crystals of some shells have many dislocations while others have very few is not yet clear, but it will be an interesting subject for our further investigation.

The calcite crystals of the prismatic layer in the shells are quite uniform in shape through all the investigated species. They only vary in size. For SEM images of the prismatic layer see Doumenge *et al.* (1991).

### X-Ray diffraction (XRD) and texture goniometry

Shell material of every species was investigated by XRD. It confirmed that the nacreous layer of every shell consisted of aragonite and the prismatic layer of calcite. Fibrous aragonite as described by Caseiro (1993) was not found in our samples.

More astonishing was the fact that the diffractograms of the nacreous layer of saltwater oysters looked different from those of freshwater mussels. The diffractograms of the aragonitic layers in freshwater mussels had some reflections that did not appear, or only to a much lesser extent, in those of saltwater oysters. We concluded that the orientations of the aragonite crystals in the nacreous layer of saltwater oysters are slightly different from those in the nacreous layer of freshwater mussels.

To confirm this theory, we used the method of texture goniometry, with which it is possible to determine the orientations of the crystal axes in a polycrystalline material. This very useful method works on the basis of X-ray diffraction, and a detailed description is given by Wenk (1985). These investigations showed that the *c*-axes of all aragonite crystals forming the nacreous layer are aligned perfectly



parallel to each other, and perpendicular to the inner surface. But the lateral axes of the aragonite crystals of the saltwater oysters were better aligned than those of the freshwater mussels. The reason for these different orientations are not known, but the factors of water temperature and concentrations of dissolved elements (which for freshwater mussels are usually lower than for saltwater oysters) may play a role.

Studies carried out by texture goniometry revealed other even more interesting results. It was clearly shown that the aragonite crystals forming the mother-of-pearl layer in all our investigated shells are single crystals. This is in agreement with some earlier studies (Towe and Hamilton, 1968; Wise 1970). However, it contradicts the findings of other authors who postulated that the pseudo-hexagonal habit of the aragonite crystals, arose as a result of twinning (Mutvei, 1970; Hänni, 1982).

Although one query has been solved a new one arises: how can an aragonite crystal with orthorhombic crystal symmetry have a hexagonal shape? The hexagonal shape and the spatial arrangement of the aragonite crystals in nacre has been described by Erben (1970) and Mutvei (1970) using SEM. Theoretically it is possible to have aragonite single crystals with orthorhombic crystal symmetry displaying a 'pseudo-hexagonal' habit (Graeser, 1992), and the question of whether these crystals are twins can possibly be answered by another result of the texture goniometry study. We detected a highly ordered phase in the mother-of-pearl layer that could not be correlated with any of the modifications of  $\text{CaCO}_3$ , (calcite, aragonite or vaterite) or with strontianite. This highly ordered phase may not be crystalline at all and the reflection could come from the organic matrix (Weiner and Traub, 1984) mentioned in the 'Background'. The exact nature of the organic matrix, which presumably covers every single crystal in the shell, could not be observed on the SEM.

### Scanning force microscopy (SFM)

With scanning force microscopy (SFM), whose lateral and vertical resolution is high enough to distinguish atoms, we were able to depict the surface of single aragonite crystals forming the nacreous layer in the shell of the Australian oyster *Pinctada maxima*.

Scanning force microscopy is essentially a further development of the scanning tunnelling microscope (STM) invented by Binnig *et al.* (1982). In contrast to the STM, which senses a tunnelling current, the force microscope senses forces between the probing tip and the sample surface. With the SFM it is possible to study surfaces of insulators as well as conductors, whereas the STM is restricted to conducting samples. Figure 8 shows a scheme for a scanning force microscope that is based on a force sensor, a displacement sensor, a feedback system which monitors and regulates the deflection of the cantilever, a mechanical scanning system and a computer system for acquisition of data and image processing. For recent reviews see Rugar and Hansma (1990) and Meyer (1992).

Two general modes of operation have been developed for SFM to sense short-range forces as well as long-range forces: the contact mode and the non-contact mode.

In this study only the contact mode was applied; therefore the description is restricted to this method. Using the contact mode, the probing tip (2) is brought close to the repulsive force range of the sample surface (3) (tenths of nanometers). In response to the repulsive short-range interatomic forces, which act on the probing tip, the cantilever (1) is bent. While scanning the sample surface with piezoelectric transducers, the deflection of the cantilever is kept constant by a feedback loop that adjusts the relative distance between sample surface and probing tip. The feedback signal is monitored as a func-

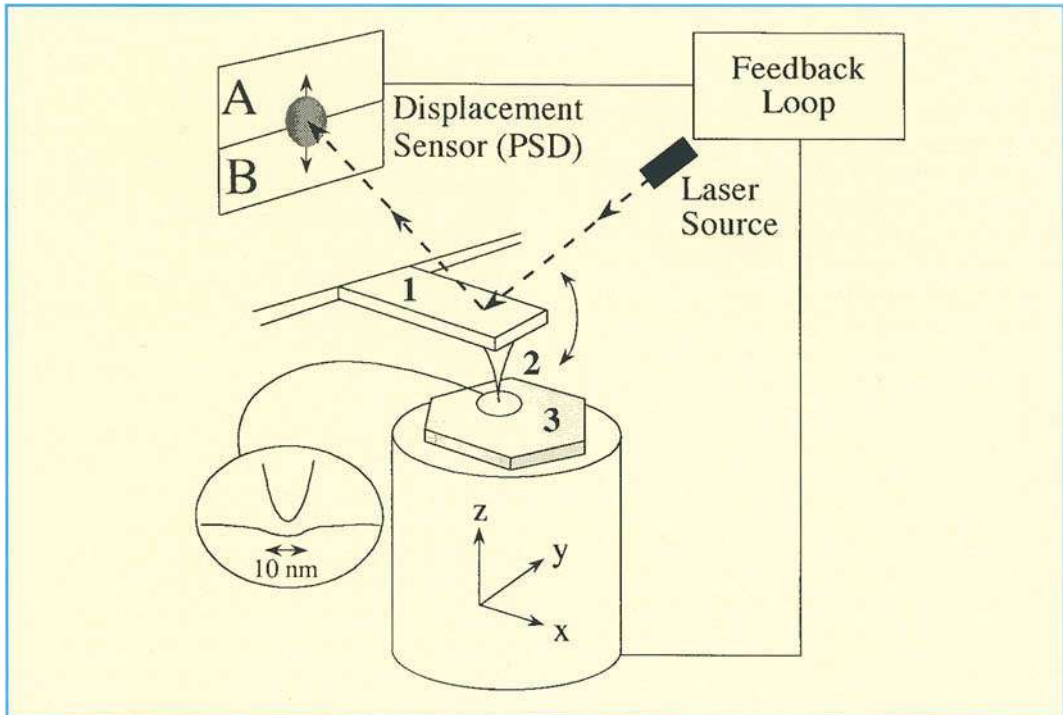


Fig. 8. Schematic diagram of a scanning force microscope (SFM). (1) Cantilever, (2) probing tip, (3) sample surface.

tion of the lateral position of the probe and the image of equiforce contours (termed force micrograph) is obtained. This relief is interpreted as the topography of the sample surface.

In this study a commercially available scanning force microscope, equipped with a beam deflection system for measuring the cantilever displacement was used. This system is widely used in commercially available microscopes because of its simplicity. A laser beam is collimated and focused on the rear side of the cantilever and there reflected off to a segment photo diode acting as a position sensitive detector (PSD). Due to the interaction between probing tip and sample surface, the cantilever is deflected elastically and thereby changes the reflection angle of the laser beam detected by the PSD (Figure 8).

Figure 9 shows a force micrograph of a single aragonite crystal from the nacreous layer. The crystal shows no re-entrant

angles as twins sometimes do (Hurlbut, 1977). It has a thickness of about 600 nm and a diameter of about 5000 nm (5 $\mu$ m). According to Weiner and Traub (1984), the growth of these aragonite hexagons is strongly influenced by an organic matrix covering every single crystal. In confirmation of this theory, the crystals of the mother-of-pearl layer all look as if they are covered with organic matter. Figure 10 is a top view of the crystal in Figure 9. Particles with diameters of 80 to 100 nm can be seen. These particles probably form the organic matrix. They also often show hexagonal shapes which are taken on by the subsequent growth of aragonite crystals (Gutmannsbauer, 1993). It is also known that organic compounds can influence the shape of inorganic crystals. Uric acid causes NaCl crystals to crystallize as octahedra instead of the cubes usually seen. It is possible that a similar process between the organic matter and the arago-

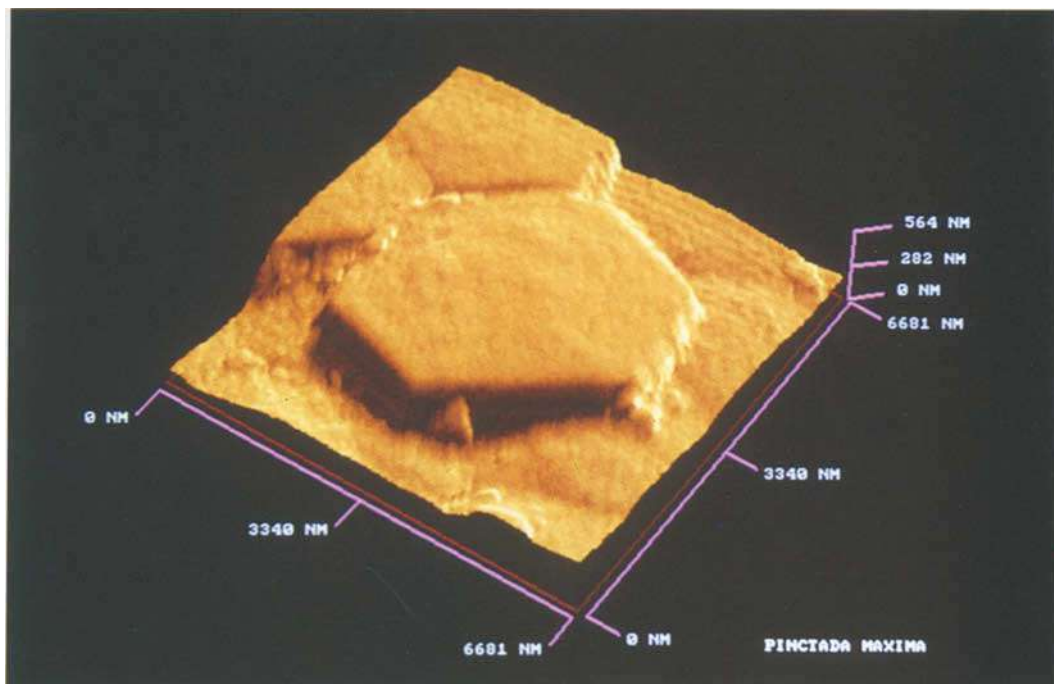


Fig. 9. Scanning force micrograph of an aragonite crystal forming the mother-of-pearl layer in the shell of the salt-water oyster *Pinctada maxima* (Australia). Diameter of the crystal:  $d=5\mu\text{m}$

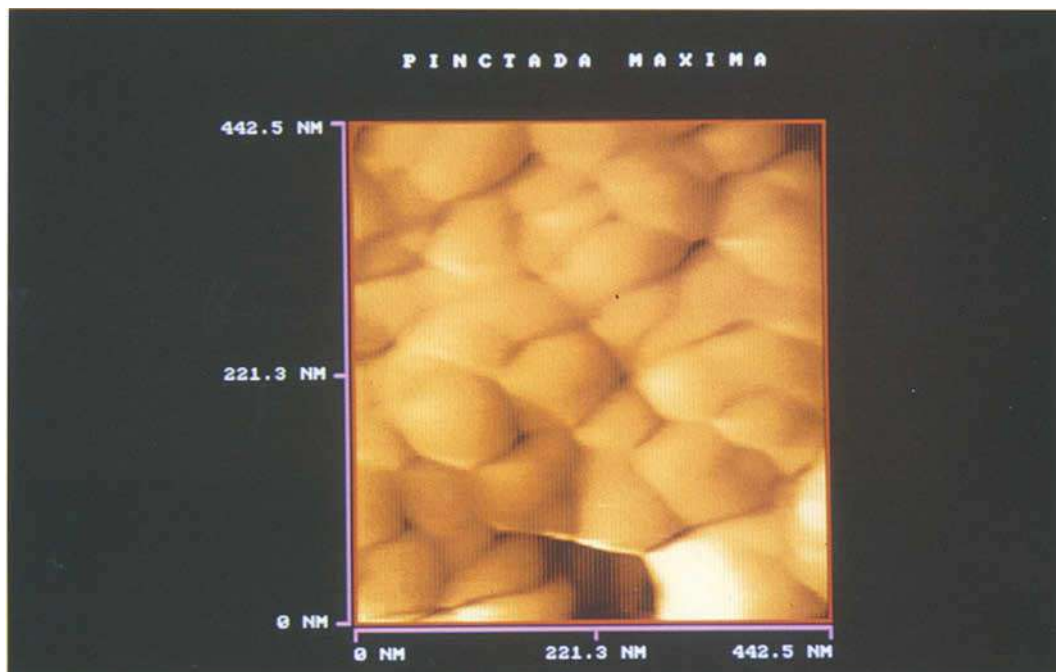


Fig. 10. Scanning force micrograph of the top of the crystal in Figure 9. This is probably the organic matrix that covers every crystal in the shell. Diameter of the polygonal domed areas forming the matrix:  $d=80\text{ nm}$ .

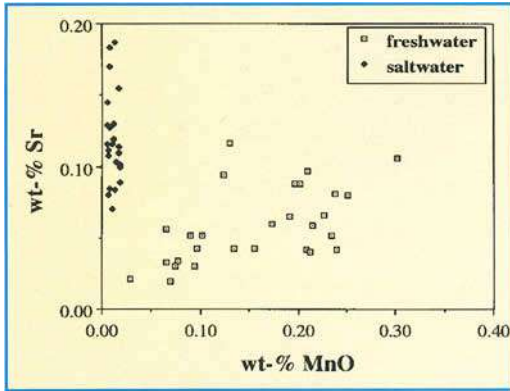


Fig. 11. EDXRF analysis of the Mn and Sr contents in the mother-of-pearl layers of saltwater and freshwater shells.

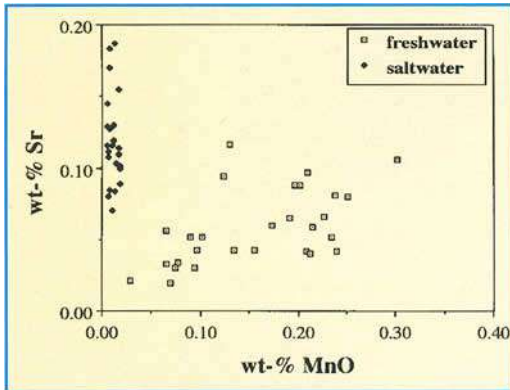


Fig. 12. EDXRF analysis of the Mn and Sr contents in the mother-of-pearl layers of the shells of the freshwater mussels *Hyriopsis schlegeli* and *Anodonta plicata*.

nite crystals influences the growth of the aragonite crystals. According to Lowenstam and Weiner (1989), there is evidence of organic matter inside the crystals.

The thicknesses of these aragonite microcrystals are within the range of wavelengths of visible light, which suggests that the rainbow colours seen on nacre are due to interference.

## Chemistry

### Energy dispersive X-ray fluorescence (EDXRF)

The chemical analyses of the shells were

carried out by EDXRF. This is a spectrometric analysis method for the determination of the chemical composition of usually solid matter. The sample is supplied with radiation energy from an X-ray tube. Due to this irradiation the atoms in the sample also emit X-rays of characteristic wavelength (line spectra) that are typical for every element. The fluorescence or energy is registered by a detector. The detection records simultaneously all major and minor elements with the atomic numbers from Z=11 (Na) to Z=92 (U). Because the power of the X-ray tube is not very high, no radiation damage is caused. For a detailed description see Hahn-Weinheimer *et al.* (1984).

With EDXRF we studied the chemical composition of the periostracum, the mother-of-pearl layers and the pearls of the different species that were available.

The results showed that the composition of the periostracum of all shell material contains a greater number of different elements and in higher concentrations than the corresponding mother-of-pearl layers and pearls. Among the elements found were Na, Mg, S, Cl, K and P. We suggest that these elements give some indication of the composition of the water the animals lived in, but because there is no gemmological relevance for these elements in the periostracum, we will not go into further details.

As earlier investigations have already shown (Farn, 1986), saltwater shells and pearls contain significant lower Mn than those from freshwater. Sr can easily be incorporated in the structure of aragonite instead of Ca, and all of the investigated mussels do incorporate Sr in their shell but not enough for the formation of the mineral strontianite. However, there is no significant difference in the concentration of Sr between salt- and fresh-water shells (Figure 11). The concentration of Mn differs even among the freshwater mussels themselves. The mother-of-pearl layer and pearls of the mussel *Anodonta plicata*

contain significantly less Mn than the mother-of-pearl layer and pearls of the mussel *Hyriopsis schlegeli* (Figure 12). There is no statistically demonstrable difference between these two species with regard to Sr content.

The mother-of-pearl layer and the pearls of the freshwater mussel *Hyriopsis schlegeli* are the only freshwater mussels that contain no K.

The chemical analyses of mother-of-pearl and pearls of the freshwater mussels originating from the Mississippi (*Unio margaritifera*) showed that it is not possible to characterize these in terms of their trace elements. The values of the element concentrations overlap the values found from all other investigated species. This can be explained by considering the vast extent of the Mississippi river system. The river passes through many different geological environments and the element concentrations of the water will vary to a large degree.

It was not possible to find any difference between the element concentrations in the mother-of-pearl layers in shells from different saltwater oysters. However, the pearls of the saltwater oyster *Pinctada martensii* have lower Sr concentrations than the other saltwater pearls.

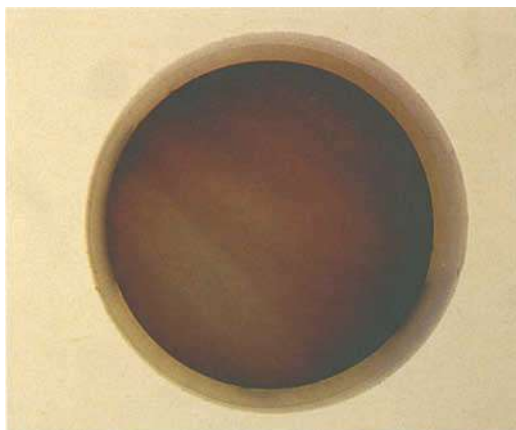


Fig. 13. Akoya cultured pearl with a bead that is treated with an organic dye. 30x

#### Fourier transform infrared spectroscopy (FT-IR)

All the shells and pearls we received were described as untreated. However, nearly all Japanese saltwater grey to black cultured pearls contained beads coloured with an organic dye. Figure 13 shows an Akoya cultured pearl of this kind. The dye causes a series of peaks in the infrared range between 2000 and 1300cm<sup>-1</sup>.

All our samples were tested using FT-IR to determine the presence of calcite or aragonite. A quick identification is possible (Speer, 1983) by checking the spectrum for peaks either at 1492-1432, 879 and 706cm<sup>-1</sup> (calcite) or 1504, 1492, 1080, 866, 711 and 706cm<sup>-1</sup> (aragonite).

#### Conclusions

This study shows that formation of mother-of-pearl and pearl is complex and can only be investigated with the use of specialized instruments. Although this study took one year of research for one of the authors (W.G.), many unsolved problems remain and some new questions have arisen.

The study showed that it is not possible to identify shell species and pearls using only one method. On the contrary, only a combination of techniques can lead to realistic interpretations. For example, the determination of the bivalve that formed a pearl is only possible by a combination of results gained from structural and chemical investigations.

To detect and confirm any treatments (e.g. dyeing) even more techniques are required (e.g. FT-IR).

The investigation of mother-of-pearl is not only of gemmological interest: the growth process itself, including biomineralization is also of great importance in medical research. The nacreous layer of the bivalve molluscs makes available a relatively simple model in which biomineralization processes can be studied.

## Acknowledgements

The large amount of data and the many different analytical methods used mean that this work could not have been done by one single person.

Grateful thanks are extended to Prof. Dr W.B. Stern for supporting this work with his great experience using the XRD and EDXRF, Prof. Dr R. Guggenheim, D. Mathys and M. Düggelin for the professional work on the SEM and Dr H. Stünitz for the investigations with the texture goniometer. Further thanks are extended to Prof. Dr H.-J. Güntherodt and to Dr P. Reimann who enabled the SFM investigations. For fruitful discussions we want to thank Prof. Dr S. Graeser, Dr R. Handschin and R. Lüthi.

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The Swiss Gemmological Institute (SSEF) is acknowledged for its support with FT-IR spectrometer and photomicrograph equipment.

One of the authors (W.G.) wants to thank his co-author and 'diploma father' for guiding him so well during his diploma thesis; and last but not least his fiancée Carmen for bearing with him during this year of research.

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## Dyed natural star corundum as a ruby imitation

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Fig. 1. Dyed natural star corundums; the middle cabochon in the front measures 11.4mm in diameter. (Photo by H.A. Hänni, Basel)

### Abstract

Natural star corundum which is treated with a red dye, most probably in India, is described. The star ruby imitation is easily identified by an uneven colour concentration in fissures or cracks, which irregularly traverse the corundum cabochons. The asterism is caused by orientated inclusions of rutile needles.

### Introduction

Dyed natural corundum as a ruby imitation was recently described by several authors (Schmetzer *et al.*, 1992; Schmetzer and Schupp, 1992; Crowningshield and Reinitz, 1992). For the dyeing procedure yellowish or nearly colourless corundum crystals, probably from East Africa, were used. Microscopic examination of dyed beads as well as cabochon-cut and faceted specimens revealed various natural inclusions and an uneven colour distribution within the samples. The red dye was con-



Fig. 2. Treated natural star corundum cabochon revealing growth zoning confined to prism faces or hexagonal dipyramids; the sample measures 10 x 12mm. (Photo by H.A. Hänni, Basel)



Fig. 3. Growth zoning and concentration of red dye in fissures of treated natural star corundum; the figure represents an area of about 0.4 x 0.6mm.

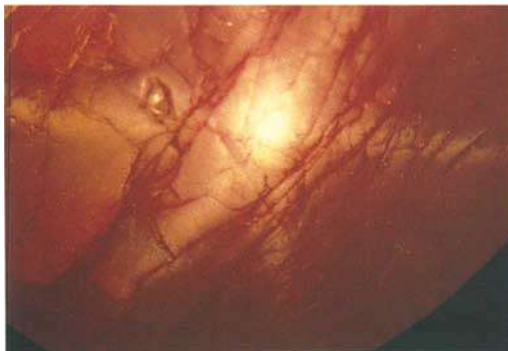


Fig. 4. Concentration of red dye in fissures of treated natural star corundum; the figure represents an area of about 0.4 x 0.6mm.

fined only to irregular fissures and cracks, which showed an extraordinarily intense yellow-orange fluorescence under long-wave ultraviolet radiation. Similar dyed specimens were mentioned by Barot and Harding (1993, 1994), who quoted Kitui in southern Kenya, a new locality for mostly pale-coloured stones, as a possible source for material dyed in India as a ruby imitation.

### Gemmology

Recently 16 cabochon-cut asteriated gemstones were purchased by one of the authors from a dealer in Germany as natural star rubies. The samples ranging from about 7mm to 12mm in size (Figures 1, 2) revealed an intense red body colour and possessed sharp six-rayed stars. From information given by the supplier, these samples were probably imported from India.

Standard gemmological tests identified the cabochon-cut stones as corundum. In several samples the rays of the stars were found to run perpendicular to traces of growth planes parallel to  $\{11\bar{2}0\}$  prism faces and/or parallel to hexagonal dipyramids (Figures 2, 3). This orientation of the six-rayed star is typical for Indian star corundum, the asterism of which is caused by inclusion of rutile needles (cf. Weibel, 1985). The concentration of rutile needles in different growth sectors of the cabochons described in this paper is sometimes variable, which is indicated by different intensities of the milky-white appearance of various growth zones in reflected light (Figure 3).

The characteristic features mentioned above in addition to the observation of natural inclusions and parting planes parallel to the positive rhombohedron  $(10\bar{1}1)$ , which were also present in some of the samples, indicate a natural origin for the cabochons.

During microscopic examination, however, it was observed that the colour of the samples was concentrated in fissures



or cracks, which irregularly traversed the corundum crystals (Figures 3, 4). Under long- or short-wave ultraviolet radiation no fluorescence was observed, neither from the corundum cabochons themselves nor from the dye concentrated in fissures. When a stone was immersed in acetone, part of the red coloration was removed and, subsequent to this test, red spots were visible even on the wrapping material of the stone.

Consequently, the samples were identified as artificially dyed natural star corundum. The lack of a pronounced yellow fluorescence of the red colouring agent in fissures and cracks indicated a different dye compared with the beads and faceted stones described recently in gemmological literature.

### Discussion

A possible source of the natural corundum specimens used for the dyeing process is the Mysore-Karnataka area in southern India, which supplied a great quantity of pale-coloured star corundum in the past. Artificially dyed material from

this locality was mentioned by Hughes (1990), although material similar to the star ruby imitation described in this paper has not previously been observed in the trade by the present authors.

Treated star corundum cabochons can be identified by microscopic examination or even with a hand lens by observation of the uneven colour concentration in fissures or cracks.

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# The rubies and spinels of Afghanistan – a brief history

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## Abstract

While ruby is one of the most important gems, in the twentieth century little has been written about one of the premier sources of antiquity—Afghanistan. The following article is divided into two parts. The first describes the history of Afghanistan's ruby/spinel deposits. Important mines are located near Jagdalek and Gharan (Badakhshan). The latter is believed to be the original source of the balas ruby (spinel); many of the most famous spinels, such as the Timur Ruby and Black Prince's Ruby, possibly originated there. The second part deals with the gemmological characteristics of Jagdalek rubies.

process, claiming it as his own), the author believes that history is better served by repeating their words exactly. Hence the extensive use of quotations from the primary literature (including the original footnotes). In so doing, the danger of misinterpretation is lessened. My own thoughts on the meaning of such quotes follow. This approach allows readers reach their own conclusions on the original authors' intent.

Some may question the need for such extensive historical detail. I include it in an attempt to show the threads of wisdom connecting us with our past. In today's modern world it is easy to believe that anything worth knowing has resulted from recent study. Such is not the case and I hope that this article can open readers' eyes to the glories (and excesses) of human tradition and history.

## Keywords

Afghanistan, Tajikistan, ruby, spinel, gems, history

## Notes on methodology

Whenever possible, quotations found throughout this article have been faithfully transcribed from the original source. The only corrections made have been minor changes in punctuation. As a result, readers may encounter inconsistencies in spelling, etc. My approach has been that, when doubt existed, the original would stand as printed.

Certain quotations are quite lengthy. Rather than rewriting or paraphrasing what others have found (and, in the

## The great enigma: Afghanistan's ruby/spinel mines

Afghanistan's ruby/spinel mines are one of the great mysteries of gemmology. Historically, rubies and red spinels have been produced from four areas: Myanmar (Burma), Sri Lanka, the Thai/Cambodian border (ruby only; no red spinel) and Afghanistan. While extensive accounts exist regarding the other deposits, in the twentieth century little has been written about the rubies/spinels of Afghanistan. Indeed, many are totally unaware of the Afghan occurrences.

While I have visited Afghanistan and have personally examined many rubies

from Jagdalek, I have not visited either of the two major deposits described. Thus the following has been assembled from a number of historical sources, with much of the primary research on inclusions in Jagdalek stones coming from the author's own research.

In terms of historical data, rather than rewriting or paraphrasing what others have found and, in the process, claiming it as his own, the author believes history is better served by repeating their words exactly, warts and all. Hence the extensive use of quotations from primary literature (including the original footnotes from those sources).<sup>1</sup>

### Early history: AD1000–1895

Afghanistan's ruby/spinel mines were mentioned in the Arabic writings of many early travellers, including al-Muqaddasi (c. tenth century), al-Biruni (b. 973; d. c. AD1050), Teifaschi (AD1240), and Ibn Battuta (AD1325–1354).

Mohammed Ben Mansur, writing in the twelfth century, stated during the time of Abbaside (caliphs who ruled from AD750 to AD1258), a hill at Chatlan was broken open by an earthquake and within a white rock in the fracture was found the 'Laal-Bedashan' (balas ruby). Women of the neighbourhood apparently tried to extract dye<sup>2</sup> from the red stones and, failing, threw them away. Later a jeweller recognized their value (Ball, 1931).

Although Marco Polo (c. AD1254–1324) apparently did not visit the mines, he passed nearby. In Henry Yule's definitive version (1920) of Marco Polo's travels is the following (with Yule's and Henri Cordier's notes following a translation of Polo's text):

#### Polo's text

BADASHAN is a Province inhabited by people who worship Mahommet, and have a peculiar language. It

forms a very great kingdom, and the royalty is hereditary...

...It is in this province that those fine and valuable gems the Balas Rubies are found. They are got in certain rocks among the mountains, and in the search for them the people dig great caves underground, just as is done by miners for silver. There is but one special mountain that produces them, and it is called SYGHINAN. The stones are dug on the king's account, and no one else dares dig in that mountain on pain of forfeiture of life as well as goods; nor may any one carry the stones out of the kingdom. But the king amasses them all, and sends them to other kings when he has tribute to render, or when he desires to offer a friendly present; and such only as he pleases he causes to be sold. Thus he acts in order to keep the Balas at a high value; for if he were to allow everybody to dig, they would extract so many that the world would be glutted with them, and they would cease to bear any value. Hence it is that he allows so few to be taken out, and is so strict in the matter.\*

#### Yule's annotation

\* I have adopted in the text for the name of the country that one of the several forms in the G. Text which comes nearest to the correct name, viz. *Badasian*. But *Balacian* also appears both in that and in Pauthier's text. This represents *Balakhshān*, a form also sometimes used in the East. Hayton has *Balaxcen*, Clavijo Balaxia, the Catalan Map *Baldassia*. From the form *Balakhsh* the Balas Ruby got its name. As Ibn Battuta says: 'The Mountains of Badakhshan have given their name to the Badakhshi Ruby, vulgarly called *Al Balaksh*.' Albertus Magnus says the *Balagius* is the female of the Carbuncle or Ruby Proper, 'and some say it is his house, and hath thereby got the name, quasi *Palatium* Carbunculi!' The Balais or Balas Ruby is, like the Spinel, a kind inferior to the real Ruby of Ava. The author of the *Masālak al Absār* says the finest Balas ever seen in the Arab countries was one presented to Malek 'Adil Kethboga, at Damascus; it was of a triangular form and weighed 50 drachms. The prices of *Balasci* in Europe in that age may be found in Pegolotti, but the needful problems are hard to solve.

No sapphire in Inde, no Rubie rich of price,  
There lacked than, nor Emerald so grene,  
Balès, Turkès, ne thing to my device.  
(Chaucer, 'Court of Love.')

L'altra letizia, che m'era già nota,  
Preclara cosa me si fece in vista,  
Qual fin *balascio* in che lo Sol percuoto.  
(*Paradiso*, ix. 67)

2. Lapis lazuli, also from Badakhshan, was an important source of pigment in ancient times (*viz.* ultramarine, which is made by crushing lapis). Thus the actions of these women are understandable. However, corundum and spinel, unlike lapis, are coloured by impurities. Thus their streak, and their colour when crushed, is colourless.

1. All footnotes attached to quotations are those of the original authors and are indicated with symbols (\*, †, etc.). My own footnotes are at the bottom of the page and are numbered - RWH.

**Cordier's annotations**

[...d'Ohsson translates a short account of Badakhshan by Yakut (+1229), stating that this mountainous country is famed for its precious stones, and especially rubies, called *Balakhsh*.] (Bretschneider, *Med. Res.* II p. 66.)—H.C.]

The account of the royal monopoly in working the mines, etc., has continued accurate down to our day. When Murad Beg of Kunduz conquered Badakhshan some forty years ago, in disgust at the small produce of the mines, he abandoned working them, and sold nearly all the population into slavery! They continue to remain unworked, unless clandestinely. In 1866 the reigning Mir had one of them opened at the request of Pandit Manphul, but without much result.

The locality of the mines is on the right bank of the Oxus, in the district of Ish Káshm and on the borders of SHIGNAN, the *Syghinan* of the text. (*P. Manph.*; Wood, 206; *N. Ann. des. V.* xxvi. 300.)

[The ruby mines are really in the Gháran country, which extends along both banks of the Oxus. Barshar is one of the deserted villages; the boundary between Gháran and Shignán is the Kuguz Parin (in Shighai dialect means 'holes in the rock'); the Persian equivalent is 'Rafak-i-Soumakh'.] (Cf. Captain Trotter, *Forsyth's Mission*, p. 277.)—H.C.]

Henry Yule, 1920,  
*The Book of Ser Marco Polo*

**The famous Moorish traveller, Ibn Battuta (Batuta) (AD1325–1354), mentioned the following:**

People generally attribute the lapis-stone [lapis lazuli; Arabic *lazward*] to Khurasan, but in reality it is imported from the mountains of [the province of] Badakhshan, which has given its name also to the ruby called *badakhshi* (pronounced by the vulgar *balakhshi*)...

H.A.R. Gibb,  
*The Travels of Ibn Battuta*, Vol. 3, 1971

In 1832, James Prinsep published a fascinating paper in the *Journal of the Asiatic Society of Bengal*. This contained abstracts of three different oriental works, translated into English by Raja Kalíkishen<sup>3</sup>, some of which covered the ruby/spinel deposit of Badakhshan:

**DODECAHEDRAL CORUNDUM  
OR SPINELLE RUBY**

Persian: *lál*; HINDU: *manik*? or *lál*.

The mine of this gem was not discovered until after a sudden shock of an earthquake, in *Badakhshan*<sup>4</sup>, had rent asunder a mountain in that country, which exhibited to the astonished spectators a number of sparkling pink gems of the size of eggs. The women of the neighbourhood thought them to possess a tinged quality, but finding they yielded no colouring matter, they threw them away. Some jewellers, discovering their worth, delivered them to the lapidaries to be

worked up, but owing to their softness the workmen could not at first polish them, until they found out the method of doing so with *mark-i-shisá*, marcasite or iron pyrites. This gem was first esteemed more than the *yaqút*,<sup>5</sup> but as its colour and hardness were found to be inferior to the latter, it became less prized. ...'

In a manuscript history of Cashmir and the countries adjacent, by Abdúl Qádir Khan, Benares, 1830, is the following description of the manner of extracting rubies from the *Badakhshan* mines: it professes to be taken from an oral account by Mirza Nazar Báki Bég Khán, a native of Badakhshán, settled at Benares.

Having collected a party of miners, a spot is pointed out by experienced workmen, where an adit is commenced. The aperture is cut in the rock large enough to admit a man upright: the passage is lighted at intervals by cotton mashúls placed in niches; as they proceed with the excavation, the rock is examined until a vein of reddish appearance is discovered, which is recognized as the matrix of the precious gem. This red coloured rock or vein is called *rag-i-lál*, or, the vein of rubies; the miners set to work upon this with much art, following all its ramifications through the parent rock. The first rubies that present themselves are small, and of bad colour: these the miners called *piadehs* (foot soldiers): further on some larger and of better colour are found, which are called *savars* (horse soldiers); the next, as they still progress in improvement, are called *amirs*, *bakshis*, and *vazirs*, until at last they come to the *king jewel*, after finding which, they give up working the vein: and this is always polished and presented to the king. The author proceeds to describe the finest ruby of this kind that had ever fallen under his observation. It belonged to the Oude family, and was carried off by Vizir Ali; he was afterwards employed in recovering it from the latter: it was of the size of a pigeon's egg, and the colour very brilliant; weight, about two tolas; there was a flaw in it, and to hide it, the name of *Julál-ud-dín* was engraved over the part; hence the jewel was called the *lál-i-jaláii*. A similar ruby to this, but considerably larger, is in the possession of *Runjit Sinh*, and has the names of five emperors engraved upon it.

James Prinsep and Raja Kalíkishen, 1832

\*The *Manaiif-ul-ahjár* dates this occurrence '350 years ago', but the date of the work is not given: the *lál* is not mentioned by *Zakarya*. Since the above was written, Mr. H.H. Wilson has favoured me with a sight of another work on jewels, entitled *Khawás-ul-*

<sup>3</sup>The information was extracted from three books, of different eras: 1, the *Ajáib-ul-makhlúkát o Gharáib-ul-moujudát*, an ancient Persian work on natural history, written by *Zakarya*, a native of *Kufa*, date unknown; 2, the *Aqul-i-ashreh*, a work on science, by Mahomed of Berar, An Hej. 1084 (AD1673); and 3, the *Jawáhir-námeh*, a modern anonymous compilation, containing much useful matter in a condensed form: it was probably written at one of the native courts, either Delhi or Hyderabad, since it mentions the opening of [then] recent mines in India (Prinsep and Kalíkishen, 1832).

<sup>4</sup>*Yaqut* is a Persian-Arabic term for corundum. Ancient Arab minerologists placed all colours of ruby-sapphire under *yaqut* (Prinsep, 1832).

### Famous balas rubies— blood-red souvenirs of conquest

Among the most storied stones of history are the large balas rubies found in museums and gem collections throughout the world. The Diamond Fund in Russia has a number of representative examples. Noted Russian gemmologist/mineralogist, Alexander Fersman, remarked ‘...in the Diamond Fund these spinels have a significant place. One of such stones, weighing 100 carats, speaks to us of the sands of Ceylon, but the majority of them come from Afghanistan, from the mountains of the province of Badakhshan. In old Russian manuscripts it was called “lal Badakhshan” (Fersman, 1946, p. 374).

Prominent among spinels in the Diamond Fund is the massive red orb atop the Imperial Russian Crown. This crimson colossus tips the scales at 414.30 ct (Twining, 1960). A rather fanciful description of this stone’s history has been given by Yevdokimov (1991). It was said to have been found by Chun Li, a Chinese-mercenary member of Timur’s army that looted Samarkand. Unfortunately for Chun Li, he failed to turn in some of the booty, and so was exiled in slavery to the ruby mines of Badakhshan. Finding the stone, he crept away in the night and made his escape. But his attempt to present it to the Chinese emperor was thwarted when a palace guard found the stone and killed him for it. This guard was similarly killed when a jeweller he tried to sell the stone to, informed on him. Thus the gem passed to the emperors. In 1676, the ruby was purchased ‘at a pretty price’ from emperor Kon Khan by Nikolai Spafari, at the behest of Alexei Mikhailovich, second tsar of the Romanov dynasty. Upon the ascendancy of Catherine II (‘the great’) to the throne in 1762, she had the stone mounted on the top of her crown, where it remains today (Yevdokimov, 1991).

The Black Prince’s Ruby is perhaps the most famous balas ruby in existence (Figure 4). Since its story has been told so many times before (see Hughes, 1990) I will not tell it again. Less well-known among spinels, but no less interesting, is the Timur Ruby, or Khiraj-i-alam (‘Tribute to the World’). The last of the great nomad kings to overrun the world, when not conquering far-off lands, Timur [also known as Shah Qiran; b. 1336?; d. 1405] made his base at Samarkand, where legendary feasts and orgies were held (Collins, 1968).

The Timur Ruby weighs 352.50 ct and is currently in the collection of HM Queen Elizabeth II. The stone carries several Persian inscriptions written in Arabic, the longest of which reads: ‘This is the ruby among the twenty-five thousand jewels of the King of Kings, the Sultan Sahib Qiran.’ The Ruby is said to have passed into his hands when he sacked Delhi in 1398 and, after the usual pillage and extortion, was later obtained by Ranjit Singh, the ‘Lion of the Punjab’. The British annexed the Punjab in 1849. Along with the province, they also ‘annexed’ both the Koh-i-Nur diamond and the Timur Ruby, which were later presented to Queen Victoria (Twining, 1960).



Fig. 4. The Black Prince’s Ruby, a historic red spinel set in the Imperial State Crown and displayed in the Tower of London. A ruby, set in gold, is secured to the top of the spinel. (Photo by F. Greenaway, by kind permission of H.M. The Queen. Crown copyright reserved)

*hejár*, translated by himself, in which the *lál* is treated of under the name of *balaksh* (*Balakshan* being synonymous with *Badakhshan*). This leaves no doubt as to the origin of the word Balas...

The inscriptions mentioned on the ruby owned by Ranjit Singh ('Runjit Sinh') suggest that this was the Timur Ruby now in the collection of the British monarch (see p.259).

In 1836, Captain John Wood began an epic journey to trace the headwaters of the Oxus river. He did attempt to visit the ruby mines in Badakhshan, but due to inclement weather was unsuccessful. The following is his account:

The ruby mines are within twenty miles of Ishkashm, in a district called Gharan, which word signifies caves or mines, and on the right bank of the river Oxus. They face the stream, and their entrance is said to be 1200 feet [366 m] above its level. The formation of the mountain is either red sandstone or limestone largely impregnated with magnesia. The mines are easily worked, the operation being more like digging a hole in sand, than quarrying rocks.... The galleries are described as being numerous, and running directly in from the river. The labourers are greatly incommoded by water filtering into the mine from above, and by the smoke from their lamps, for which there is no exit. Wherever a seam or whitish blotch is discovered, the miners set to work; and when a ruby is found it is always encased in a round nodule of considerable size. The mines have not been worked since Badakhshan fell into the hands of the Kunduz chief, who, irritated, it is supposed, at the small profit they yielded, marched the inhabitants of the district, then numbering about five hundred families, to Kunduz, and disposed of them in the slave market. The inhabitants of Gharan were Rafizies, or Shiah Mohamedans, and so are the few families which still remain there.

John Wood, 1841  
*A Journey to the Source of the River Oxus*

A mention of the Badakhshan mines was made by Pandit Manphúl, in a report dated 1867. His report is important for, unlike most others, he seems to have examined actual specimens. Manphúl said:

The Ruby Mines are situated in *Ishkasham*, bordering on *Shighnán*.... The Ruby mines have not been worked for the last twenty years and upwards. They were then given up in consequence of the labour spent on them not having been sufficiently rewarded; whether the mines had been exhausted, or whether the workers were unskilful, or managed to steal the more precious stones, is not certain. The present Mir,

who had one of the mines worked last year (AD1866), at my request, made over to me some of the best specimens brought to him. They are not the best of their kinds, unless the one encased in a nodule turn out to be so. The Mir, depreciating the skill of the present workers, who are natives of the country, and, according to an established usage, labour for nothing, is anxious to secure the services of competent miners... It is believed that the mines are still stealthily worked by the people living near them, with, or without the countenance and connivance of the servants of the Mir charged with their management. The mines are known to have yielded rubies of six different colours, viz. red, green, white, yellow, violet, and rosy. The specimens with me are white, violet, and rosy. The ruby (*lál*) has given Badakhshan a lasting celebrity in the world of Oriental poetry. The *Sohanmakkhi*\* also comes out of the Ruby Mines.

\*Corundum?

Pandit Manphúl,  
*Badakhshán and the Countries around it*  
(see Yule, 1872)

Valentine Ball (1881), Irishman *extraordinaire*, former head of the Geological Survey of India and author of *Tavernier's Travels in India*, also remarked on the mines, under the topic of spinel:

*Afghanistan*—In the year 1879 the so-called ruby mines of the late Amir of Afghanistan, Shir Ali, which are situated near the village of Jagdalak in Kabul, were visited by Major Stewart of the Guides. Two specimens of stones, called *yakul* by the natives, and samples of the matrix, were forwarded to the office of the Geological Survey for examination. The stones proved to be spinel, and the matrix a crystalline micaceous limestone. Major Stewart\* states that the Amir kept a strict guard over the mines and only allowed particular friends of his own to work them.

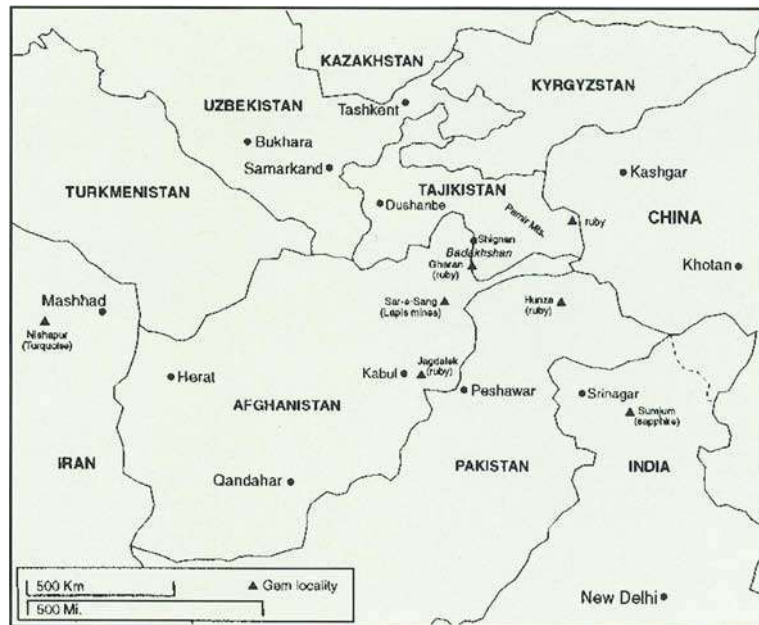
*Badakhshan*—The balas ruby mines of Badakhshan are situated on the banks of the Shighnan, a tributary of the Oxus. They have been known by reputation for very many centuries, and the name balas is derived from Balakshan, another form of writing the name of the country or from Balkh the capital town.† This may possibly be the origin of the common mistake made in English works on precious stones, namely, that these mines are situated in Balochistan! ...

\*Proc. As. Soc. Bengal, 1880, p. 4.  
†Prinsep J. Jour. As. Soc. Bengal, Vol. I, p. 359

Valentine Ball, 1881  
*A Manual of the Geology of India, Part III: Economic Geology*, pp 429-30

Ball claimed that the Jagdalek stones were spinel. While spinel could possibly also occur there, a later analysis reported by F.R. Mallet (1887) proved that the two

Fig. 1. Major gem deposits of central Asia. Corundum is found at Sumjum (India), Hunza (Pakistan), Jagdalek (Afghanistan) and Gharan (Afghanistan/Tajikistan), as well as along the China/Tajikistan border.



specimens collected were, in fact, rubies.

An early mention of the rubies of Badakhshan is found in the writings of the Spaniard, Ruy Gonzalez de Clavijo, who visited the court of Timur<sup>5</sup>, at Samarkand in the years AD1403–06.

The lord [Timour] caused all the Meerzas and nobles in the land of Samarcand to come to this festival; amongst whom was the lord of Balaxia, which is a great city, where rubies are procured; and he came with a large troop of knights and followers.

The ambassadors went to this lord of Balaxia, and asked him how he got the rubies; and he replied that near the city, there was a mountain whence they brought them, and that every day they broke up a rock in search of them. He said that when they found a vein, they got out the rubies skilfully, by breaking the rock all round with chisels. During the work, a great guard was set by order of Timour Beg; and Balaxia is ten days journey from Samarcand, in the direction of India.

C.R. Markham, 1859  
*Embassy of Ruy Gonzalez de Clavijo to the Court of Timur, at Samarcand, AD 1403–6*

Bauer (1904) describes both the Jagdalek and Badakhshan deposits. Of the latter,

5. Tamerlane is an English corruption of *Timur i leng* ('Timur the lame'), as Timur was crippled in battle when about 27 years old (Collins, 1968).

Bauer said:

The ruby mines of Badakhshan were famous in olden times, and they supplied some of the vast store of treasure amassed by the Great Mogul. They are situated in Shignan, on the bend of the Oxus river, which is directed to the south-west, in latitude about 37°N. and longitude 71.5°E. They lie between the upper course of the Oxus and its right tributary the Turt, near Gharan, a place the name of which is said to signify 'mine,' sixteen miles [26 km] below the town of Barshar, in the lower, not the higher, mountain ranges...

It is possible that the rubies and spinels which have recently come into the market through Tashkent, and which, according to the merchants, were mined in the Tian-Shan Mountains, are in reality from these same mines. There is no reliable information as to the existence of ruby mines in the Tian-Shan Mountains or in Tibet, so that the 2000 carat ruby recently received by Streeter, and said to come from Tibet, may also have been found in these mines on the Oxus.

Max Bauer, 1904  
*Precious Stones*

There is little mention of the Badakhshan mines after Bauer, possibly because they lie on the border of, or inside, Tajikistan, a region of the former USSR little visited by foreigners. Barthoux (1933) discussed the mines, stating that they lay near the village of Siz, in the area of *Gharan*, on the right



Fig. 2. View overlooking the Jagdalek ruby mines, Afghanistan. The mines are located in a limestone band which appears as a thin white line on the most distant hills at the rear of the picture. (Photo by Gary Bowersox)



Fig. 3. Afghan miners drilling the limestone for rubies at Jagdalek, Afghanistan. (Photo by Gary Bowersox)

bank of the Oxus. He reported that huge, translucent, purplish pink octahedrons (*'le rubis balais'*) over 20 cm in size were extracted at that locality. Almandine garnet was said to occur on the left bank. Barthoux also stated that a more important occurrence of ruby was at Jagdalek (*'Djagdalik'*). The larger pieces were mostly massive, but smaller pieces showed traces of *'p* {10 $\bar{1}$ 1}, *a* {0001}, *d* {11 $\bar{2}$ 0} and *e* {22 $\bar{4}$ 3}'. They were found with spinel and most were pink in colour. Also occurring with the rubies were humite, chondrodite, phlogopite, fuchsite, rutile, sphene, hematite and pyrite (Barthoux, 1933; trans. for the author by Olivier Galibert, 3 June 1994).

After Barthoux, discussion of Afghan rubies was restricted to the Jagdalek mines. During the Soviet occupation, mining of all Afghan gem and mineral deposits was controlled by the state (Boa, 1987). However, since many mines lay in inaccessible areas, such mining became an important source of income for the rebels. With the Soviet withdrawal, modern exploration and



### Badakhshan ruby/spinel: myth or reality?

From the historical record, it is clear that the Badakhshan mines were of great importance during the period from AD1000–1900. While it is impossible to speculate about ruby, it is safe to say that, based on the numerous historical accounts, the Badakhshan mines were the source of many of the finest early red spinels in gem collections around the world, such as those in the crown jewels of Iran, the collection in Istanbul's Topkapi, Russia's Kremlin and Diamond Fund, and England's Tower of London.

Unfortunately, in modern times, such mines are largely overlooked. Twentieth-century gemmologists persist in the belief that the only source of big red spinels is Myanmar (Kammerling, *et al.*, 1994). This is not based upon any particular evidence, such as inclusion studies; for these studies do not exist, either for Myanmar spinels or for those from Badakhshan.\* Instead, it simply rests upon the belief that what is today, has always been.

While evidence for the existence of the Badakhshan mines is not direct, it is substantial. We have the name *balas ruby*, which is apparently derived from an ancient word for Badakhshan, we have numerous detailed accounts of the mining, we have spinels with Arabic inscriptions and we have historical names, such as the *Timur* ruby. Circumstantial? Indeed. But if circumstantial evidence was of no value, the world's jails would be empty.

\*Occasional photos of inclusions in Burmese and Sri Lankan spinel have been published. But since no *in situ* collecting has been done at the Badakhshan mine, and little in Burma, it is impossible to say whether similar inclusions will be found at each deposit. Remember, rutile silk has been found in rubies from virtually every deposit except Thailand/Cambodia. Similar inclusions are often found in stones from different mines.

exploitation might become possible, thus increasing the output from Afghanistan.

#### Other Afghanistan localities

Streeter (1892) did mention a ruby of 10.50 ct brought to England from mines at Gandamak, about 20 miles (32 km) from Jagdalek. Due to the proximity of these localities, it is possible that the stone actually came from Jagdalek. Griesbach (1892) reported rubies 20 miles (32 km) west of Tatang in a coarse, micaceous marble.

Gary Bowersox reported that gem-quality ruby had been found north-east of Kabul (Koivula, 1987). No further details are available. Ghaggi has also been reported as a source of ruby. About 1986, American dealer Dudley Blauwet purchased a large, euhedral yellow sapphire crystal said to have originated from Dharipiche, Kunar Province, north-eastern Afghanistan (pers. comm., 19 Sept 1994).

#### Tajikistan

In the late 1980s, large reddish spinels were reported from the Pamir mountains of what is now Tajikistan. One 532 ct rough yielded cut gems of 146.43 and 27.81 ct (Bancroft, 1989, 1990). It is not known if the mine that produced these specimens is the same as the Badakhshan mine described above (Peter Bancroft, pers. comm., June 1994). Ruby was also reported in eastern Tajikistan, near the border with China, in the early 1980s (Bank and Henn, 1990; Henn, *et al.*, 1990). The mine is said to be located at Turakuloma, some 40 km north-west of Murgap, at 4500 m above sea level, in a mineralized zone of marbles. However, this deposit is far from the Afghan border.

#### Summary

The above accounts clearly describe two separate mines for ruby and/or spinel.

One, located at Jagdalek (spelled variously, *Jagdalak* or *Jegdalek*), 51.5 km (32 miles) east of Kabul, and another further north in Badakhshan, on the banks of the Shignan, a tributary of the Oxus (Amu Darya), near Gharan, just north of Ishkâsham.

According to Alexander Fersman (1946–47), noted Russian mineralogist/gemmologist, 'From the mines at the mouth of the Kuga-Lial River, the East for a thousand years has been getting its red stones—bright rubies and pinkish-red spinels, called *lal*.'<sup>6</sup> Gary Bowersox has told the author that the Afghan name of the Badakhshan mine is *Kuh-i-lal* ['the place of ruby/spinel'] (pers. comm., 1 July 1994). Undoubtedly the localities described by Fersman and Bowersox are identical.

Political difficulties and rugged terrain make Afghanistan a difficult country to explore, and Tajikistan is no better. Until someone manages to visit the Badakhshan mines, and lives to tell the tale, we must be content with mere speculation.

### Characteristics of Afghanistan ruby (Jagdalek)

Nothing exists in the literature regarding the gemmological characteristics of rubies or spinels from Badakhshan, primarily because no twentieth-century eyewitness accounts exist of the mines. In addition, gemmological descriptions of the important specimens of history, such as the Timur ruby and the Black Prince's ruby, have never been published.

The situation at Jagdalek is somewhat better. Material has filtered out throughout the 1980s. In the early part of that decade, the author acquired a number of faceted and rough specimens from Jagdalek. The following is based on his first-hand studies, supplemented by those of Bowersox (1985), Barthoux (1933), Beesley (1986), Brückl (1937) and Themelis (1988).

### Occurrence:

Afzali (1981) has reported the Jagdalek mine to lie in Kabul province at 34° 26' N, 69° 49' E. For those who read German, the most complete description of the mine is that of Brückl (1937). The rubies are said to occur embedded in a regionally-metamorphosed marble cut by granitic intrusions of Oligocene age.

### Colour range:

Rubies from Jagdalek are only rarely encountered in faceting quality, but when clean can be magnificent. In terms of colour, Jagdalek rubies resemble most the gems of Vietnam, Burma and Sri Lanka, being strongly fluorescent and often of a slightly pinkish or raspberry-red hue similar to rubellite tourmaline. A small percentage are of violet hue.

### Solid inclusions:

Various types have been found in Afghan rubies. Common are colourless blocks displaying rhombohedral cleavage, most likely of calcite. Inclusions of calcite are not surprising, considering the fact that Jagdalek rubies are found in a marble matrix, just as in Burma. Transparent plates and books of hexagonal outline are also seen. Due to their anisotropic character between crossed polars and prominent basal cleavage, they are most likely mica. Other plate-like inclusions consist of irregular distorted shingles which are opaque and black or slightly gold in color. These also display a somewhat micaceous appearance. Additional solid inclusions seen were rounded colourless grains of low relief and, in one specimen, corroded blocks of a yellow colour. Several specimens examined by the author contained deep red-orange prisms of square outline and submetallic luster. Some were knee-shaped twins with obvious re-entrant angles, indicating rutile.

6. *Lal* is the Persian word for balas ruby. In Chinese, it is *la* (Bretschneider, 1887).

Table I: Properties of Jagdalek (Afghanistan) ruby

<i>Property</i>	<i>Description</i>
Colour range/phenomena	<ul style="list-style-type: none"> <li>Near colourless to a deep red, often slightly purplish, strongly fluorescent. Violet stones are seen on occasion.</li> </ul>
Geological formation	<ul style="list-style-type: none"> <li>Ruby is found embedded in a regionally metamorphosed marble cut by granitic intrusions of Oligocene age.</li> </ul>
Crystal habit	<ul style="list-style-type: none"> <li>Most crystals are hexagonal prisms (short or long) with development of rhombohedron and pinacoid faces. Spindle-shaped bipyramids are also sometimes seen.</li> </ul>
RI and birefringence	$n_E = 1.762$ ; $n_O = 1.770$ ; birefringence = 0.008
Specific gravity	~4.00
Spectra	<b>Visible region</b> <ul style="list-style-type: none"> <li>Strong Cr spectrum (similar to rubies from other localities)</li> </ul>
Fluorescence	<b>UV</b> <ul style="list-style-type: none"> <li>Strong reddish to reddish-orange fluorescence (LW stronger than SW).</li> </ul>
Other features	May be dyed or heat treated.
<i>Inclusion types</i>	<i>Description</i>
Solids	<ul style="list-style-type: none"> <li>Calcite; rhombs</li> <li>Phlogopite mica; books</li> <li>Rutile; prisms and knee-shaped twins</li> <li>Garnet</li> <li>Chondrodite</li> <li>Apatite</li> <li>Pyrite</li> <li>Spinel</li> <li>Graphite</li> <li>Hornblende</li> <li>Dolomite</li> </ul>
Cavities (liquids/gases/solids)	<ul style="list-style-type: none"> <li>Primary negative crystals.</li> <li>Secondary healed fractures are common. They occur in a variety of patterns and thicknesses.</li> <li>Iron oxide stains are common in cracks (these stains can be eliminated during heat treatment).</li> </ul>
Growth zoning	<ul style="list-style-type: none"> <li>Straight, angular growth zoning parallel to the faces along which it formed; irregular 'treacle'-like swirls in other directions. Distinctive are the blue colour zones intermingled in most stones, similar to Vietnamese rubies. Growth zoning is extremely sharp and prominent.</li> </ul>
Twin development	<ul style="list-style-type: none"> <li>Growth twins of unknown orientation.</li> <li>Polysynthetic glide twinning on the rhombohedron.</li> </ul>
Exsolved solids	<ul style="list-style-type: none"> <li>Dense zoned clouds of (often, but not always) tiny particles (probably rutile), parallel to the hexagonal prism (3 directions at 60/120°) in the basal plane.</li> <li>Boehmite, long white needles along intersecting rhombohedral twin planes (3 directions, 2 in one plane, at 86.1 and 93.9°).</li> </ul>

### Cavities:

Both primary and secondary liquid inclusions are seen, the latter being responsible for the lack of clarity which most of these rubies display. Irregular, liquid-filled cavities with jagged edges (much like those in Colombian emeralds) are also found. However, the cavities of the Jagdalek rubies are somewhat thicker. The fingerprints and feathers which fill these stones often show a ragged appearance, with coarse tubes that can easily be confused with the flux inclusions in flux-grown synthetic rubies.

### Growth zoning:

Colour zoning in Jagdalek rubies is extremely sharp and narrow, forming in the typical hexagonal pattern when viewed parallel to the *c* axis. The most distinctive feature of Jagdalek rubies are the small spots or zones of a sapphire-blue colour. At times, these blue zones may be hexagonal in outline while in other cases they consist of narrow bands, but all show a sharp division between red and blue. Similar blue zoning is seen in Vietnamese rubies and in Myanmar rubies from Mong Hsu.

### Twin development:

Rhombohedral polysynthetic twin lamellae are seen in most specimens, inevitably accompanied by long white boehmite needles meeting at 86.1/93.9°.

### Exsolved inclusions:

While exsolved rutile needles have not been found, clouds of tiny exsolved particles of what may be rutile have been seen. The lack of true silk means that star rubies are not produced. Cabochons may show a silvery sheen though, from reflection off the particles. Exsolved boehmite needles are common at the junctions of intersecting rhombohedral twin lamellae.

### Acknowledgements

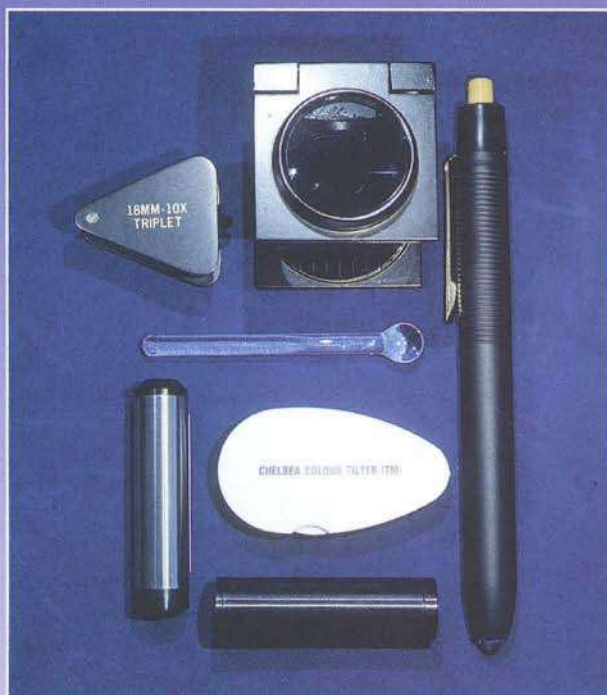
The author would like to give thanks to those who have assisted in this article. First, to Bob Frey, a prince of a man, who has gone above and beyond the call of duty in both editing and helping the author locate obscure references. May all his dreams come true. Secondly, to Paul Picus, of rapier wit and red pen, whose advice has been a constant source of joy. Thirdly, to Gary Bowersox, American-born, but doubtless an Afghan in a previous lifetime. Finally thanks are expressed to the Lord Chamberlain's Office and to Her Majesty's Stationery Office for permission to reproduce a picture of the Black Prince's Ruby.

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## Mineral and chemical compositions of jadeite jade of Myanmar

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### Abstract

This research work contributes mineralogical and chemical data for jade varieties of Myanmar (Burma). From petrographic examination and XRD analysis, jade of Myanmar can be defined as a monomineralic (pure jade) or polymineralic (impure jade) rock. Twenty five specimens were studied and about two thirds consist essentially of jadeite and one third of jadeite plus amphiboles and/or other pyroxenes. Edenite, richterite and tremolite are major associated minerals; kosmochlor, enstatite and chromite/ magnesiochromite are minor associated minerals. Rutile/ilmenorutile are frequently present as acicular inclusions in jadeite. No albite was observed in any of the jade specimens studied. XRF analyses demonstrated a wide range in bulk chemical compositions from a pure jadeite to impure jade compositions depending upon the content of amphiboles and/or other pyroxenes.

### Introduction

Literature on jade and its counterfeits is abundant, but that specifically on jade of Myanmar is less well known. Mineralogical and chemical data are scarce or not available for the different varieties of jade of Myanmar. As used in this paper the term jade of Myanmar refers to jadeite.

The earliest geological accounts of the jade mine areas in northern Myanmar are due to Noetling (1892). The occurrences of jade have been reported by Bleeck (1908), Coggin Brown (1921), Chhibber (1932; 1934). General descriptions of jade colours and qualities have been given by many authors such as Webster (1948; 1949; 1975) and Coggin Brown (1948). The mineral constituents and chemical compositions (not bulk composition) of very limited specimens of jade of Myanmar can be found in the papers by Lacroix (1930), Yoder (1950), Bauer (1969), Coleman (1961) and Mével et al. (1986). Analytical data are mainly for jadeite itself.

Jade rocks or jade pieces used in the jade trade may be monomineralic or polymineralic. It was, therefore, considered that the mineralogical and chemical characteristics would be required for a more representative study of different varieties of jade of Myanmar.

Some discrepancies between previous data on jade of Myanmar and present results were encountered. For instance, the locally called 'maw-sit-sit' is technically neither jade because of lack of jadeite nor albite-jadeite rock as has been described before (e.g. Gübelin, 1965).

The term 'jade' normally refers to one of two mineral species - jadeite or nephrite. Jade counterfeits have usually been named with prefixes, such as, 'South African jade', 'British Columbian jade' for grossular and hydrogrossular, 'Swiss jade' for chalcidony, etc. On the other hand, a jeweller

may use the terms 'Chinese jade' and 'New Zealand jade' to refer to the true jades, jadeite and nephrite respectively, with a justifiable indication of locality. Thus, the use of this kind of locality prefix may cause confusion. Therefore, we propose that the term 'Jade of Myanmar (or Burma)' is preferable to 'Myanma jade' in order to differentiate between true jade and pseudo-jade.

### Sampling and sample preparation

For this research work the Myanma Gem Enterprise has provided jade specimens in many different colours and varieties. Some specimens were collected from the Geological Museum, Geology Department of Yangon (formerly Rangoon) University and from personal collections. These specimens were from the following mining centres: Hpakan, Lonkin, Tawmaw, Nantmaw, Whay Khar Maw, Haungpa and Knamti.

Assorted samples were carefully selected for appropriate analyses on the basis of variation in colour, texture, transparency and weathered crust. The colours of jade samples under investigation ranged from white through grey to almost black, shades of green, dark green, emerald green, lavender, yellowish through brown to reddish-brown, bluish and greyish blue-green. Textures vary from almost glassy to coarse grained as seen in hand specimen. The weathered crusts in some specimens may be thick or thin, rough or smooth and compact or porous; some specimens lack

crusts.

In sample preparation, care was taken to obtain representative results of mineral and chemical compositions. For X-ray diffraction analysis each sample was crushed and roughly sorted by hand-picking under a stereo-zoom microscope.

### Mineral compositions determined by optical and XRD methods

Each jade specimen was sectioned for petrographic examination before and after XRD identification of the mineral constituents. A computer controlled Rigaku X-ray diffractometer 'Geigerflex' D/Max III B was used for mineral identification.

In the panel below are mineral assemblages identified by both XRD analysis and optical examination in the jade of Myanmar.

In a collection of 25 specimens of assorted jade varieties (see Figures 1-4) about two thirds are essentially composed of jadeite and about one third consist of two or more essential minerals. Acicular rutile and ilmenorutile, as confirmed by XRD occur occasionally as tiny inclusions in some grains of jadeite.

Pure jade is almost white in the absence of colouring agents and the emerald-green colour in jadeite-jade is due to chromium. On the other hand, kosmochlor in impure jade specimens gives a similar or even a deeper green. For example, the bright-green colour of maw-sit-sit from the Tawmaw area is due to kosmochlor. Unlike Gübelin's (1965) samples, our three

Monomineralic ( <i>pure jade</i> )	- Jadeite - Jadeite ± rutile/ilmenorutile - Jadeite ± chromite/magnesiochromite ± rutile
Polymineralic ( <i>impure jade</i> )	- Jadeite + edenite + richterite ± chromite - Jadeite + kosmochlor ± ilmenorutile - Jadeite + enstatite + tremolite - Jadeite + tremolite + edenite + richterite + kosmochlor ± ilmenorutile

Note: The sign ± denotes minor accessory mineral.



maw-sit-sit samples (two from Myanma Gems Enterprise (MGE) and one from Mandalay jade market) do not contain jadeite or albite. (A mineralogical account of maw-sit-sit is in preparation.) The amphiboles are largely responsible for greenish grey, dark green and black colours.

#### Chemical composition determined by XRF analysis

A wavelength dispersive X-ray fluorescence spectrometer (model: RIGAKU 3060 P) was used for analysis of major and trace elements in various jade specimens. The international igneous rock standards – AG V.1, BCR-1, G-2, W-1 and BR – were employed in the determination of all major elements except Na, Mg and Cr where synthetic jade mixtures were used. The concentration ranges of the oxides in these

standard mixtures are: for  $\text{SiO}_2$  10.69 - 71.11%, for  $\text{Al}_2\text{O}_3$  10 - 40%, for  $\text{Na}_2\text{O}$  2 - 18%, for  $\text{Cr}_2\text{O}_3$  0.10 - 12%, for  $\text{Fe}_2\text{O}_3$  0.10 - 7%, for  $\text{MgO}$  0.05 - 4%, for  $\text{CaO}$  0.05 - 4% and for  $\text{K}_2\text{O}$  0.01 - 2%.

XRF analyses of 15 jade specimens are given in Table I. The measured values for Na and Mg may be slightly low due to the use of a tungsten X-ray target; also Mn and water were not determined. These factors, although small in magnitude, probably account for the low totals in Table I. Nevertheless, these compositions are believed to be representative of the jade varieties of Myanmar.

In Table I, the specimens 1 (mauve) and 2 (white) are pure jadeite. The specimens 3-11 contain considerable amounts of calcium and iron, although they are still essentially monomineralic.

The excess components of calcium and

Table I. XRF Analysis of jadeite-jade of Myanmar

	1	2	3	4	5	6	7	8
$\text{SiO}_2$	59.80	59.67	59.42	59.79	59.50	59.65	59.55	59.08
$\text{Cr}_2\text{O}_3$	0.22	n.d.	0.17	0.03	0.23	0.21	0.20	0.28
$\text{Al}_2\text{O}_3$	24.18	23.04	22.56	23.11	23.66	23.16	23.58	22.24
$\text{Fe}_2\text{O}_3$	0.93	0.98	1.74	1.37	1.11	1.32	1.06	1.44
$\text{MgO}$	0.01	0.05	0.66	0.75	0.29	0.33	0.36	0.80
$\text{CaO}$	0.33	0.72	1.79	1.71	1.21	1.22	1.22	1.82
$\text{Na}_2\text{O}$	13.44	15.52	12.35	12.48	12.93	12.93	13.28	12.86
$\text{K}_2\text{O}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	98.92	99.99	98.70	99.25	98.94	98.83	99.26	98.53
	9	10	11	12	13	14	15	
$\text{SiO}_2$	59.45	59.16	58.95	56.14	59.79	58.67	58.64	
$\text{Cr}_2\text{O}_3$	0.03	0.19	1.16	0.70	0.10	0.17	0.12	
$\text{Al}_2\text{O}_3$	23.27	23.79	22.16	15.34	22.80	20.67	17.51	
$\text{Fe}_2\text{O}_3$	1.12	1.12	1.40	1.42	1.13	2.34	1.97	
$\text{MgO}$	0.50	0.26	0.85	9.88	0.60	1.72	3.17	
$\text{CaO}$	1.32	1.10	1.90	10.84	1.47	2.59	5.40	
$\text{Na}_2\text{O}$	13.02	13.04	12.99	5.66	12.56	12.61	11.65	
$\text{K}_2\text{O}$	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	
	98.72	98.67	99.42	99.99	98.46	98.78	98.47	



Fig. 1. Photographs of jade varieties of Myanmar.\*

(a,1) Jadeite. Mar-sar Maw. (b,3) Jadeite + ilmenorutile + rutile + magnesiochromite. Phakangyi Maw.

(c,4) Jadeite + ilmenorutile. Nant Maw. (d,5) Jadeite. Chauk-oo Maw. (e,7) Jadeite. Chauk-oo Maw.

(f) Jadeite + richterite + rutile + chromite. Phakan-gyi Maw. (g) Jadeite + ilmenorutile. Chauk-oo Maw.

\* Numbers in brackets refer to the sample no. in Table I.



Fig. 2. Photographs of jade varieties of Myanmar.\*

(h,8) Jadeite + rutile. Phakan-gyi Maw. (i,10) Jadeite + rutile + magnesiochromite. Tar-ma-khan Maw.

(j,9) Jadeite + rutile. Whay-khar Maw. (k) Jadeite + rutile. Whay-khar Maw. (l,12) Jadeite + richterite +

tremolite + kosmochlor + ilmenorutile. Nant Maw. (m,13) Jadeite + edenite + kosmochlor + rutile. Maw-maung Maw.

\* Numbers in brackets refer to the sample no. in Table I.

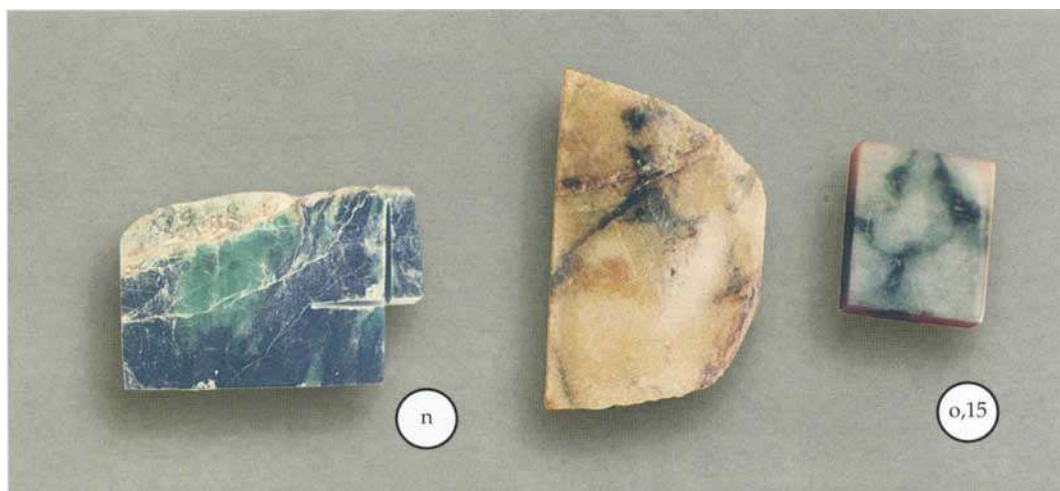


Fig. 3. Photographs of jade varieties of Myanmar.\*  
 (n) Jadeite + richterite + kosmochlor + tremolite. Whay-khar Maw.  
 (o,15) Jadeite + enstatite + tremolite. Ka-tone-yat Maw.  
 \* Numbers in brackets refer to the sample no. in Table I.

iron may be attributed partly to chemical impurities and tiny crystal inclusions in jadeite itself and/or partly to a small molecular component of augite.

From optical and XRD examination the specimens 12-15 were found to be pyroxene-amphibole jades and a considerable range of chemical variation was to be expected.

Qualitative XRF analyses of 9 selected samples were also made to provide a general survey of trace elements present in the various jades of Myanmar. Ti, Sr, Zr, + Nb, + Ni and +Zn are present, in addition to Cr and Fe as shown in Table I. The + sign indicates that the element may be present or absent in some specimens.

### Conclusions

The present study demonstrates that jade of Myanmar may include a much wider range in mineral constituents and chemical composition than was previously recognized. All the jade varieties in a range of colours may be either monomineralic or polymineralic. The monomineralic type is entirely made up of jadeite, whereas

edenite, richterite, tremolite, kosmochlor and enstatite are characteristic associates of jadeite in polymineralic varieties. Chromite, magnesiochromite, rutile and ilmenorutile are frequent accessories; no albite has yet been found among the true jade samples studied.

XRF analyses of the bulk chemical compositions of various jades showed that there was a significant range of chemical variation from almost pure jadeite to impure jade compositions. The impure varieties contain more Ca, Mg, Fe and sometimes Cr, and less Al and Na. These variations are mainly due to the contents of amphiboles and/or other pyroxenes.

The jade specimens studied are believed to be fairly representative. Therefore, based on the present evidence, it is suggested that jade of Myanmar should be defined as a rock consisting essentially of jadeite with or without interlocking amphiboles and/or other pyroxenes.

### Acknowledgements

The authors are grateful to the former geology Professors U Ba Than Haq and U

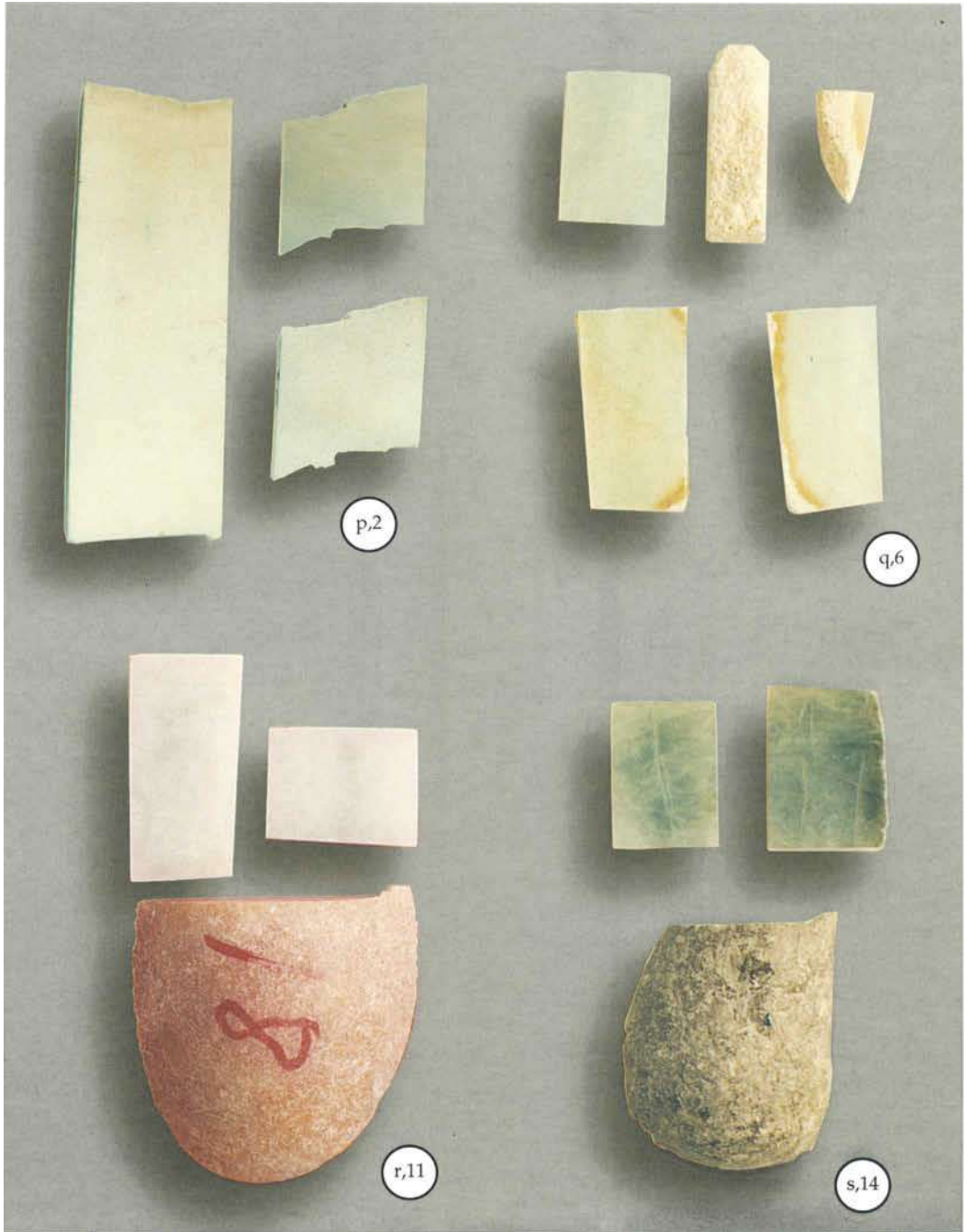


Fig. 4. Photographs of jade varieties of Myanmar.\*  
 (p,2) Jadeite. Nant Maw. (q,6) Jadeite + rutile. Chauk-oo Maw. (r,11) Jadeite. Met-lin Maw. (s,14) Jadeite + kosmochlor + ilmenorutile. Tar-ma-khan Maw. .  
 \* Numbers in brackets refer to the sample no. in Table I.

Clarence Thacpaw and Professor Dr Maung Thein, who permitted them to carry out this research project. The authors are also indebted to Dr Zin Aung, former Associate Professor of Physics and Head of Universities' Research Centre, for laboratory facilities provided for this study. Grateful acknowledgement is made to the Managing Director and the staff of Jade Section, Myanmar Gems Enterprise for providing the valuable jade specimens.

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## A new occurrence of dendritic opal in south-eastern Zambia

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\*\*Ministry of Mines, Lusaka, Zambia

### Abstract

Gem-quality dendritic opal from a newly discovered deposit in south-eastern Zambia is transparent to translucent, yellow to brownish-yellow and is found in fractures and cavities of sedimentary rocks. Chemical analyses suggest that the dendrites consist of the manganese oxide psilomelane.

### Introduction

Besides amethyst and malachite occurrences, it was the rediscovery and new finds of emerald in the 1970s and their consequent massive exploitation which formed the basis of Zambia's dramatic entry into the gemstone supply scene. This led to widespread exploration and, as a result, gemstones such as aquamarine, garnet and tourmaline have been found and there is certainly more potential not yet realized. Most recently, yellow to brownish-yellow, gem-quality dendritic opal has been discovered in south-eastern Zambia.

Opal as such is a non-crystalline, colloidal substance consisting of very minute spheres of silica gel with various amounts of water, mostly between 3 and 5 wt% H<sub>2</sub>O. In contrast to precious opal, where the silica spheres are relatively consistent in size and are regularly stacked thereby causing a three-dimensional diffraction grating and, as a result, a play of colour,

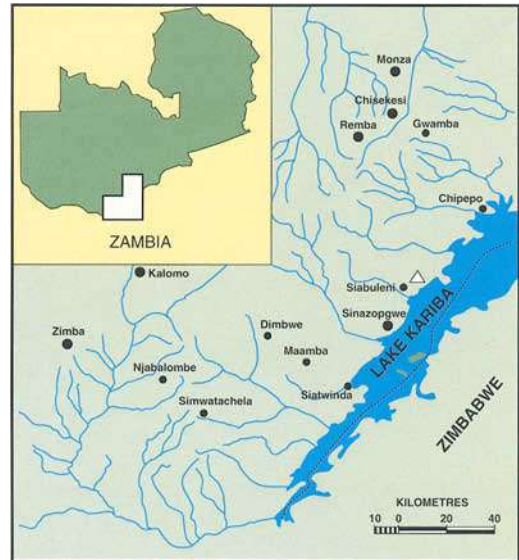


Fig. 1. Simplified geographical map of south-eastern Zambia showing sample location (triangle)

no such diffraction of light occurs in common opal because the silica spheres vary in size and are randomly stacked. White and multi-coloured common opal often contains inclusions of other minerals with tree-like forms which are termed dendrites. Such is the case with dendritic opal known from Zimbabwe, South Africa, Tanzania, various places in the United States (Webster, 1983; Gübelin and Koivula, 1986) and, most recently, from Zambia.

The new Zambian opal find is located approximately 40km north-east of the town Maamba at Lake Kariba in south-eastern



Fig. 2. The Zambian opal occurs in veins in Karroo sandstones

Table I. Properties of dendritic opal from Zambia

Colour	Yellowish to brownish-yellow	
Diaphaneity	Transparent to translucent	
Fracture	Conchoidal	
Refractive index	1.459	
Specific gravity	2.15	
UV luminescence	Distinct	
Long-wave UV	Yellowish	
Short-wave UV	Greenish-yellow	
NIR-Absorption Spectrum	Typical opal-spectrum	Assignment
	Absorption maxima	vibrations of H <sub>2</sub> O
	1420-1460 nm	vibrations of H <sub>2</sub> O
	1915 nm	vibrations of SiOH
	2213 nm	vibrations of SiOH
	2315 nm	vibrations of SiOH





Fig. 3. Two cut opals with dendritic inclusions from south-eastern Zambia. Width of photograph 3.5cm

Zambia (Figure 1). The material occurs in veins and cavities in sandstones (Figure 2) which belong to the upper Carboniferous to Jurassic Karroo Suite as indicated on the Geological Map of Zambia.

The standard gemmological properties of the Zambian material, as well as the results of chemical analyses are given below.

#### Gemmological Properties

The gemmological properties are listed in Table I. The colour of the opal samples examined is yellow to brownish-yellow and their diaphaneity ranges from transparent in small samples to translucent mostly in larger specimens. They typically show a conchoidal fracture. In some cases

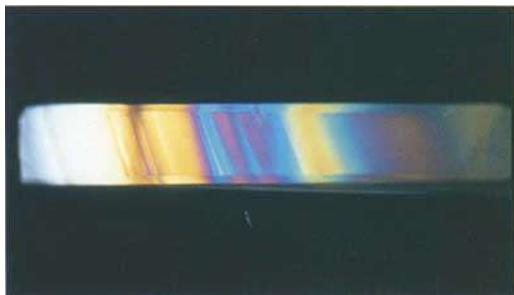


Fig. 4. Interference effect of a cut opal under crossed polars. Width of photograph 3.5cm

the opals contain black, dendritic inclusions which originate from veins and form patterns resembling trees or even landscapes (Figure 3).

#### Refractive index and specific gravity

Using a standard gemmological refractometer, the RI was determined to be  $n = 1.459$ . Some samples show a strain induced birefringence and, as a result, an iridescent effect when examined under crossed polars (Figure 4). The SG was measured using a hydrostatic balance and yielded a value of 2.15.

#### Ultraviolet luminescence

When exposed to ultraviolet (UV) radiation, the opal samples show a distinct yellowish fluorescence with long-wave UV radiation and a distinct greenish-yellow under short-wave UV.

#### Spectroscopic analysis

The infrared spectrum is plotted in Figure 5. The sample displays a near-infrared (NIR) spectrum which is consistent with the general patterns found in natural opal (e.g. Langer and Flörke,

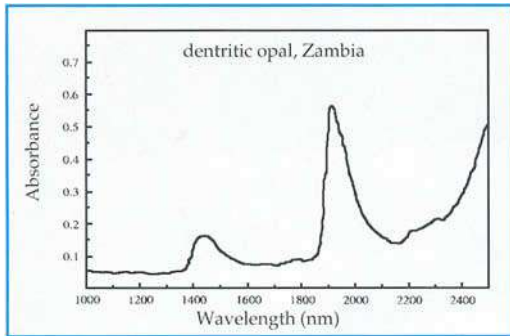


Fig. 5. Infrared absorption spectrum for an opal specimen from south-eastern Zambia (for explanation see text)

1974; Fritsch and Stockton, 1987). The opals tested show combination vibrations of molecular water ( $H_2O$ ) between 1420 and 1460nm and at 1915nm. Additional absorption maxima occur at 2213 and 2315nm, both caused by combination vibrations of SiOH groups.

#### Chemical analysis

The dendritic mineral inclusions were chemically analyzed using an EDAX energy dispersive analytical system fitted on a scanning electron-microscope. The spectrum is shown in Figure 6. The strong Si-peak results from the opal-host, whereas both Ba and Mn are present in the inclusions. It is thus probable that the inclusions are psilomelane, a colloidal manganese oxide including barium oxide and water  $[(Ba, Mn^{3+})_3Mn_8O_{16}(O, OH)_6]$ .

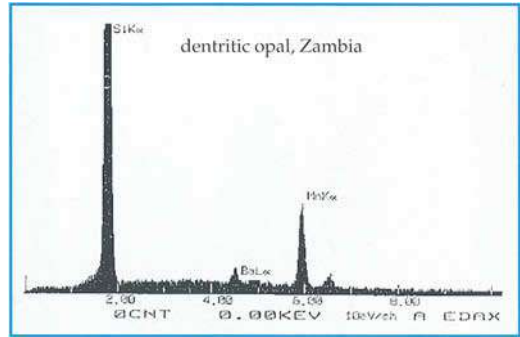


Fig. 6. Energy dispersive X-ray fluorescence spectrum of the dendritic inclusions (for explanation see text)

#### Conclusions

The gemmological properties of this common opal correspond to those described for other common opal occurrences. The beautifully arranged psilomelane inclusions make this new Zambian material interesting for the gem trade. Large quantities of dendritic opal are apparently available and there are good prospects for commercial exploitation.

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[Manuscript received 13 December 1993]

## Letters

*From J.B. Nelson, PhD, FGA Research Diploma*

Dear Sir

*On diamond-filling glasses and  
Nelson's speculations*

I was not surprised to see from his Letter to the Editor in the July issue of the *Journal*<sup>1</sup> that my favourite curmudgeon, Kurt Nassau, has followed up the two salvos<sup>2,3</sup> from his Lebanese battlements at a previous paper of mine<sup>4</sup>, by yet another one.

His judgement of the currently offending paper<sup>5</sup> is that '...while [Nelson's] discussion is actually not often wrong, much of it is irrelevant ...'.

I am grateful to Dr Nassau for allowing me the further opportunity for expanding on matters related to this topical subject.<sup>1,2</sup>

After the submission of a thesis to the GAGTL on 'The glass filling of diamonds', the writer was awarded the title of FGA Research Diploma. The articles in the *Journal* are based on this thesis. It appears that Nassau's comment on the irrelevancy of the ideas does not accord with the verdicts of the thesis examiners.

He begins by stating '... [Nelson] has therefore missed the important boron content of these [Yehuda] glasses ...'

This wording wrongly conveys to the reader that a quantitative boron analysis was reported in the GIA laboratory's elegant paper of 1989.<sup>3</sup> Not even a qualitative detection of boron was claimed. Nor, I feel sure, has its presence in Yehuda glasses been reported in the literature since that date.

He was therefore careless in failing to insert the essential word 'possible' between the words 'important' and 'boron'. His firm belief that boron is the missing element probably stems from:

a) his familiarity with the composition of low flow-point and solder glasses where boron oxide is an important additive, b) the results of an X-ray elemental analysis with the GIA's energy-dispersive X-ray fluorescence spectrometer attachment to a scanning electron microscope (SEM-EDS).<sup>4</sup> These were semi-quantitative analyses of spot areas lying along various outcropping glass-filled fractures on the same stone.<sup>3</sup> Chlorine, along with lead and bismuth, was detected. The results were reported as '... The chlorine concentration consistently *seemed* [emphasis added] to approximate the sum of the lead and bismuth concentrations ...' Because of the 'semi-quantitative' nature of the observations, the cautious GIA analyst chose to express the chlorine content in the less precise terms which the less-cautious Nassau would prefer us to ignore.

From these two viewpoints, he firmly concludes '... that boron is the only practicable (and indeed expected) candidate ...'

There have always been great doubts by analysts on the quality of X-ray spectrochemical results which attempted to measure the percentage of a very light element occurring in a matrix of a very heavy element. The inverse situation, e.g. a small percentage of say lead (Z=82)\* or bismuth (Z=83) occurring in a predominantly boron (Z=5) matrix, would invariably yield results of high accuracy.

For this reason only, I declined to pursue the 'logic' of the GIA analysis, as Nassau feels that I should have done.

It is really not sensible to speculate on missing elements on such flimsy evidence. Is it not far better to actually determine their concentration? Why indeed has this

\* Z is the characteristic number of an element. It is the number of protons in its nucleus.

not been done? If it had, it is not beyond belief that lithium ( $Z=3$ ) or beryllium ( $Z=4$ ) could equally well have been found to serve as Nassau's missing element.\*\*

Quite unwittingly, he has drawn attention to one of the more intractable problems facing present-day inorganic analytical chemistry. The low atomic number elements, lithium ( $Z=3$ ), beryllium ( $Z=4$ ), boron ( $Z=5$ ), carbon ( $Z=6$ ) and nitrogen ( $Z=7$ ) cannot be detected, let alone measured, by X-ray fluorescence energy-dispersive spectrometers (XRF-EDS). These instruments, of the non-destructive kind still in use at the GIA laboratory,<sup>4</sup> have been the mainstay of modern elemental analysis. However, they are quite unable to detect and measure elements of lower  $Z$  number than sodium ( $Z=11$ ).

In general, the light elements play an as yet little understood role in gemmological science. I have recently completed a brief account of the historical developments of the analytical methods used to determine them. A different scene is now emerging. It is now possible with a new generation of X-ray fluorescence, wavelength dispersive spectrometers (XRF-WDS) to measure, accurately and non-destructively, all the elements from uranium ( $Z=92$ ) to beryllium ( $Z=4$ ), except lithium ( $Z=3$ ). It is quite likely that this too, will soon yield to the instrument engineer. The account, under the title '... The troublesome trio; boron, beryllium and lithium', will hopefully appear in a future issue of the Journal.

It is now necessary to return to Nassau's other comments.

*Glass formulations.* He has advised me to look up his list of references on lead, bismuth and boron oxide glasses. This is not a task which I feel obliged to do as I have no intention of starting up a fracture-filling station.

As mentioned in my paper, no analyses

of the glasses of any diamond enhancer other than Yehuda had been reported. Nassau's later, undated and unpublished personal communication from Fritsch of the GIA, stating that bromine had been found in one fracture-filled diamond of unstated origin, comes as no surprise. Following Yehuda's trail-blazing invention, it would be astonishing if other entrepreneurs had not tried out various cocktails. I would find it easy to accept that a Koss or other glass consisted of  $PbO$  and  $PbBr_2$  with a small addition of  $B_2O_3$  or  $Li_2O$  to adjust for a low flow point, better glass stability and the desired RI.

*Laboratory safety.* As to his warnings about the oil-quenching process being '...an extreme explosion and fire hazard! ...', may I ask him to perform the following experiment? Take a teaspoonful of motor engine oil and heat it with an alcohol lamp. He will find that it is quite difficult to set alight. After all, engine oil has had all the volatiles distilled off, otherwise it would be a fuel and not a cylinder lubricant. He will discover that it has to be heated to smoking temperatures before it becomes a laboratory hazard. The alcohol lamp itself is much more dangerous!

My suggestion for dribbling the molten glass into a large bath of cold motor engine oil has long been the preferred quenching method in phase equilibrium studies of alloys and inorganic compounds. It has the advantage of thermally-shocking the glass into small fragments which are ideal for rapid remelting. It is by far the most effective way of ensuring that there is no devitrification. Sodium chloride in the glassy state can be produced only in this way. The 'splat' method by which the molten sodium chloride is poured on to a cold, thick, polished copper plate does not work. Alas, I cannot share Nassau's belief that glasses do not devitrify easily. They do, and often quite unexpectedly. He must surely have been aware of the devitrification at  $250^\circ C$  of the 90 per cent silica glass ('Corex') envelopes of halogen lamps. Only a touch of moist fingers containing

\*\* For carrying out X-ray powder diffraction studies of organic substances sensitive to  $H_2O$ ,  $CO_2$  and  $O_2$ , the writer has made and used thin-walled capillary tubes of 'Lindemann Glass'.<sup>5</sup> This X-ray transparent glass has the approximate composition  $5Li_2O \cdot BeO \cdot 6B_2O_3$ .

sodium chloride traces is enough to catalyse the conversion to cristobalite.

*Glass-filling apparatus.* As to a real laboratory hazard, I was horrified at the suggestion that his DIY test-tube apparatus as shown in his Figure 1b could be used for fracture filling. I would not dream of asking anyone to attempt these experiments without a large, thick Perspex screen placed in front of the hot evacuated glass-ware. Vacuum implosions are almost as devastating as pressure explosions. Flying molten glass, solid hot glass splinters and incandescent diamonds are much to be avoided.

His costings make interesting reading. His test-tube arrangement of Figure 1b 'could be purchased for £5.00 ...'. A Pyrex test-tube, yes, but not a Bunsen burner. As for a suitable two-stage, ballasted, oil vacuum pump such as the Edwards RV3, it would cost him about £1300. Again, his estimate of the cost of about £5000 for my suggested filling unit is quite far out. I could not expect to have it made for less than £20 000.

*Precision diamond polishing.* Finally, he states that it would not be possible to polish diamond-glass surfaces without undercutting. A diamond polishing friend in the trade had assured me that it could be done, but not as in the routine manner. A thin film of some coolant or lubricant such as a light mineral oil or isopropyl alcohol would be required to be maintained on the scaife. With a very light load and a long polishing period, it should be possible to prepare good, polished, strictly-coplanar flat surfaces without any undercutting or heating.

I would put it to Nassau that his own letter is totally irrelevant. His rebuttal of my rebuttal, which is sure to follow, will be eagerly awaited as they say.

Yours etc.  
James B. Nelson  
Nelson Gemmological Instruments  
Hampstead, London.  
25 July 1994

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*Response from Dr Kurt Nassau, PhD, FGA*

Dear Sir

*More on diamond-filling glasses  
and Nelson's speculations*

I fully agree with James B. Nelson<sup>1</sup> that boron has not yet been demonstrated to be present in the fracture-filling glasses used on diamonds; I thought I had made this clear in my letter<sup>2</sup>. Perhaps instead of saying that 'boron is the only *practicable* (and indeed expected) candidate' for the missing cation component, I really should have said *possible* or *probable* there and elsewhere in my letter<sup>2</sup> commenting on Nelson's article<sup>2</sup>.

No - I was not 'unwitting', as Nelson puts it<sup>1</sup>, when it comes to the difficulty of analyzing for the presence of low atomic weight cations in small samples: this well-known limitation always presents a problem. Yet a 'glass-former' needs to be present, and the lithium or beryllium Nelson suggests as alternatives just will not do. In my opinion, boron is the only possible candidate, a conclusion not grounded merely on the limited basis Nelson<sup>1</sup> attributes to me. As neither the GIA, Nelson, I, nor anyone else who has analyzed these glasses has had access to the special capability needed to determine boron, certainty will only result from such an analysis. But the possibility of the presence of boron cannot be ignored.

Yet Nelson has missed the essential point of my letter<sup>2</sup> which was intended as a polite and, I hoped, gentle reminder for him to

familiarize himself adequately with the literature on glasses before attempting to draw subtle conclusions. He may indeed be well acquainted with the physical properties of glass, yet reading his article<sup>3</sup> and his subsequent letter<sup>1</sup> makes it clear to me that his knowledge of possible glass-forming compositions and glass preparation techniques does not have the necessary depth.

And I am totally baffled by Nelson's stated<sup>1</sup> unwillingness to look up the references I suggested because he has 'no intention of starting up a fracture-filling station'. Should not a scientist feel the obligation to consult suggested new sources before deciding on their irrelevance?

I might note that over the last 20 years I have studied the preparation and properties of a wide variety of glasses (fused silica, silicates, other mixed oxide, heavy metal and halide glasses, also including rapid quenching and crystallization studies), with over 50 publications on glasses in recognized journals. Based on this experience I can assure Nelson of the following.

One can definitely work with low-melting glasses in fused silica with only minimal contamination. I have done this many times, even making my own tubes - I picked up glass-blowing in my youth. I have frequently used vacuum without ever experiencing an implosion. Of course I used safety shields and goggles, as does any prudent experimenter. And I did not include the cost of these, of the bunsen burner, vacuum pump, or glass-blowing torch in my £5.00 estimate, because every laboratory I have ever worked in contained such standard equipment. I accept Nelson's estimate of £20 000 for building his apparatus as being reasonable; my £5000 was obviously just an order of magnitude guess.

Dropping a red-hot glass into oil is definitely not the same as Nelson's heating a teaspoon of it over an alcohol lamp! I too have dropped red hot phase diagram

samples into oil and other fluids on many occasions, but this is usually done with very small quantities. For the topic under discussion however, the preparation of bulk glass, I can guarantee at least a minor eruption on dropping a hundred grams of molten glass into oil and a definite major explosion if this were done with a kilogram amount. What happens is that the oil is 'cracked' on contact with the high temperature glass to yield volatile and flammable low molecular weight fragments. Please do not try it!

Incidentally, I did not say that glasses do not devitrify easily, as stated by Nelson<sup>1</sup>. I did say that solder glasses do not usually do so unless specifically designed and processed to do so<sup>2</sup>. And I ignore comments of Nelson irrelevant to the topic at hand such as those on X-ray diffraction, the devitrification of 'Corex', and so on.

My deduction of the probable presence of boron was based on a consideration of the nature of known glass-forming systems, on the usual necessity for the presence of a good 'glass-former', combined with the missing cations (all of Nelson's speculations notwithstanding, these cannot be ignored). In my judgement, a non-crystallizing glass consistent with the available analyses with enough fluidity to penetrate thin fractures in a reasonable time at a reasonable temperature just does not seem plausible in the absence of significant boron.

I am also quite unimpressed by the assurance given to Nelson<sup>1</sup> by his diamond-polishing friend of his ability to avoid undercutting *totally* and to achieve the 'exactly coplanar' surface required for Nelson's measurement<sup>1</sup>. I shall believe this one only when it has actually been demonstrated.

Feedback that helps to put facts into a meaningful perspective is considered to be part of the scientific approach. None of us can know everything, however expert. I myself have found comments on my own reports useful and therefore assume that so

would others.

Yours etc.

Kurt Nassau

Nassau Consultants

Lebanon, NJ 08833, USA

24 August 1994

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2. Nassau, K., 1994. Letter: On diamond-filling glasses and Nelson's speculations. *Journal of Gemmology*, 24, 183-4
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*From Professor Cornelius S. Hurlbut*

Dear Sir

I write in reference to the article by T. Farrimond in the *Journal of Gemmology* (1994, 24, 3, 161-3), 'Hydrostatic measurement of specific gravity'. In this article Dr Farrimond concludes that accurate determinations of specific gravity can be made on gemstones 0.25ct or greater by the hydrostatic method using water.

Because of its low surface tension, toluene has been used in place of water as an immersion liquid for specific gravity measurements of small stones. By adding a detergent the surface tension of water can be lowered to a point approaching that of toluene. For this reason Dr Farrimond feels there is little point in using toluene. He mentions as a disadvantage the rather large variation in its density with changes in temperature and the necessity of making a density/temperature correction.

It is stated that the density of toluene at 25°C is 2.3 per cent less than at 5°C, whereas the density of water changes only about 0.02 per cent between 4°C and 70°C making compensation unnecessary. There is an error in this last percentage figure. The density of water at 4°C is of course 1.0; at 70°C it is 0.9778 a difference of 0.0222 or 2.22 per cent, more than 100 times greater than stated. We are not told the tempera-

ture at which Dr Farrimond made his determinations but if it were 25°C (at which water has a density of 0.9971) a downward correction of 0.29 per cent should have been made to obtain more accurate values. The SG of diamond measured as 3.45 would be 3.44 and the 4.01 for corundum lowered to 4.00.

These differences are not large and probably no greater than other experimental error. However, since in using toluene a correction *must* be made, the reported values are probably more accurate than those obtained in using water with no correction. When a specific gravity is reported correct to the third decimal place (as that given for quartz in this article) without a density/temperature correction, it is suspect.

Yours etc.

Cornelius S. Hurlbut,

Professor of Mineralogy, Emeritus,  
Department of Earth and Planetary Sciences,  
Harvard University, Cambridge,  
Mass 02138, USA.

29 August 1994

*Response from Dr T. Farrimond*

Dear Sir

I should like to express my appreciation to Professor Hurlbut who correctly points out an error in my article entitled 'Hydrostatic measurement of specific gravity' (*J. Gemm.*, 1994, 24, 3, 161-3). On page 163, the sentence referring to the effects of temperature on the density of water should read: 'Since water only changes by about 0.2 per cent between 4°C and 20°C no compensation need be made.' Although the figures are different, the rationale remains unaltered, since at normal temperatures up to 20°C, the density of water is little different from unity. All SG determinations were made at 17°C.

Professor Hurlbut notes that temperature correction for water at 25°C would change the SG value for a diamond of 0.053ct from 3.45 to 3.44 and for a corundum of 0.46ct from 4.01 to 4.00. At lower temperatures the difference made by temperature correction could also be made for water if thought necessary.

Although it is true that the low surface tension of toluene brings benefits, its 13 per cent lower density of 0.867 at 20°C relative to water (0.998) would decrease the magnitude of the balance readings, so exacerbating the influence of other factors including surface tension.

Professor Hurlbut also refers to the quoted SG for quartz questionable if standing alone, but the standard deviation of the sample places the value between 2.64 and 2.66.

The term 'accuracy' used in the article is qualified by the statement that:

'For stones in excess of 0.25ct hydrostatic determinations become more accurate and at about 0.46ct the error is only 0.5 per cent.'

Given the above limitations of hydrostatic measures of SG using water, the method is quick, convenient and sufficiently accurate to make it a means of obtaining useful ancillary information for stone identification.

Toluene, if used regularly, requires controlled conditions so that the fumes are not breathed in by the operator. I encountered at first-hand the effects of olfactory adaption brought about by the regular use of the chemical carbon tetrachloride. Some members of the staff at a coal research laboratory, where I was employed for a short time when a student, used the liquid for washing samples of coal prior to analysis. One hot summer's day, they did not turn up for lunch as usual and upon investigation they were all found to be unconscious on the floor.

Damage to lungs, nervous system and liver, as well as changes in behaviour involving slurred speech and uncoordi-

nated movements resembling drunkenness, have all been reported as a result of inhalation of toluene fumes.

The avoidance of health hazards such as these by using water whenever practicable, instead of toluene, is largely an exercise in prudence.

Yours etc.

Dr T. Farrimond,  
Thornton Road, Cambridge, New Zealand  
12 September 1994

*From Alec E. Farn*

Dear Sir

*John M. Jerwood MC FGA*

I was surprised when my wife, who was reading the Review section of the *Sunday Telegraph* of 12 June, looked up and asked me if I knew a John Jerwood. I replied that I did (past tense) and enquired why the question?

She passed to me the full page Arts Review portraying artists and their style of work.

A write-up described the Jerwood Painting Prize of £30 000 to be awarded annually. The criterion being 'excellence in Modern British Painting' the only condition required that entrants must have lived and worked in this country for the past ten years. It was an aspect of John Jerwood who gained his Diploma in Gemmology in 1937 which was new to me as was his Military Cross won in the Italian Campaign. His firm featured in the early days of the Laboratory of the Diamond Pearl and Precious Stone (trade section) of the London Chamber of Commerce holding positions of deputy chairman of the Standing Committee 1931 and Hon Secretary to the section. John Jerwood was well known to Basil Anderson in laboratory terms of pearl testing. I personally made contact with him by correspondence towards the end of my time at the labora-



tory on matters concerning the Japanese production of non-nucleated cultured pearls from Lake Biwa.

He was a fount of first hand information having cultured pearl farms in Japan and Australia. He sent me a report on the decline of pearl fishing in Australia and of cultured pearl production of Mabe pearls in the *Pinctada maxima* oyster. I had often wondered why these expensive oysters which were in fairly short supply were used to produce Mabe cultured blister pearls\*. He gave me important addresses to which to write to in Japan for production figures and dollar earnings. It seems ironic that it was not until November 1983

when I started (in retirement) to write *Pearls Natural, Cultured and Imitation* that I met him personally. He had then lived in Japan for many years. In my early days at the laboratory I seldom dealt with the pearl trade. Coloured stones and gem set jewellery were my metier. Few gemmologists today will have heard or known of John Jerwood.

Yours etc.  
A.E. Farn,  
Seaford, E. Sussex.

\* See A.E. Farn, 1986. *Pearls natural, cultured and imitation*, Butterworth, London. pp 79-80.

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## ABSTRACTS

Diamonds

Gems and Minerals

Instruments and Techniques

Synthetics and Dimulants

Diamonds

**[Morphogenetic peculiarities of placer diamonds from Anabar River alluvial deposits and a problem of their genesis.]** (Russian with English abstract)

A.I. DEGTJAREVA, T.V. POSUKHOVA AND V.K. GARANIN. *Proc. Russian Mineralogical Society*, **123** (1), 1994, pp 71-80.

Data are presented from the morphological analysis of diamond crystals found in a total of six alluvial deposits in tributaries on both banks of the Anabar River and on the coast of the Laptev's Sea. The degree of mechanical wear and some other hypogene alteration of these diamonds were investigated by SEM. The weight of the diamond crystals ranges from 3.3 to 52.7 mg. The typomorphic peculiarities of the crystals lead to the suggestion that the diamonds have reached these placer deposits from different sources; the nature of these sources is discussed in the light of the reported observation.

R.A.H.

**Superkimberlites: a geodynamic diamond window to the Earth's core.**

S.E. HAGGERTY. *Earth & Planetary Science Letters*, **122** (1-2), 1994, pp 57-69.

Diamonds are geologically ancient (3300 m.y.) and originate deep in the mantle (> 180km); rare diamonds are from the transition zone (400-670km) and others possibly nucleated in the lower mantle (>670km). Transport to the surface is via volatile (C-O- H-N-S)-charged highly explosive kimberlite and lamproite volcanoes, sited exclusively in the oldest (> 1700 m.y.), tectonically most stable and thickest (~200km) regions of crust and upper mantle lithosphere. The energies required for volcanism are so exceptional and the sources so deep that possible connections between and among the core, geo-

magnetism, plumes and diamonds are explored; some correlations are established and others are implied. The results are sufficient to allow the author to suggest that kimberlites and the geographically and temporally associated carbonatites are continental recorders of plumes dating back to  $\geq 2800$  m.y., and that some diamonds may have recorded core events dating back to 3300 m.y., or possibly earlier. Peaks in kimberlite magmatic activity correlate, on average, with normal and reverse superchron and subchron behaviour of the geomagnetic field. The time lag between magnetohydrodynamic activity in the core and kimberlite eruptive cycles at the Earth's surface is of the order of 25 to 50 m.y., consistent with the travel times modelled for the passage of plumes from the D'' layer to the subcontinental lithosphere. Although the existence of plumes and the nature of D'' are debated, the correlations established for the past 500 m.y. between and among superchrons, subchrons, kimberlites and entrained diamonds are considered to weigh heavily in favour of the following scenario: solid core growth, the consequent release of Si, O, C, H, S, K and possibly N and B to D'', disruption of D'' at some critically unstable threshold thickness (200-300km), enhanced core convection and the stabilization of a constant non-reversing magnetic dipole field, rising plumes and subsequent volcanism. If protokimberlitic magma and entrainment begin at the core-mantle boundary, a number of geochemical and mineralogical anomalies in diamonds are at present best satisfied if D'' is invoked. These include, but are not limited to, intensely reduced (i.e. oxygen deficient) SiC, metallic Fe, an abundance of sulphides, silicate perovskite and wüstite-periclase mineral inclusions in diamonds. The most abundant source of diamonds is unequivocally from cratonic root zones with C possibly implanted by ancient plumes; eclogitic suite dia-

### ABSTRACTORS

R.A. Howie  
M. O'Donoghue  
R.J. Peace

R.A.H.  
M.O'D.  
R.J.P.

P.G. Read  
R.E. Samson  
I. Sunagawa

P.G.R.  
R.E.S.  
I.S.

monds are equivocal, and diamonds transported from the transition zone and the lower mantle are best explained by entrainment in highly reduced plumes. Carbon in the great majority of diamonds appears to be primordial. By analogy with a chondritic Earth and chondrites, carbon was acquired during accretion in gaseous complexes, in the form of nanometre-size amorphous C, and as hydrocarbon particles; it may also have been added as crystalline nanodiamonds that served as seeds for subsequent diamond growth.

R.A.H.

**'Primary' diamond deposits. What controls their size, grade and location? Giant ore deposits.**

H.H. HELMSTAEDT. *Society of Exploration Geologists*, special publication no. 2, 1993, pp 13-81, 26 figs.

Kimberlites and lamproites are shown not to be primary deposits for diamond in the sense that diamond originated within them, although they are principal source rocks for diamond. These rocks were transporting agents for diamonds forming in harzburgitic and eclogitic source rocks in the subcontinental lithosphere. The 'primary' deposits are analysed to show sources, modes of transportation and deposit locations. It is not possible to distinguish between 'giant' deposits which may have arisen from different processes and smaller deposits. A notable dilution in diamond grade between source rocks and 'primary' deposits suggests that 'giant' deposits may be those represented by concentrations of eclogitic source rocks in the upper mantle and that these would be far larger than any known 'primary' deposits.

M.O'D.

**Gem Trade Lab Notes.**

R.C. KAMMERLING, C.W. FRYER, G.R. CROWNSHIELD, T. MOSES, K. HURWIT AND S.F. McCLURE. *Gems and Gemology*, 30 (1), 1994, pp 39-46, 20 illus. in colour.

The Centenary diamond was graded on site in London and at 273.85ct was declared the largest 'D' colour, flawless or internally flawless diamond graded to date; a colour report was made on the 545.65ct diamond known as 'Unnamed Brown' and shown to be fancy yellowish-brown of natural colour; a fancy coloured orange to brown rough diamond was shown to be natural although cutting produced a near colourless stone; clusters of fine dark needles in fancy intense yellow diamonds strongly suggested a type-Ib stone; orientated platelets appeared to be unique to type -IaA fancy yellow diamonds.

R.J.P.

**Diamond radiation detectors.**

R.J. KEDDY, T.L. NAM. *Radiation Physics & Chemistry*, 41 (4-5), 1993, pp 767-73 (Apr-May), 10 figs, 28 refs.

A review to date is given of the status of diamond as a detector of ionising radiations. The use of diamond as a thermo-luminescence device, as an ionisation chamber (pulse and dc modes), as a scintillation counter for  $\alpha$ -particles and for high dose applications using radiophotoluminescence is discussed. Some of the data obtained have also led to a better understanding of physics and crystallographic structures of the diamond lattice. Appropriate examples and references are given. Particular attention is paid to the role played by the impurity atoms within the lattice. (Author's abstract).

R.J.K.

**[Clastogenic\* pyropes and diamonds of northern Karelia.]** (Russian with English abstract)

S.F. KLJUNIN AND A.A. ZAKHAROV. *Proc. Russian Min. Soc.*, 122 (6), 1993, pp 43-7.

New data on the composition, morphology and types of crystal surface are presented for chrome-pyropes and diamonds found in heavy-mineral concentrates obtained by sampling the 'pyrope aureole' in N. Karelia. EPMA results are reported for 19 pyropes. Photomicrographs are given of the surface textures of grains of garnet and diamond; their morphology and the stepped development of faces on diamond bear witness to the short distance of transportation undergone by these minerals. It is concluded that prospecting for diamond deposits in this area should be promising.

R.A.H.

\*Editor's note: the term 'clastogenic' is generally used in connection with fire fountains and may be considered in a kimberlite volcanic context thus: fallout from a fire fountain produces a spatter rampart around the vent and if the accumulation rate is high the molten spatter may coagulate to form a flow of lava known as a clastogenic flow.

**Rb-Sr ages of Proterozoic kimberlites of India: evidence for contemporaneous emplacement.**

A. KUMAR, V.M. PADMA KUMARI, A.M. DAYAL, D.S.N. MURTHY AND K. GOPALAN. *Precambrian Research*, 62 (3), 1993, pp 227-37, 2 maps.

Rb-Sr analyses of leached phlogopite macrocrysts from kimberlite pipes 1, 2, 5 and 7 in S India give concordant ages of  $1091 \pm 20$ ,  $1092 \pm 15$ ,  $1093 \pm 20$  and  $1091 \pm 10$  m.y., respectively, indicating contemporaneous emplacement. The present results contradict earlier measurements. Groundmass mineral assemblages with low Rb/Sr ratios give a tight set of initial Sr ratios at  $0.7029 \pm 0.0002$ ,  $0.7019 \pm 0.0002$ ,  $0.7029 \pm 0.0002$  and  $0.7030 \pm 0.0004$ , suggesting derivation of the

primary kimberlite magma from a relatively uniform and depleted mantle source. A similar age and initial Sr isotopic ratio of one sample of the Majhgawan lamproite from central India imply that the Proterozoic kimberlite/lamproite activities in India, although widely separated in space, were almost contemporaneous. R.E.S.

**A high-chromium corundum (ruby) inclusion in diamond from the Sao Luiz alluvial mine, Brazil.**

G.R. WATT, J.W. HARRIS, B. HARTE AND S.R. BOYD. *Mineralogical Magazine*, 58 (3), 1994, pp 488-91.

A highly chromian, red corundum inclusion (~100 µm long) was found in a type II diamond with a variable  $\delta^{13}\text{C}$  (-11.56 to -15.21 vs PDB). Electron microprobe analyses gave  $\text{SiO}_2$  0.58,  $\text{TiO}_2$  0.10,  $\text{Al}_2\text{O}_3$  90.37,  $\text{Cr}_2\text{O}_3$  8.58,  $\text{FeO}$  0.28,  $\text{MnO}$  0.04,  $\text{MgO}$  0.40,  $\text{CaO}$  0.01,  $\text{Na}_2\text{O}$  0.01, = 100.39. The high Cr content of the São Luis corundum relative to corundum from eclogitic xenoliths may reflect formation at sub-lithospheric depths, analogous to increased Cr partitioning in kyanite with pressure. R.A.H.

**Comments on 'An unusual octahedral diamond' by A. Yacoot and M. Moore.**

A.R. LANG. *Mineralogical Magazine*, 58 (3), 1994, pp 506-510.

A recent application of X-ray topography to a natural diamond [*Min.Mag.* 56, 1992, 111-13] is considered to have incorrectly interpreted the evidence. A new interpretation is put forward, with the emphasis on the cuboid protuberances, and a possible explanation for the present shape of this diamond is proposed. R.A.H.

## Gems and Minerals

**Structural changes of nephrites at elevated temperatures as revealed by their IR-spectra.**

A. BANERJEE AND P. WANG. *Neues Jahrbuch für Mineralogie Monatshefte*, 1994 (7), pp 317-27.

Correlation between the Fe and Mg contents of two nephrites [no localities given] and their IR absorption bands was investigated. The more magnesian nephrite had one absorption band at  $3674\text{cm}^{-1}$  due to OH-stretching vibration; this band splits to give an additional absorption band at  $3660\text{cm}^{-1}$  for the more iron-rich sample. The changes in the IR spectra with heating to  $900^\circ\text{C}$  were also studied. R.A.H.

**L'amazonite de Santa Maria de Itabira (Minas Gerais, Brésil) (part 1)**

J.-P. CASSEDANNE. *Revue de gemmologie*, 119, 1994, pp 5-6, 2 illus. in colour.

Amazonite from the iron-bearing area of Itabira is described. The region is 100km east-nor-east of Belo Horizonte, Minas Gerais, Brazil, specifically in the Fazenda de Geraldo Duarte on the left bank of the Corrego do Patriminio. Amazonite occurs in a granite pegmatite cutting a granite gneiss and is associated with quartz, albite and biotite. M.O'D.

**Cordierites à effets spéciaux.**

C. DA CUNHA. *Revue de gemmologie*, 119, 1994, pp 11-14, 2 illus. in black-and-white, 2 in colour, 2 figs.

Chatoyant and star cordierites are described, both 4- and 6-ray versions of the latter being recorded. Though hematite and/or lepidocrocite are proposed as the cause of the chatoyancy the minerals responsible for the asterism were not identified. A note on a cordierite showing aventurescence identifies the presence of biotite and muscovite in the literature and these may be the cause of some of the aventurescence observed in the author's studies but this is uncertain. M.O'D.

**Gravure sur pierres précieuses: les saphirs.**

M. DUCHAMP. *Revue de gemmologie*, 119, 1994, pp 7-10, 6 illus. in black-and-white, 3 in colour.

Engraving on sapphire is traced from early times with notes on specimens from a number of collections. M.O'D.

**The Indaia sapphire deposits of Minas Gerais, Brazil.**

D.S. EPSTEIN, W. BRENNAN AND J.C. MENDES. *Gems & Gemology*, 30 (1), 1994, pp 24-32, 11 illus. in colour.

Although the total amounts of sapphire mined during the last three years have been relatively small, the discovery of deposits in this region may be of major significance. The sapphires are recovered from alluvium. Spectroscopy is consistent with iron-rich sapphires from other localities. Optical characteristics and microscopy are given in detail with a high percentage of stones showing colour change. Whether more sophisticated mining methods will be practical and economical remain questionable. R.J.P.

**Les perles rouges de Pinna noblis (continued).**

J.-P. GAUTHIER, J. CASEIRO AND B. LASNIER. *Revue de gemmologie*, 119, 1994, pp 2-4, 3 illus. in black-and-white, 2 in colour, 1 fig.

Pearls with aragonite composition are a little rarer than those composed of calcite and usually measure from 1-4mm. A section of one pearl

showed seven distinct growth stages. Some specimens apparently owed their nucleation to the presence of a 'nodule' placed at the base of the mantle close to the viscera. The structure of the nodule shows a fibrous and radiating picture with concentric growth zones. The material was found to be calcite with some aragonite.  
M.O'D.

#### The name game.

R.W. HUGHES. *The Australian Gemmologist*, 18 (10), 1994, pp 311-15.

Although written in a light-hearted style, the author nevertheless gives the reader much to think about and is master of his topic. The whole system for naming varieties is in need of serious overhaul and will require a concerted effort by all concerned bodies.  
R.J.P.

#### A combined magnetic resonance and gamma-irradiation study of some green beryls.

D.R. HUTTON AND G.J. TROUP. *The Australian Gemmologist*, 18 (10), 1994, pp 315-317, 7 illus. in black-and-white.

Part of a continuing series, the article shows how a combined Electron Spin Resonance technique (ESR) with gamma-irradiation can detect vanadium in the presence of both iron and chromium providing that the Fe<sup>3+</sup> and/or Cr<sup>3+</sup> lines are not too broad. In the study, Colombian emeralds from the Chivor and Muzo mines contained vanadium whilst Brazilian and Zambian emeralds together with Torrington emerald showed an absence of vanadium. The role of the radiation is to produce paramagnetic vanadium ions which can then be detected by the ESR method.  
R.J.P.

#### Gem Trade Lab Notes.

R.C. KAMMERLING, C.W. FRYER, G.R. CROWNINGSHIELD, T. MOSES, K. HURWIT AND S.F. McCLURE. *Gems and Gemology*, 30 (1), 1994, pp 39-46, 20 illus. in colour.

A snuff bottle was shown to be primarily plagioclase feldspar with garnet of the grossular-andradite-uvarovite series; a black stone which was highly magnetic was shown to be about 75 per cent hercynite and 25 per cent spinel; a lavender-coloured jadeite had been polymer impregnated; several translucent greenish-blue carved pendants with the appearance of finest Mexican chalcedony were confirmed as opal by X-ray diffraction; assembled cultured blister pearls were shown to be early Japanese; a pearl necklace was proved to be cultured with one pearl having a distinctive plastic nucleus; a star sapphire with a buff-top cut was found to be natural; a colour change synthetic sapphire had

its red colour enhanced by red foil or paint on the pavilion facets in a closed setting.  
R.J.P.

#### World gemstone market invaded by sizeable amount of Burma ruby.

C. KREMKOW. *Israel Diamonds and Precious Stones*, 136 (May), 1994, p. 64,68 (2 pages), 1 illus. in colour.

A newly developed ruby mine at Mong Hsu in western Myanmar is now producing sizeable quantities of commercial-quality ruby, and significant quantities of fine-quality goods particularly in sizes up to one carat. Larger sizes are rare and only available in the lower qualities. The deposit was first discovered in 1991, with commercial quantities being produced from 1992 when the Myanma government officially declared the area a gemstone tract. The supply of rough has enabled dealers to offer calibrated sizes up to 8 x 6 mm, including rounds up to 5mm. Virtually all Mong Hsu ruby is heated to eliminate blue zoning.  
P.G.R.

#### Der Blue John-Fluorit. Ein Besuch in den Flussspatgruben von Castleton, Derbyshire, England.

W. LIEBER. *Lapis*, 19 (6), 1994, pp 13-22, 1 illus. in black-and-white, 14 in colour, 3 maps.

A useful description with historical notes of the Blue John fluorite occurrences in Derbyshire, England. Many artefacts are illustrated.  
M.O'D.

#### Edel- und Schmucksteine aus Österreich.

G. NIEDERMAYR. *Mineralien Welt*, 5 (4), 1994, pp 17-23, 1 illus. in black-and-white, 16 in colour.

The gem minerals of Austria include emerald, garnet, quartz, nephrite, fluorite, lazulite, corundum, diopside, topaz, sphene, feldspars and phenakite, all occurring with reasonable frequency. Rarer species include datolite, sphalerite, apatite, scheelite, cordierite, scapolite, vesuvianite and rutile. All are briefly described.  
M.O'D.

#### Comparative study of beryl from various Indian occurrences - beryl from Jammu & Kashmir [continued from vol. 4. no. 1].

J. PANJIKAR. *Indian gemmologist*, 2 (2), 1994, pp 3-7, 6 tables, 2 figs in black-and-white, 6 in colour.

Kashmir beryls show protogenetic solid inclusions identified as biotite and three types of syngenetic single phase solid inclusions identified as quartz, fluorite and tourmaline. Primary and secondary fluid inclusions occur frequently in all observed specimens. Two-phase (gaseous and liquid) and three-phase inclusions are also reported. Multiphase inclusions including variously-shaped crystals (one identified as hematite)

are also observed. Colour zoning is reflected in the arrangement of the inclusions, both features being syngenetic. Chemical analyses are given. [To be continued.] M.O'D.

#### Synthèse du rubis en phase gazeuse.

D. ROBERT. *Revue de gemmologie*, 119, 1994, pp 15-18, 1 table, 1 fig.

A short review of the principles observed for crystal growth from the gaseous phase with particular reference to ruby. M.O'D.

#### Torrington emerald update.

K. SCHMETZER. *The Australian Gemmologist*, 18 (10), 1994, pp 318-19, 1 table, 2 illus. in black-and-white.

Evidence was cited for this green-coloured beryl from Torrington, New South Wales, to be described as emerald. This included spectrophotometric examination which confirmed the presence of chromium. Chemical analysis by electron microprobe and wet chemical determinations showed extreme zoning with alternating green emerald and colourless beryl. Vanadium intensified the green colour due to chromium. Microscopic examination of the crystals showed intense colour zoning parallel to the basal pinacoid. R.J.P.

#### On the presence of OH groups in Zabargad olivine gems.

P.F. SCIUTO. *Neues Jahrbuch für Mineralogie, Monatshefte*, 4, 1994, pp 145-56, 5 tables.

Single-crystal XRD study of an olivine from Zabargad shows a structure suggesting that an essentially hydrous phase is present. Hydrogen content is not measurable by this technique. The crystal examined was gem quality. Internal disorder evaluation showed that inter-crystalline exchanges ceased at an upper limit of approximately 600°C. M.O'D.

#### Lepidolith und Heliodor aus Rožná in Westmähren/CR.

J. STANEK. *Lapis*, 19 (6), 1994, pp 49-50, 1 illus. in black-and-white, 2 in colour.

Gem-quality yellow to yellow-green beryl is found in pegmatites in the neighbourhood of Rožná, Czech Republic. M.O'D.

#### Moçambique emerald.

A. THOMAS. *South African Gemmologist*, 6 (1), 1994, pp 10-11.

Brief note on the present status of mining of emerald in Moçambique reports that the Cabral enterprise is in ruins though sporadically worked, with other deposits, by itinerant garimpeiros. Light green crystals were recovered

in the vicinity of pegmatite veins in the metamorphosed Moçambique belt. The mines at Morrue have worked lenses of emerald-bearing schist in the contact zone of the pegmatite veins. The Maria I, Maria II and Maria III mines have produced the bulk of emerald from the area. M.O'D.

#### The Anahí Ametrine Mine, Bolivia.

P.M. VASCONCELOS, H. WENK AND G.R. ROSSMAN. *Gems and Gemology*, 30 (1), 1994, pp 4-23, 23 illus. in colour.

Ametrine (intergrown amethyst and citrine) only appeared commercially from this source in 1978 and its natural nature was challenged. The authors studied its nature at source and suggested that the sharp colour distribution was crystallographically controlled. Theories of colour formation were suggested and one involving quenching of the amethyst colour by natural radiolysis of the higher water content in citrine areas was not borne out by analysis of crystals from a different source. The geology and mineralogy were thoroughly discussed. The difficult access to the mine and former mining restrictions imposed by the authorities accounted in part for the mystery surrounding this deposit. R.J.P.

#### Blauer Kluffberyll aus der Südschweiz.

S. WEISS. *Lapis*, 19 (6), 1994, pp 25-40, 1 illus. in black-and-white, 5 in colour.

Blue beryl crystals, some appearing to be gem quality, are found as cleft minerals near the Basidino Glacier, Ticino, Switzerland. Some crystals reach 1.25cm in length. M.O'D.

#### Mineralogy of the Bennett pegmatite, Oxford County, Maine.

M.A. WISE, T.R. ROSE AND R.E. HOLDEN JR. *Mineralogical record*, 25 (3), 1994, pp 175-184, 2 tables, 9 illus. in black-and-white, 1 fig., 1 map.

Fine crystals of morganite, tourmaline and fluorapatite are among the minerals found at the Bennett pegmatite in western Maine, USA. Aquamarine of gem quality is also known from this location. A fine morganite crystal known as the 'Rose of Maine' was discovered in 1989 and was cut into gems. The original weight was approximately 23kg. Some elbaite is of gem quality and is found as water-melon and 'cucumber' [water melon reversed] crystals, though examples are relatively rare. Dark to pale green and pink crystals are also found. M.O'D.

#### Mikro-Achate aus Ost-Thüringen.

H. ZYPRIAN. *Mineralien Welt*, 5 (3), 1994, pp 44-6, 2 illus. in black-and-white, 5 in colour.

Small but attractive specimens of banded agate are described from eastern Thuringia, Germany. The sizes are around 3mm in general. M.O'D.

### Schöne Mineralien aus dem Setesdal Mineral Park. [No author given]

*Mineralien Welt*, 5 (3), 1994, pp 16-24, 19 illus. in colour.

Crystals of gem minerals are exhibited at a newly-established Mineral Park in Setesdal, Norway. Some of the examples are illustrated. M.O'D.

## Instruments and Techniques

### Visual optics—the Hodgkinson method: an update.

A. HODGKINSON. *The Australian Gemmologist*, 18 (10), 1994, pp 320-2, 4 illus. in colour.

In this welcome up-date the author acknowledges the contributions by Dr Hanneman to amplify the quantitative aspects of the technique and it is hoped that the proposed kit will enable the technique to be separated from the word 'instrumentless' which has hitherto been applied. R.J.P.

## Synthetics and Simulants

### Density-driven liquid-liquid phase separation in the system $Al_2O_3$ - $Y_2O_3$ .

S. AASLAND AND P.F. MCMILLAN. *Nature*, 369, 1994, pp 633-6, 1 table, 4 illus. in black-and-white, 3 figs.

The sluggishness of crystallization of yttrium aluminium garnet, host material for  $Nd^{3+}$  ions in YAG lasers, may be due to the existence of two coexisting liquid phases in the supercooled melt of  $Al_2O_3$ - $Y_2O_3$  both with the same composition and existing just above the glass transition at ambient pressure. It is proposed that the two phases differ only in density and that the transition is entropically driven. M.O'D.

### Fraudulent use of synthetic sapphire.

R. MACKENZIE. *South African Gemmologist*, 8 (1), 1994, pp 7-9, 3 illus. in colour.

Synthetic ruby rough is reported to have been offered as natural ruby in some south-east Asian markets. Material shows diffused colour banding (curved striae), rounded to elongate gas bubbles and masses of partly fused whitish alumina originating at the point of attachment between boule and refractory pedestal. Rough synthetic sapphire has also appeared on the

South African market. Both blue and pink to purple colour-change varieties are reported; both show characteristic signs of flame-fusion growth. M.O'D.

### Doubletten und Tripletten.

G. NIEDERMAYR. *Mineralien Welt*, 5 (3), 1994, pp 15-16, 5 illus. in colour.

Brief survey with excellent photographs of the various types of gemstone composites with emphasis on emerald imitation. M.O'D.

### Synthetische, nach dem Schmelz-diffusionsverfahren hergestellte Smaragde.

G. NIEDERMAYR. *Mineralien Welt*, 5 (4), 1994, pp 15-16, 5 illus. in colour.

Brief, useful description of the flux-melt method of emerald synthesis with photographs of characteristic inclusion. M.O'D.

### New developments in synthesis of gemstones.

J. PANJIKAR AND K.T. RAMCHANDRAN. *Indian Gemmologist*, 2 (2), 1994, pp 14-16.

Brief overview of some of the commoner synthetic gemstones covering ruby, emerald, spinel and alexandrite. M.O'D.

### [Nucleation and growth of diamond.] (Japanese with English abstract)

M. WAKATSUKI. *Journal of the Japanese Association of Crystal Growth*, 16 (2), 1989, pp 106-17.

The characteristic behaviour exhibited during the nucleation process of synthetic diamonds in a metal-carbon system under high-*P*, high-*T* conditions was explained by a reaction model in which the nucleation of diamond and recrystallization of graphite compete with each other. From the model, it became possible to deduce a suitable *P-T* cycle for obtaining well-crystallized particles and a new method of growing single crystals using seeds, which is different from the conventional temperature-gradient method. The formation of surface dendrites, commonly observed on synthetic diamonds, was prevented by slow cooling at the end of growth. I.S.



## Book Reviews

### **Führer durch das Deutsche Edelsteinmuseum.**

H. BANK, 1994. Vereinigung der Freunde der Mineralogie und Geologie, Heidelberg. pp 128, illus. in black-and-white and in colour. [Forms *Der Aufschluss* 45, 4/5, 1994: ISSN 0004-7856.]

While Idar-Oberstein has more than one publicly-displayed gemstone collection, over the past 25 years the Deutsche Edelsteinmuseum, housed in the Diamant- und Edelsteinbörse and thus conspicuously easy to find, has taken pride of place. It has long needed a comprehensive guide and now has one in this monographic issue of *Aufschluss*.

The guide opens with a short history of the museum which took up its present quarters in 1973, occupying one of the lower floors of the multi-storey bourse building. Movement towards the establishment of a gemstone museum in the town began as long ago as 1853 and before the latest move the collection was housed in the *Gewerbehalle*, familiar to all who have taken courses with the Deutsche Gemmologische Gesellschaft. The present quarters are superbly arranged as I have found on many visits and the new guide takes the visitor through the display systematically, having discussed the establishment of the gemstone industry in Idar-Oberstein - this dates at least from the fourteenth century.

The descriptive part of the text begins with a discussion of the nature of gemstones and their properties, the main gemstone-producing locations with brief notes on their geology, on rarities and on the use of gemstones and ornamental minerals in history. The book then describes the gemstones in chemical order, following the arrangement of the traditional mineral cabinet, giving chemical composition, crystal system, physical and optical properties, details of geological occurrence and main producing locations. Details of the major synthetic and imitation products follow.

Since Idar-Oberstein is one of the world's cutting and carving centres, it is welcome to find a short section on these topics (there is room for an up-to-date book on gemstone carving); this is followed by a discussion on nomenclature and by notes on gemstones found in the present century which form a separate display. Tables list numerical data for the major species and also list stones which might be confused with

diamond, ruby, blue sapphire and emerald. More useful is a chronological table giving the dates when the more important synthetic gemstones appeared. A final table gives the names of gem species first found in the present century.

The text is accompanied by first-class colour photographs by Gerd Becker and although the text is gemmological rather than popular there seems no reason why the guide, while part of a specialist scientific journal, should not become the standard for other collections. M.O'D.

### **Natural Glasses.**

V. BOUSKA, Z. BOROVEC, A. CIMBALNIKOVA, I. KRAUS, A. LAJCAKOVA AND M. PACESOVA, 1993. Ellis Horwood, New York and London. pp 354. Price £45.00.

This book considers natural glasses in terms of the time required to form them. Classified according to their mechanisms of formation, they include fulgurites, dialectic glasses formed by impact, impact glasses formed by thermal melting of the parent minerals and rocks during the impact event, tektites, and volcanic glasses (on Earth, Moon or the planets). The physical properties and chemical compositions of the various glasses are described and there is a final chapter on the practical uses of these glasses. R.A.H.

### **Gemstone enhancement: history, science and state of the art. Second edition.**

K. NASSAU, 1994. Butterworth Heinemann, Oxford. pp xii, 252, illus. in black-and-white and colour, softcover. Price £30.00. ISBN 0 7506 1797 7.

Few texts have been as eagerly awaited as this one which appears at a time when gemstone treatment is now affecting most of the major gem species and thence to the dealer and customer. Conferences have been devoted to this difficult topic and the publication of the first edition of this book in 1984 served to shed light on events which many in the trade had never considered.

While the main text is presented in the same way as in 1984, there have inevitably been amendments and these are considerable in some areas. The spread of fracture filling and the near-flooding of the blue stone sector of the market by treated topaz are two places which the author highlights in the preface - there are at least four

different techniques by which blue topaz can be irradiated. Even more alarming is the identification of seven (at the time of writing) types of treated yellow sapphires, a species which has now laboured under considerable disadvantage commercially for many years. The diamond story is no less complex though the references appended to this section of the book show the amount of work being carried out.

As in the first edition the author gives us much of the knowledge we might need to treat our own stones while showing us how dangerous and unpredictable such an activity would be. While many gemmologists will be interested in the chapters describing the practice and history of the different treatments, more (especially in gem testing laboratories) will turn to the alphabetical descriptive section where species are described in turn with prefatory summaries introducing the major species and references closing each description. Tables, useful addresses and amplification of the earlier chapters on heating and irradiation complete the text - or nearly: readers will be pleased to hear that in normal conditions of wear the Maxixe and Maxixe-type blue beryls will not fade for at least 20 to 40 years. This is just what student gemmologists in particular like to know and it is characteristic of this superb text that they can find out. Somehow this says it all!

M.O'D.

#### **Fluorescence: gems and minerals under ultraviolet light.**

M. ROBBINS, 1994. Geoscience Press, Phoenix, AZ. pp ix, 374, illus. in black-and-white and in colour. Price US\$40.00. ISBN 0 945005 13 X.

Books on luminescence are not too easy to come by and several years have passed since one appeared on the market. Geoscience Press have built up a reputation for good-quality books in the earth science field and this example is worth buying. Some of the material is taken from articles in *Rocks and minerals* and some of the text is updated from the author's previous book *The Collector's book of fluorescent minerals* (1983).

Beginning with an account of fluorescence the book continues with descriptions of two major localities, Mont St Hilaire, Quebec, Canada, and Franklin, New Jersey, USA. Both sites produce such fine specimens of fluorescent minerals that they are felt to merit a chapter to themselves. Lists of minerals are given for both places. The next chapter describes how fluorescence is activated and from this point the book deals with mineral species or groups one by one, each having its own chapter.

One chapter is dedicated to gemstones and provides useful information conveniently brought together from various sources. It is followed by an account of fluorescent faces and zones in minerals and then by a catalogue, with descriptions, of fluorescent minerals, in chemical order and including gem minerals. The text concludes with a table of activators, a set of experiments that the reader can try out and an excellent bibliography.

This is a useful book and fills a serious gap. While largely concerned with minerals that few people will ever see, there is enough on better-known and gem species to guarantee wide sales and gemmologists will do well to have a copy handy. The colour photographs, grouped in a single section, are the best I have seen so far in a book on this topic.

M.O'D.

#### **Fundamentals of crystals.** Second, enlarged edition.

B.K. Vainshtein, 1994. Springer-Verlag, Berlin. pp xxi, 480, illus. in black-and-white and in colour, hardback. Price DM119.00. ISBN 3 540 56558 2.

Covering (and subtitled) symmetry and methods of structural crystallography, this revised edition of what quickly became a standard work is welcome. While revising the original text and updating it where necessary, the author has added quasicrystals, developments in molecular-beam epitaxy, surface melting, improper ferroelectrics and incommensurate phases, with other topics. New techniques included are tunnelling microscopy, extended X-ray absorption fine structures (EXAFS) and position-sensitive detectors for X-rays. The excellent bibliography has also been extended and revised. For the interest of readers quasicrystals were 'discovered' when the structure of rapidly cooled  $Al_{86}Mn_{14}$  alloy was investigated by electron diffraction. The diffraction patterns gave a system of reflections which in reciprocal space had icosahedral  $m\bar{5}m$  symmetry, previously considered impossible as 5-fold rotation axes were incompatible with 3-dimensional translation symmetry in crystal structure. But don't amend your textbooks yet!

As in the first edition coloured diagrams of important crystal symmetry patterns make a welcome and useful addition to what is a complex subject, lucidly treated.

M.O'D.

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

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### OBITUARY

**Professor Igor S. Loupekine** (D.1963 with Distinction), Santa Julia de Loria, Principality of Andorra, died recently.

**David Wilkins**, Yeovil, died on 1 September 1994. A full obituary will be published in a future issue of *The Journal*.

### GIFTS TO THE ASSOCIATION

The Association is most grateful to David Callaghan of Hancocks & Co., London, for the gift of synthetic ruby beads for research and teaching purposes.

### NEWS OF FELLOWS

On 6 July 1994 **Peter Read** gave an illustrated talk to the Bournemouth Natural Science Society in their Christchurch Road premises on the subject of 'Gem mining in Sri Lanka'. Included in his presentation was a display of gemmology books and a selection of Sri Lankan rough and polished gemstone specimens in which thirteen species were represented.

### MEMBERS' MEETINGS

#### London

On 19 September 1994 at the Gem Tutorial Centre at 27 Greville Street, London EC1N 8SU, Susan Anderson gave an illustrated lecture entitled 'The gem materials of Zimbabwe'.

#### Midlands Branch

On 30 September 1994 at Dr Johnson House, Bull Street, Birmingham, Alan Hodgkinson gave a talk entitled 'Poking about in gemmological corners'.

#### North West Branch

On 21 September 1994 at Church House,

Hanover Street, Liverpool 1, Stephen Kennedy gave an illustrated talk entitled 'Pearls in the Arabian Gulf'.

### GEM DIAMOND EXAMINATIONS

In June 1994 97 candidates sat the Gem Diamond Examination worldwide, of whom 66 qualified including four with Distinction. The names of the successful candidates are as follows:

#### *Qualified with Distinction*

Haddock, Brendan, Edinburgh.  
Kneebone, David G., Penzance.  
Scott, Damian T., London.  
Stossel, Hillary, London.

#### *Qualified*

Baddoo, Alfred A., London.  
Bailey, Anne M., London.  
Bailey, Lisa J., Birmingham.  
Balducci, Annette, Neston.  
Ball, Pamela, Hong Kong.  
Bao, Chunhui, Wuhan, China.  
Bastians, Indramal, London.  
Brady, Deanna M., Wirral.  
Bray, Betty A., Abilene, Tex., USA.  
Brown, Allen G., Birmingham.  
Carvalho, Rui Galopim de., Lisbon, Portugal.  
Chan Ka Fung, Louisa, Hong Kong  
Chen Shulan, Wuhan, China.  
Chew Lee Lee, Hong Kong.  
Christian, Helen E., Bolton.  
Clover, Wai Ying, Birmingham.  
Crabbe, Jeremy P., Hong Kong.  
Di Jingru, Wuhan, China.  
Everitt, Sally A., London.  
Fu Yun Long, Wuhan, China.  
Galloway, Linda L. Vacca-, Hong Kong.

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Geoghegan, Noel R., Wellesbourne.  
 Griffin, Anthony, Godalming.  
 Guo Shougou, Wuhan, China.  
 Han Hui, Wuhan, China.  
 Henn, C. John W., Wolverhampton.  
 Hughes, Helen, London.  
 Huang Jun, Wuhan, China.  
 Jackson, Brian, Edinburgh.  
 Jhaveri, Devang, London.  
 Jones, Amanda, Hagley.  
 Kilby Hunt, Judith A.F., London.  
 Krikos, Alexandra, London.  
 Lee, Jin Young, London.  
 Lewis, Rob, Totternhoe.  
 Lian Bee Chen, Pauline, Hong Kong.  
 Lowe, David J., London.  
 Lu, Jei-Chih, London.  
 Ludlow, Andrew P., London.  
 Massow, Kenneth J., Rochford.  
 Mathiopoulou, Regina, Athens, Greece.  
 O'Brien, Gillian M., North Berwick.  
 Page, Christopher, Newmarket.  
 Parker, David T., Sunderland.  
 Penton, Keith, London.  
 Pratt, James, London.  
 Qi Lijian, Wuhan, China.  
 Saxton, Carol A.L., Alton.  
 Siu Lam Ma, Hong Kong.  
 Sondack, Julia, London.  
 Sum-Pui F. Yu, Kowloon, Hong Kong.  
 Sutton, Daniela N., Cheltenham.  
 Tarazi, Mirna Y., London.  
 Taylor, Roger J., Bordesley Green.  
 Thomson, Joanna, Peebles.  
 Walker, Averil S., London.  
 Wong Nim Chi, Phyllis, N.T., Hong Kong.  
 Xu Shirong, Wuhan, China.  
 Yan Weixuan, Wuhan, China.  
 Yang Mingxing, Wuhan, China.  
 Zhang Shuyun, Wuhan, China.  
 Zhou Min, Wuhan, China.

#### EXAMINATIONS IN GEMMOLOGY

In the June 1994 Examinations in Gemmology 366 candidates sat the Preliminary examination, 255 of whom qualified; 354 sat the Diploma Examination and 148 qualified including four with Distinction.

The Tully Medal for the candidate who

submits the best set of answers in the Diploma examination which, in the opinion of the Examiners, are of sufficiently high standard, was awarded to Mr Neil Rose of Stockport.

The Anderson Bank Prize for the best non-trade candidate of the year in the Diploma examination was awarded to Miss Hiroko Fukagawa of Osaka, Japan.

The Diploma Trade Prize for the best candidate of the year who derives his main income from activities essentially connected with the jewellery trade was awarded to Mr Neil Rose of Stockport.

The Anderson Medal for the best candidate of the year in the Preliminary examination was awarded to Miss Deborah Wilson of Boston, Lincolnshire.

The Preliminary Trade Prize for the best candidate under the age of 21 years on 1 June 1994 who derives her main income from activities essentially connected with the jewellery trade was awarded to Miss Alicia Arnold of London.

#### DIPLOMA

##### *Qualified with Distinction*

Fukagawa, Hiroko, Osaka, Japan.  
 McIntosh, Robert P., Edinburgh.  
 Rose, Neil R., Stockport.  
 Watatsuki, Reiko, Kawasaki, Japan.

##### *Qualified*

Alaniva, Orvokki, Helsinki, Finland.  
 Alexander, Maria K., London.  
 Antzoulakos, George, Athens, Greece.  
 Armstrong, Michael J., Whitley Bay.  
 Au Ming Cheung, Hong Kong.  
 Au Yang So-Wah, Natasha, Hong Kong.  
 Audichya, Pradeep, Jaipur, India.  
 Barcados, Alexander J., Toronto, Ont., Canada.  
 Bastians, Indramal, London.  
 Bevers-Reinders, L.M., Rotterdam, The Netherlands.  
 Bezeredi, Svetlana, W. Vancouver, BC, Canada.  
 Bishop, Heather M., Ipswich.  
 Bollack, Josee, Strasbourg, France.

## FORTHCOMING MEETINGS

### London

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

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

- |             |   |                 |
|-------------|---|-----------------|
| 22 November | <b>Gemstones on display at the Natural History Museum:<br/>past, present and future</b> | Cally Hall      |
| 5 December  | <b>Sapphires in the Laboratory</b>  | Stephen Kennedy |

### Midlands Branch

- |                 |   |                      |
|-----------------|---|----------------------|
| 6 November      | Autumn Seminar at the Cobden Hotel, Hadley Road, Birmingham |                      |
| 25 November     | <b>How to buy gemstones</b>                                 | Grenville Millington |
| 3 December      | 42nd Annual Dinner  |                      |
| 22 January 1995 | Gem Club  |                      |
| 27 January      | <b>The treatment of diamonds</b>                            | Eric Emms            |
| 19 February     | Gem Club  |                      |
| 24 February     | Clive Burch (subject to be announced)                       |                      |
| 19 March        | Gem Club  |                      |
| 31 March        | <b>Jewellery through the ages</b>                           | Nigel Dunn           |

The meetings will be held at Dr Johnson House, Bull Street, Birmingham. Further details from Mandy MacKinnon on 021-444 7337.

### North West Branch

- |             |                        |
|-------------|------------------------|
| 16 November | Annual General Meeting |
|-------------|------------------------|

Meetings will be held at Church House, Hanover Street, Liverpool 1. Further details from Joe Azzopardi on 0270 628251.

- Bossenbroek, A.E.H., Doorn, The Netherlands.  
 Boyens, Christine P., Auckland, New Zealand.  
 Bruce, Rachel M., Edinburgh.  
 Butcher, Anna, London.  
 Carr, Simon D., Garstang.  
 Carroll Marshall, Anne E., Hong Kong.  
 Carvalho, Roberta Melo De, Rio de Janeiro, Brazil.  
 Chan, Kin-Chung, John, Hong Kong.  
 Chan Kwok Keung, Hong Kong.  
 Chan Wai Ching, Joanne, Kowloon, Hong Kong.  
 Chan Yuk Victoria, Hong Kong.  
 Chao, Tan-Chi, Dandy, Taipei, Taiwan.  
 Chen, Pauline Lian Bee, Hong Kong.  
 Chen Chin-Ho, Taipei, Taiwan.  
 Cheng Fung Kei, Hong Kong.  
 Cheng Lap Fan, Hong Kong.  
 Chokhani, Shiv Vishwanath, Bombay, India.  
 Chua, Virna Ngo, Hong Kong.  
 Chung Yam Ming, Hong Kong.  
 Cliff, Graham, Greenwich.  
 Coghlan, Karen, Exeter.  
 Cooke, Joanne T., Petchburi, Thailand.  
 Cookson, Ian P., Sheffield.  
 Cracco, Alexia, London.  
 Devon, Jill V., Felsted.  
 Dickinson, Barry E., Blackburn.  
 Diserens, Myriam, London.  
 Dragland, Frode, Sortland, Norway.  
 Eames, Lucy, London.  
 Farion, Jean-Christophe, London.  
 Fung Yuk Fung, Hong Kong.  
 Gamst, Terje, Breivikbotn, Norway.  
 Gemin Cherkaoui, Nadine, Geneva, Switzerland.  
 Goldschmidt-Husein, Asli, St. Ingbert-Owb, Germany.  
 Goss, Sanya L., Aldershot.  
 Graff, Elliott M., London.  
 Green, Kimberly H., Birmingham.  
 Gunell, Carola, Kirjala, Finland.  
 Hamidulla, Suzan, Helsinki, Finland.  
 Hamza, Mohamed Hassan, Colombo, Sri Lanka.  
 Hasler, Christian S., Toronto, Ont., Canada.  
 He, Wei, Wuhan, China.  
 Hindley, Stuart W., Worksop.  
 Hu Hai, Wuhan, China.  
 Hui Sze Wai, Hong Kong.  
 Hui Wai Yee, Wendy, Hong Kong.  
 Jang Sool Cho, Seoul, Korea.  
 Jansen, E.T.D.M.L., Wijchen, The Netherlands.  
 Jargiello, Barbara A., Lublin, Poland.  
 Jin, Yi, Wuhan, China.  
 Jung, Gwang-Gyo, Seoul, Korea.  
 Kam Siu Tong, John, Hong Kong.  
 Kato, Ayako, Tokyo, Japan.  
 Kervezee, R., Berkel-Rodenrys, The Netherlands.  
 Ketomaki, Tapio, Helsinki, Finland.  
 Kilby, Linda E., Blackburn.  
 Kim Sang Sun, Seoul, Korea.  
 Kizsel, Elisabeth M., Vancouver, BC, Canada.  
 Kobayashi, Masahide, Osaka, Japan.  
 Kon Kiang Fung, Hong Kong.  
 Kumar, V. Krishna, London.  
 Kwan Wai Shun, Hong Kong.  
 Lakhtaria, Yashwin, London.  
 Lam, Christina, Toronto, Ont., Canada.  
 Leventopoulou, Ageliki-Loudovika, Athens, Greece.  
 Liang, Tao, Wuhan, China.  
 Lin, Hsin-Pei, Taipei, Taiwan.  
 Lord, Karen, Lutterworth.  
 Louie Miu Man, Hong Kong.  
 Lu, Yi, Wuhan, China.  
 Lu, Yung Ching, Taipei, Taiwan.  
 Mackenzie, Nicola-Jane, Hong Kong.  
 Mak, So Yi, Hong Kong.  
 Mann, William M., Gloucester.  
 McCarthy, Emily, Dublin, Ireland.  
 McKay, Euan S., Newport-on-Tay.  
 Molloy, Nicola, Ipswich.  
 Ng Lok Chung, Angela, Hong Kong.  
 Okada, Takayuki, Osaka, Japan.  
 Or Chi Ching, Hong Kong.  
 Pan, Huijin, Wuhan, China.  
 Papadopoulos, Iraklis, London.  
 Paredes Quevedo, Juan, Madrid, Spain.  
 Park, In-Sook, Seoul, Korea.  
 Park Young Ah, Seoul, Korea.  
 Pavlides, Vassilis, Athens, Greece.  
 Pegg, Delia, Petts Wood.  
 Perez Munoz, Jorge, Madrid, Spain.  
 Picallo Rodriguez, Ma Teresa, Santiago De Compostela, Spain.

- Proffitt, Graham S., Liverpool.  
 Pulkkinen, Kari T., Helsinki, Finland.  
 Purkiss, Christopher R., London.  
 Ramos-Gonzalez, Stephen P., London.  
 Ranasinghe, L.D.S., Eheliyagoda, Sri Lanka.  
 Randall, Gary M., Lowestoft.  
 Reilly, Clare, Birmingham.  
 Rubin, Maria, Lannavaara, Sweden.  
 Sakai, Takeo, Chiba Pref., Japan.  
 Schroetter, Ralph E., Whitby, Ont., Canada.  
 Shi, Dan, Wuhan, China.  
 Sinton, Sarah K., Newcastle-upon-Tyne.  
 Smyth, Lesley J., London.  
 Song, Jun-Ho, Seoul, Korea.  
 Sorrill, Rachel, London.  
 Stather, Lorne F., Hong Kong.  
 Stilwell, Lesley, Berkhamsted.  
 Stoner, Jonathon P., Bradford.  
 Sutton, Daniela N., Cheltenham.  
 Syren, Riitta, Helsinki, Finland.
- Tang Man Wah, Connie, Hong Kong.  
 Tang Wai Chun, Hong Kong.  
 Tao, Du, Wuhan, China.  
 Terras, Fay, Newton Abbot.  
 To An You, Peter, Hong Kong.  
 Tse, Pauline Lai-Kiu, Hong Kong.  
 Tse Woon Lam, Hong Kong.  
 Varey, Irena Maria, Leicester.  
 Wang Tai-Hwan, Taipei, Taiwan.  
 Welton, Andrew, London.  
 Wilson, Deborah T., London.  
 Windwick, William, Elgin.  
 Xu, Hong, Wuhan, China.  
 Yeom, Chang-Woo, Pusan, Korea.  
 Ying Kai Yiu, Hong Kong.  
 Yip Ngai, Hong Kong.  
 Yuen, Flora Tsz Wai, Hong Kong.  
 Zhao, Hechun, Wuhan, China.  
 Zhao, Rugong, Wuhan, China.  
 Zhou, Jie, Wuhan, China.  
 Zhu, Wenhui, Wuhan, China.

## GAGTL GEM TUTORIAL CENTRE

### Recognizing Treatments and Synthetics

2-3 November

An opportunity for you to handle treated and synthetic gem materials currently encountered in the trade, plus materials which have recently appeared. Improve your technique for detection work on these materials.

*Price £223.25 (including sandwich lunch)*

### The Gem Diamond Practical Tutorial

9-11 and 14-16 November

Limited places are available to anyone requiring basic practical training or a practical review for trade purposes. This is a tutorial structured over six days and is designed to give home study students a complete grounding in practical aspects. It will cover clarity and colour grading of polished diamonds, using 10x lens, microscope and colour comparison stones. You will also handle simulants and clarity-enhanced stones, rough and crystals.

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### Two-day Diploma Practical Workshop

7-8 January 1995

The long-established intensive practical course to help students prepare for the Diploma practical examination or for non-students to brush up on technique. This is the course to help you practice the methods required to coax results from instruments which can be difficult or awkward to use. The course includes a half-length mock exam for you to mark yourself.

*Price £160.39 (£111.04 for GAGTL registered students)*

*includes sandwich lunches*

Just phone, fax or write for details to Doug Garrod at the  
 GAGTL Education Office - 27 Greville Street, London EC1N 8SU

Tel: 071-404 3334 Fax: 071-404 8843

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- Abbott, Debra, Harrogate.  
 Adams, Victoria, London.  
 Aiken, Glenn, Tunstall.  
 Akerblom, Tom E., Helsinki, Finland.  
 Ambrose, Steven J., London.  
 Anderson-Slight, Jamie, London.  
 Ankh, Catrin M., Stockholm, Sweden.  
 Arnold, Alicia M., London.  
 Au Yeung Kwok Ho, Hong Kong.  
 Audichya, Pradeep, Jaipur, India.  
 Badibanga Bialusambo, Carine, Brussels, Belgium.  
 Bailey, Alison, Hong Kong.  
 Baolin, Ma, Wuhan, China.  
 Baxter, Richard P., Birmingham.  
 Beesley, Wendy D., Birmingham.  
 Betten, Marja L., Schoonhoven, The Netherlands.  
 Bray, Betty A., Abilene, Tex., USA.  
 Briginshaw, Richard C., London.  
 Britton, Andrea L., Woking.  
 Brooke-Webb, Susannah Y., London.  
 Buckie, Peter R., Cambridge.  
 Burrige, Marcelle, Aldershot.  
 Cadby, John H.V., Trowbridge.  
 Callaghan, Stephen, Horsham.  
 Carlsson, Johanna A., London.  
 Carr, John R., Cheltenham.  
 Chan, Grace K.M., Kowloon, Hong Kong.  
 Chan, Ka Mei, Cynthia, Hong Kong.  
 Chan, Tony Chung Sing, Toronto, Ont., Canada.  
 Chan, Yik Pun, Hong Kong.  
 Chan, Yuk, Christine, Kowloon, Hong Kong.  
 Chan Chi Ling, Phyllis, Hong Kong.  
 Chen Shulan, Wuhan, China.  
 Cheng, Edmund Shui-Man, Hong Kong.  
 Cheng, Po Wah, Kowloon, Hong Kong.  
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At a meeting of the Council of Management held on 20 July 1994 at 27 Greville Street, London EC1N 8SU, the business transacted included the election of the following:

##### *Fellowship*

Deora, Naresh, Jaipur, India.

##### *Ordinary Membership*

Branch, Henry C., Hampton.  
 Chu-Jueh Chen, Debbie, Taipei, Taiwan.  
 Sulub, Abdirizak M., London.  
 Webb, Christine, London.  
 Weng, Li Li, Taipei, Taiwan.

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

##### *Transfers - Ordinary Membership to DGA*

Bray, Betty A.

##### *Transfers - Ordinary Membership to FGA*

Beyers-Reinders, L.M., Rotterdam, The Netherlands.  
 Bollack, Josee, Strasbourg, France.  
 Butcher, Anna, London.  
 Carr, Damien P., Preston.  
 Chao, Tan-Chi, Dandy, London.  
 Chen, Chin-Ho, Taipei, Taiwan.  
 Cheng, Su Chen, Taipei, Taiwan.  
 Cliff, Graham, London.  
 Devon, Jill, V., Felsted.  
 Eames, Lucy, Ljubljana, Slovenia.  
 Farion, Jean-Christophe, London.  
 Fukagawa, Hiroko, Osaka, Japan.  
 Goss, Sanya Lisa, Aldershot.  
 Kato, Ayako, Tokyo, Japan.  
 Kerzee, R., Berkel-Rodenrys, The Netherlands.  
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*Transfers - FGA to FGA/DGA*

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 Portugal.  
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 Galloway, Linda L. Vacca, Hong Kong.  
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 Henn, C. John W., Tong.  
 Hughes, Helen, London.  
 Jackson, Brian, Edinburgh.  
 Jones, Amanda, Stourbridge.  
 Kneebone, Garfield D., Penzance.  
 Krikos, Alexandra, Birmingham.  
 Lewis, Rob, Dunstable.  
 Lowe, David J., London.  
 Lu, Jui-Chih, London.  
 Ludlow, Andrew P., Buckhurst Hill.  
 Ma, Siu Lam, Hong Kong.  
 Massow, Kenneth J., Rochford.  
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 Page, Christopher, Newmarket.  
 Penton, Keith, London.  
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 Scott, Damian T., London.

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 Sutton, Daniela N., Evesham.  
 Thomson, Joanna, Peebles.  
 Walker, Averil S., Kingston-on-Thames.  
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Baddoo, Alfred A., London. 1994  
 Chew, Lee Lee, Hong Kong. 1994  
 Everitt, Sally A., South Kensington. 1994  
 Parker, David T., Roker. 1994

*Fellowship*

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 Carroll Marshall, Anne, Hong Kong. 1994  
 Cheng, Fung Kei, Hong Kong. 1994  
 Coghlan, Karen A., Weston-Super-mare.  
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 Dickinson, Barry, Clitheroe. 1994  
 Graff, Elliott M., Cockfosters. 1994  
 Lam, Tai Sing, Denys, Kowloon, Hong  
 Kong. 1994  
 Molloy, Nicola, Ipswich. 1994  
 McKay, Euan S., Newport on Tay. 1994  
 Proffitt, Graham S., Liverpool. 1994  
 Schroetter, Ralph E., Whitby, Ont., Canada.  
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 Stoner, Jonathan, Bradford. 1994  
 Terras, Fay, Newton Abbot. 1994

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 James, William, Delafield, Wisconsin, USA.  
 Jones, Maureen, Coventry.  
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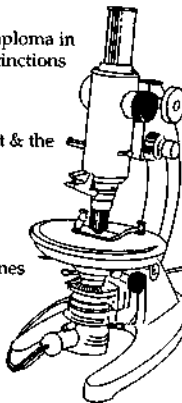
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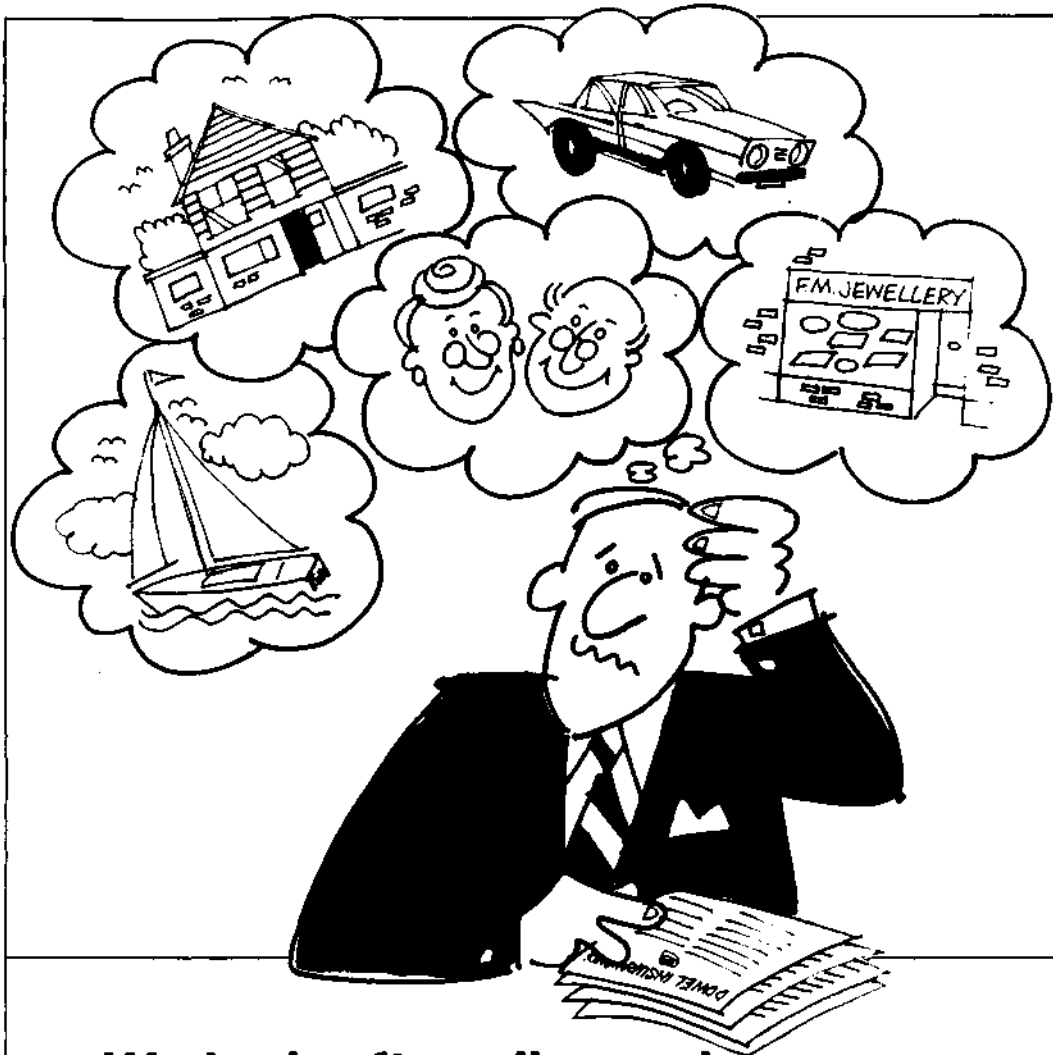


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