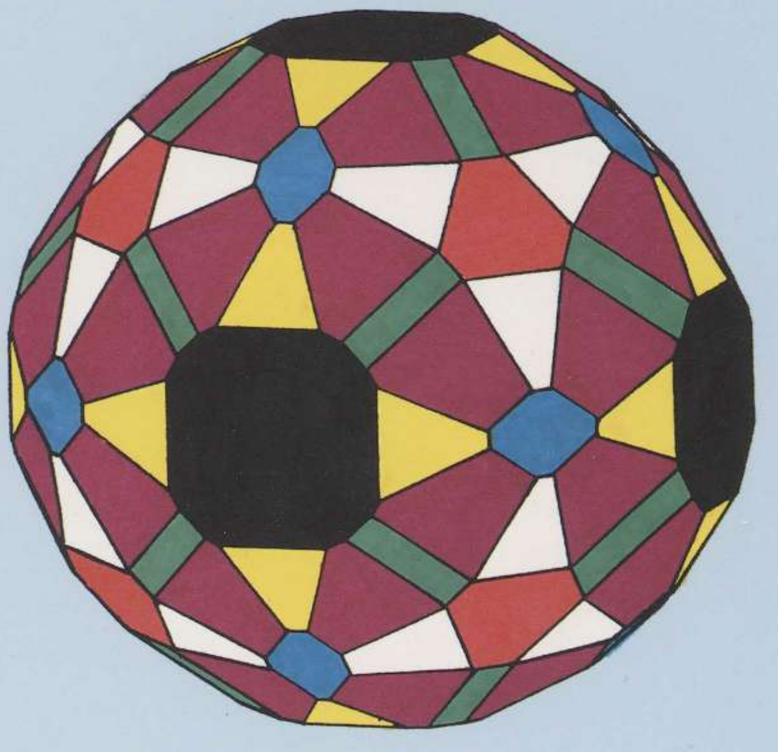
Volume 23 No. 4. October 1992

The Journal of Gemmology



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The Gemmological Association and Gem Testing Laboratory of Great Britain
27 Greville Street, London EC1N 8SU
Telephone: 071-404 3334 **Fax: 071-404 8843**

The Journal of Gemmology

VOLUME 23

NUMBER FOUR OCTOBER 1992

Cover Picture

A 146-faced 'sphere' formed by the combination of the cube, octahedron, rhombdodecahedron, trisoctahedron, hexoctahedron, icositetrahedron and tetrahexahedron. (See 'Symmetrical polyhedra for gemstones' on p. 207).

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FORTHCOMING MEETINGS

1992 ANNUAL CONFERENCE AND PRESENTATION OF AWARDS

The second GAGTL Annual Conference is to be held on Sunday 8 and Monday 9 November at the Great Western Royal Hotel, Paddington, London.

Dr K. Nassau will deliver the keynote lecture on treatments in a full programme dealing with coloured stones, diamonds, valuation procedures and the Duchess of Windsor's jewellery.

The Conference will be followed on the evening of Monday 9 November by the Presentation of Awards which will take place at Goldsmiths' Hall, Foster Lane, London EC2. This year the awards will be presented by Dr K. Nassau.

MEMBERS' MEETINGS

London

On 24 November 1992 at the City Conference Centre, Mark Lane, London EC3R 7JN, lectures will be given on the gemstone deposits of Africa and the trade associated with them. Admission by ticket only, at a cost of £5.00 for GAGTL members, £10.00 a member and a guest, and £8.00 for non-members. For further details and tickets contact the GAGTL.

Midlands Branch

Meetings will be held at Dr Johnson House, Bull Street, Birmingham. Further details from Gwyn Green on 021-440 1428 or 021-445 5359.

25 September 1992	Open Forum. Any questions to our panel.
30 October 1992	Bring and Buy. Specimens, books, equipment - 10% to Branch funds.
1 November 1992	Annual Practical Gemmology Seminar, to be held at the Cobden Hotel, Birmingham. Tickets £18.00 from David Larcher, Midlands Branch Chairman, c/o GAGTL.
27 November 1992	Nigel Dunn. 'Jewellery through the ages'.
5 December 1992	Fortieth Anniversary Dinner.
27 January 1993	Edgar Taylor. 'Fossicking in Wales'.
26 February 1993	Robert Campbell-Legg. 'The art of the engraver'.
26 March 1993	Peggy Stock. 'Crystal healing'.
30 April 1993	AGM and filmshow.

North West Branch

Meeting to be held at Church House, Hanover Street, Liverpool 1. Further details from Irene Knight on 051-924 3103.

21 October 1992	Dr Jamie Nelson. 'Optical attributes of a diamond'.
18 November 1992	Annual General Meeting.

Oxidation treatment of the sapphires from Shandong Province, China

Wang Chuanfu, Yang Yaoshan and Li Guoxun

301 Lab, General Research Institute for Non-Ferrous Metals
Beijing 100088, P.R. China

Abstract

It is now well known that a large number of dark blue sapphires are found in Shandong Province, China. In order to improve the grade of these sapphires, the traditional heating treatment was used at the temperature of 1700°C. However the blue hue of sapphire was almost lost and became a grey colour. Instead, a new method was applied to enhance the clarity of the sapphire so as to improve its quality. In this method the electrolysis technique using molten salts was used to produce a very vigorous oxidation of the corundum. The Fe^{2+} contained in the sapphire was partly oxidized; as a result the samples treated by electrolysis show a very beautiful colour with a light blue hue. The absorption spectra of the specimens also confirm that the sapphire colour was improved.

Introduction

Recently, large natural corundum resources have been found in Shandong Province, China. However there are only a few gem-grade sapphires among these corundums and many of them show an especially distinct pleochroism. These sapphires show bluish-violet colours perpendicular to the *c*-axis of the crystal, and green or greenish-yellow colours parallel to the *c*-axis. These stones cannot be used as gemstones but they might possibly convert to gem-grade sapphires after treatment. Usually these sapphires are heated at different temperatures in the range of 1400-1850°C for varying periods of time. This may enhance the clarity of these sapphires, but treated samples showed bluish-grey or grey colours. The sapphires which show grey colours would not sell. In this investigation such stones were treated by a new method using an oxidation technique with molten salts at the temperature of 940°C only. These treated sapphires can show good blue hues and better clarity compared with the sapphires treated by the heating method.

Experimental

The molten salts used are AlF_3, Na_3AlF_6, CaF_2, TiO_2 and Al_2O_3. The composition is approximately 75.5% Na_3AlF_6, 5% AlF_3, 5% CaF_2, 4.5% TiO_2 by weight and the Al_2O_3 content should be held at near the saturation solubility (10-11wt%). The salts were mixed and placed into the carbon crucible inside a temperature-controlled furnace. As shown in Figure 1, Pt (platinum) wire was used as the anode and the sapphire sample was also coiled by the platinum wire. The carbon crucible was used as the cathode. At the cathode, aluminium metal containing a little titanium was produced and deposited on the bottom of the crucible. Once the electrolyte was molten, the anode and sample were immersed together into the bath and electrolysis was conducted at a cell voltage of 3.0 volts for 30-45 minutes, then the anode and sample were taken out of the bath and cooled at the rate of 9°C/min.

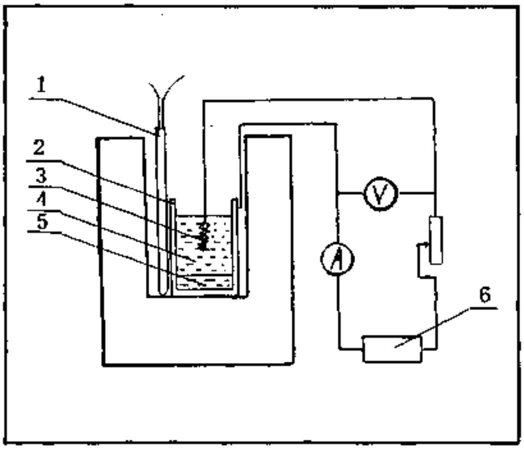

Fig. 1. Electrolysis test assembly
1 thermocouple; 2 carbon crucible; 3 Pt anode with sample; 4 electrolyte; 5 aluminium; 6 direct supply.

For the heating treatments the sapphires were placed in the carbon crucibles and heated in a high frequency furnace in air, and held for 10 hours at the temperature of 1700°C and then cooled at the rate of approximately 9°C/min. The treated samples were cut and polished to present flat parallel surfaces which were examined spectroscopically perpendicular to the *c*-axis of the sapphires.

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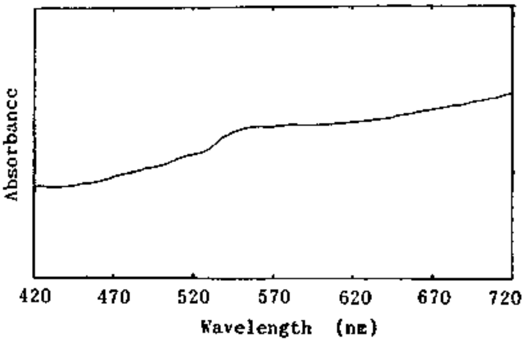

Fig. 2. Absorption spectrum before treatment.

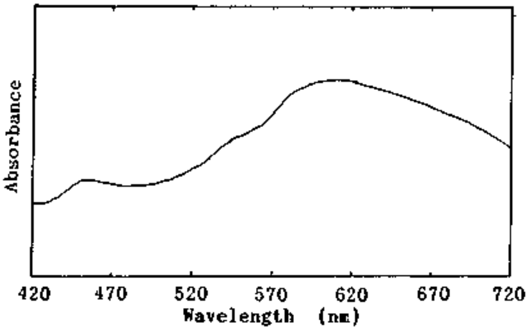

Fig. 3. Absorption spectrum after electrolysis treatment

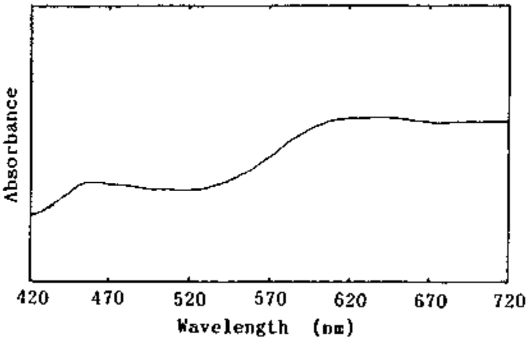

Fig. 4. Absorption spectrum after heat treatment.

Results

Most samples can be changed to a light blue colour from dark blue after electrolysis. The clarities of the samples were obviously improved. The samples showed a pure blue colour perpendicular to *c*-axis of the crystal and the grey hue was not observed. However, samples were dissolved slightly by the melts and lost approximately 8% in weight.

During the heating at 1700°C most of the samples turned into bluish-grey or grey and their clarities were improved slightly also. In the crucible itself traces of Ti were checked by electron microprobe analysis, but the sapphires lost very little Ti during high-temperature heat treatments. The absorption spectra of these sapphires taken perpendicular to the *c*-axis, clearly show the difference before and after treatment by different methods. These results are shown separately in Figures 2, 3 and 4.

Discussion

The blue sapphire is a single crystal of Al_2O_3 containing minor Fe and Ti oxides. The pure Al_2O_3 single-crystal is colourless and absolutely transparent. Small amounts of Fe and Ti contained in the crystal can absorb certain wavelengths of light and this results in the sapphire having colour. The colour and clarity of the sapphire entirely depend on the contents and states of Ti and Fe contained in the sapphire crystal. There is a high content of Fe in the dark sapphire, especially Fe^{2+}, which leads to the sapphire looking dark blue. By decreasing the Fe content or oxidising Fe^{2+} to Fe^{3+}, the dark sapphire would turn to lighter blue and the clarity would be improved.

The traditional heat treatment method is used for the purpose of the oxidation of Fe^{2+} ions, but this oxidation process requires a high temperature, approximately 1700°C. However the Ti ions in the crystal may diffuse outwards and be lost under such a high temperature (over 1300°C). The sapphire that loses only a little Ti exhibits a grey colour. So the sapphire sample heated at 1700°C shows bluish-grey, but its clarity is improved. Figures 2 and 4 show that absorption peaks occur at 450nm after heat treatment, and these have been assigned to Fe^{3+} (1). The heat treatment has led to the oxidation of Fe^{2+} to Fe^{3+} inside the crystal. Comparing Figure 2 with Figure 4, the absorption band at around 550nm, associated with Ti^{3+} (1), is reduced or disappears after heating. Meanwhile, Ti traces were found in the crucible after the heat treatment. This suggests that some Ti contained in the sapphire was surely lost because of heat treatment.

In order to oxidize the sapphire, but prevent it losing Ti, the electrolysis technique was used. The fluoride melts can corrode the crystal lattice of the sapphire (Al_2O_3) at the temperature of only 940°C.

Alumina (Al_2O_3) can be readily dissolved by the fluoride melts. The saturation solubility is above 11 wt% at the temperature of 940°C. Thus the mass transfers are very easy to execute at the interface between the sapphire and the molten salts. During the electrolytic process, much oxygen and a little fluorine gas were produced on the Pt anode. Fluorine and oxygen have a very strong ability to oxidize at high temperatures. The fluorine atom is very small, so fluorine and oxygen may enter the crystal lattice and oxidize Fe^{2+} to Fe^{3+} and the content of Fe^{3+} increases significantly inside the sapphire. The absorption bands at 450nm have been assigned to Fe^{3+} (1) and the broad absorption bands beyond 570nm have been associated with Fe^{3+} (2). The spectra so obtained confirm oxidation of Fe^{2+} to Fe^{3+} (see Figures 2 and 3).

The samples that were treated by electrolysis develop a light blue colour from dark blue and the grey hue was not observed. During electrolysis at 940°C, Ti ions diffuse with difficulty because of the relatively low temperature. Meanwhile the Ti ion concentration (as TiO_2) of the electrolyte is about 4%wt, more than the concentration of Ti in the sapphires. Thus, even though there is the diffusion of Ti ions, they diffuse into the sample from the melt, which probably leads to the Ti content of the sapphires increasing slightly; this is consistent with the spectra. The absorption near 550nm has been associated with Ti^{3+} (1). Before treatment, samples exhibited a weak absorption band at 550nm and after electrolysis it still persisted, or has an enhanced intensity of absorption maybe owing to diffusion from melt to crystal (compare Figure 2 with Figure 3).

Based on above conclusions the following model is presented to explain the transformations taking place during the electrolysis and heating treatment of the sapphires:

(1) heat treatment can promote the oxidation of Fe^{2+} to Fe^{3+} in the sapphire crystal, which improved the clarity of sapphire;
(2) in the 1700°C heating process, some Ti ions of the sapphire were lost which made sapphire show a grey colour;
(3) during electrolysis at 940°C, the Fe^{2+} of the sapphire was oxidized to Fe^{3+}, which improved the sapphire colour significantly;
(4) at 940°C with the electrolysis process, the Ti ions of the sapphire cannot be lost, and the sapphire could even absorb some Ti ions from the molten salts, so retaining or even increasing the Ti content and colour of the sapphire.

Acknowledgements

The authors are grateful to Beijing Syntone Gem Plant, which supplied the samples for investigation.

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[*Manuscript received 3 February 1992; revised 13 July 1992*]

CONGRATULATIONS TO THE DEUTSCHE GEMMOLOGISCHE GESELLSCHAFT E.V. ON THE OCCASION OF THEIR 60TH ANNIVERSARY

It is a pleasure to salute the achievements of the German Gemmological Association in promoting the scientific study of gems and dissemination of information from one of the most famous centres for coloured gemstones in the world.

May the DDG prosper in the future and maintain the high standards of enquiry, reporting and communication established worldwide through its meetings and journal.

With very best wishes
from

The Gemmological Association and Gem Testing
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27 Greville Street, London, EC1N 8SU

J. Gemm., 1992, 23, 4

Determination of the age and origin of emeralds using rubidium-strontium analysis

Ph. Vidal[1], *B. Lasnier*[2] *and J-P. Poirot*[3]

[1]Université Blaise Pascal et URA 10 CNRS, Clermont-Ferrand, France
[2]Université de Nantes, C.R.G., France
[3]Service Public du Controle de Diamants, C.C.I.P., Paris, France

Abstract

The rubidium-strontium method has been used to determine the age of natural and synthetic emeralds. Precise ages of emeralds from Precambrian Shields (Brazil, Zambia, Madagascar) have been calculated. Although the age of emeralds of geologically younger formations is more difficult to establish, Colombian emeralds are probably 61 ± 5 million years old.

Introduction

"Where does this emerald come from?" is a common question asked by collectors. Not satisfied by the beauty alone of a gem, they also want to know where it has been formed by Mother Nature. To penetrate the secret of an emerald, the gemmologist studies its inclusions, reflecting its paragenesis, and may thus determine occasionally a likely geographical origin when only a few deposits of the same type are known.

It is also the inclusions that enable a gemmologist to distinguish with certainty, man-made emeralds and chrome-bearing beryls (named synthetic emeralds). Nevertheless there are some synthetic emeralds that have no typical inclusions. Then it becomes difficult to objectively affirm their artificial origin, even if subjectively it is suspected: the investigation of trace elements, by destructive procedures through neutron activation analysis (NAA), for example, may then become necessary (Schrader, 1983).

Another approach in solving these problems is to determine exactly the age of an emerald. Generally, an emerald's age will be closely related to that of the environment of its growth, which can be dated by isotopic geochronology. Among the methods commonly used in geochronology (Faure, 1986), the rubidium-strontium (Rb-Sr) method is the one to offer most prospects in the study of emeralds and their host rocks. Indeed, it is known that some natural emeralds can contain measurable quantities of rubidium, a geochemical companion of potassium.

Normal Rb-Sr analysis methods cannot be routinely applied to cut gemstones as small amounts of powder from the specimen must be dissolved for determination. However only a few milligrams (a few percent of a carat) are needed for the analysis, and the taking of small samples from a batch of stones may be considered acceptable.

The rubidium-strontium geochronology method (Faure, 1986), uses the transformation, through the emission of β-rays, of the rubidium 87 isotope into the strontium 87 isotope. The ^{87}Rb is said to decay to ^{87}Sr and it does so at a constant rate which is most easily expressed as a 'half life'. The time taken for 1 gram of Rb to decay to 0.5 grams (the half life) is about 50 thousand million years, and the product, 0.5 grams of Sr, is known as radiogenic strontium.

Analytical Technique used on Emeralds

Details of the Rb-Sr techniques as carried out in the Clermont-Ferrand (France) Laboratory with regard to sampling, control of purity, cleaning, equipment, processing, and calculations of ages, by means of 'model-age' or 'isochron method', can be obtained from one of the authors (P.V.).

Results:

The results are summarized in Table I and may be considered in three groups:

EMERALDS FROM PRECAMBRIAN ROCKS (Brazil, Madagascar, Zambia) have significantly high enrichment in radiogenic strontium; the major reasons are their age, and their rather high rubidium content. Where high radiogenic strontium is present in a mineral with low initial (non-radiogenic) strontium the conditions are favourable for calculating a 'model age'. This can be done for the emeralds in this group and the determined 'model' ages are obtained with nearly 2% precision. They match with the known evolution of these Precambrian shields.

EMERALDS FROM YOUNG ROCKS (Colombia, Pakistan, Afghanistan), have low radiogenic strontium enrichments, because of their younger ages and their low rubidium contents; they also have relatively high primary strontium contents. These

ISSN: 0022-1252

Table I – Rb/Sr analyses of emeralds from various localities.

Origin		weight mg	Rb (μg/g)	primary Sr (I) – (μg/g)	^{87}Rb/^{86}Sr (2)	^{87}Sr/^{86}Sr	Model Age with initial ^{87}Sr/^{86}Sr = 0.705. Million years (Ma)
Brazil	em.1*	16.4	76.9	0.085	1148.	42.59	2517
	em.2*	66.0	77.4	0.098	1779.	59.07	2273
Santa Terezinha	em.1	169.7	11.8	162.8	0.210	0.72036	
	em.2	92.8	21.9	3.48	18.49	0.8357	496
	sch	74.0	14.3	308.3	0.0134	0.72061	
Socoto	em.	234.4	51.3	1.24	119.4	2.717	1180
	mi.	24.0	1062.	11.1	956.0	25.65	1814
Itaberai	em.1	76.4	14.3	1.02	38.64	0.98805	514
	em.2	46.9	17.0	1.77	26.33	0.88830	489
	mi.	81.4	209.	2.32	334.1	3.55	597
Madagascar	em.1	179.7	76.0	2.26	96.9	1.5578	618
	em.2	142.9	93.7	2.85	94.9	1.3744	497
Zambia	em.1	91.4	28.1	0.029	1627.	12.309	500
	em.2	94.1	94.4	0.005	10934.	65.65	598
Colombia (Penas Blanca)	em.1	195.3	1.0	0.45	6.29	0.7197	
	em.2	161.6	2.26	0.28	22.6	0.7324	
	em.3	108.1	1.42	0.20	18.61	0.7316	
	em.4	114.1	1.80	0.17	27.43	0.7380	
	ca.	56.0	1.47	42.8	0.0995	0.71281	
Pakistan	cm.	130.7	5.0	0.85	16.83	0.71599	
Afghanistan	cm.	151.1	16.5	7.15	6.69	0.71388	
Lennix		31.9	0.45	0.038	13.9	0.7122	
Gilson	1	42.7	1.59	n.d.		n.d.	
	2	30.1	1.55	n.d.		n.d.	

(1) Primary strontium content has been determined by subtracting the laboratory strontium blank (1.8ng) from the analyzed strontium in the sample.
(2) ^{86}Sr = primary ^{86}Sr + blank ^{86}Sr.
* Precise locality unknown.
em: emerald; mi: mica; ca: calcite; sch: schist.

three factors combine to give low measured ^{87}Sr/^{86}Sr ratios and 'model ages' are not precise enough to give satisfactory results.

However, the use of several samples from the same deposit enables the use of another technique to obtain the age, called the isochron method. This is illustrated in Figure 1, where four samples of Colombian emeralds (Penas Blanca deposit) plotted on a graph of ^{87}Sr/^{86}Sr vs ^{87}Rb/^{86}Sr indicate an age of 61 ± 5 million years (Ma).

SYNTHETIC EMERALDS: Lennix emeralds contain low Rb and low Sr with no detectable additional Sr due to the radioactive decay of Rb. The Sr content is lower than in most natural emeralds. Similar results were obtained from Gilson synthetic emeralds. We conclude that for these samples the synthetic emeralds have Rb-Sr chemical and isotopic characteristics very different from those of natural emeralds.

Prospects

The rubidium-strontium method has the potential to authenticate and even date emeralds. In comparison with natural emeralds, synthetic emeralds may have noticeably different characteristics.

Other studies should be undertaken, and it would be interesting, from the genetic point of view, to determine isotopic compositions of associated minerals and host-rocks. In the context of this investigation, the Penas Blanca (Colombia) emeralds are in isotopic equilibrium with their associated calcite, and those from Santa Terezinha (Goias State, Brazil) are in equilibrium with their host-rock. Rubidium and therefore radiogenic strontium

Fig. 1. Four Penas Blanca (Colombia) emeralds isochron providing a 61 ± 5 Ma age.

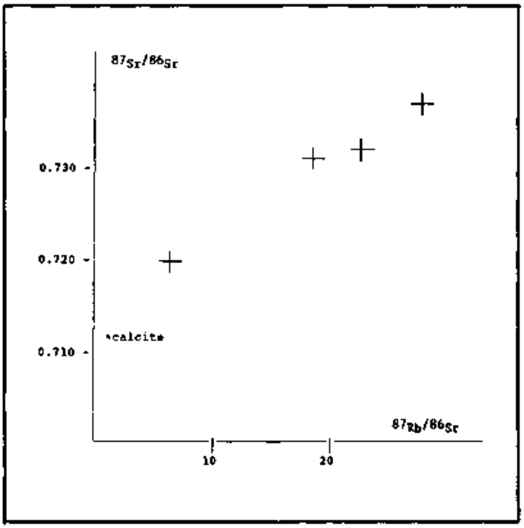

Table II – Acid leaching experiments on Zambian emerald sample.

	weight mg	Rb (μg/g)	primary Sr (I) – (μg/g)	^{87}Rb/^{86}Sr (2)	^{87}Sr/^{86}Sr	Model Age with initial ^{87}Sr/^{86}Sr = 0.705. Million years (Ma)
Unground sample	77.2	130.0	0.38	2188.	13.270	403
ground sample residue	102.5	10.8	0.44	71.56	1.226	510
solution	1.6	0.20	0.53	1.135	0.7115	

could be contained within emeralds, possibly in the structural canals (as in morganites), or possibly also in fluid and solid inclusions. With this in mind, Giuliani and Weisbrod (1988) have studied phlogopite inclusions in Brazilian emeralds. Even primary strontium should be interesting to localize. Table II shows the results of a pilot test in which a few opaque sulphide granules and thin tubes parallel to the *c*-axis were studied. Their fluid content could not be determined by Raman probe for their section (less than 0.1mm) is too small to measure by this method. A second approach was by conventional isotopic analysis of a sample. Thirdly, part of the sample was finely ground, the powder was leached with acid, and residues as well as leachates were separately analyzed. It is clear from these analyses that all the rubidium and radiogenic strontium is contained in the emerald structure, and not inside fluid inclusions which would have been released during leaching.

Finally, it is advisable to comment on the reason for the spread of model ages of Precambrian emeralds (see Tables I and II) beyond analytical error. This spread is probably attributable to variable loss, along dislocations, of radiogenic strontium which is loosely held in the crystal structure. This phenomenon is widely-known in minerals rich in rubidium and poor in primary strontium, such as micas, which undergo a thermal event after crystallization. Besides, it seems that emeralds should be more sensitive to the radiogenic strontium loss than associated micas, according to Table I results (Socoto, Bahia State; Itaberai, Goias State – Brazil).

Acknowledgements

The authors are particularly grateful to MM P. Cario, P. Fumey, G. Giuliani, and M. Piat, for providing them with emeralds of known origins. They are also greatly indebted to Mme M. May for her translation work.

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[*Manuscript received 29 October 1991; revised 15 July 1992*]

Identification of fissure-treated gemstones

Dr H.A. Hänni

Swiss Gemmological Institute (SSEF), Basel, Switzerland

Introduction

The subject of enhancing the appearance of various gemstones in which fractures have a detrimental effect on their beauty or saleability has been addressed previously by a number of authors (e.g. Ringsrud, R., 1983; Kane, R., 1984; Scarratt, K., and Harding, R.R., 1984; Martin, D.D., 1987; Hänni, H.A., 1988; Koivula, J.I., *et al.*, 1989; Themelis, T., 1990; Shida, J., 1991; Kammerling, *et al.*, 1991; Hänni, H.A., 1992).

Fissures in gemstones, originate from mechanical tension, pressure or temperature stress. They originally contain vacuum, gas or a fluid. If such fractures reach the surface of the stone, the narrow voids of the fractures are filled with air. All of the above media possess refractive indices considerably lower than that of the gemstone itself. The fractures are therefore capable of reflecting light. This is an undesirable capability that would be considerably reduced if they were to be filled with a substance of a similar refractive index to that of the gemstone.

The objective of this short review is to bring the topic of artificially introduced filling substances, which may be used in gemstone enhancement procedures to the attention of the reader. It seems to the author that developments in this field have either not been given sufficient exposure, or have gone unnoticed by certain elements of the trade during the last few years. It is also important to be able to differentiate clearly between natural deposits on fracture planes (e.g. iron hydroxide) and organic artificial matter, commonly but very often incorrectly called 'oil'.

Why a treatment can be effective

Light entering a faceted gemstone only reemerges after multiple internal reflections between several facets. Along its path the light is absorbed selectively and in a manner that the transmitted spectral colours result as the perceived colour of the gemstone. The shorter the distance the light travels, the weaker the absorption and the lighter the colour. Should the light path be interrupted by a fracture, because it is reflected at this point, the length of light path is shorter than it might be if the crack were not present and the colour thus weaker. Also the reflecting fractures are conspicuously lighter to the observer (or darker if the fracture plane is observed from behind the 'mirror' of the reflecting plane).

If a filler replaces the air previously in the fracture, and the filler substance has a refractive index higher than air and near to that of the treated stone, it inhibits a reflection of light rays from most incoming directions. The light may then travel across the fracture plane and is not deviated or reflected. The fracture no longer acts as an obstacle in the light path.

On many occasions fractures, pores or grain boundaries of polycrystalline stones are used to introduce colour into the material. Recently jadeite has been treated with acid, then heated to widen the grain boundaries and increase the porosity. The stones are now easier to treat with an artificial resin. The result is called B-Jade and in the Far East leads to a superabundance of supposed Imperial jade.

Another example is represented by an originally colourless, heavily fractured corundum which is cut into beads for necklaces (Figure 1). The beads are treated with a ruby-red stain, which may be seen on fractures and twin planes. The material makes a very convincing imitation of ruby (Schmetzer *et al.*, 1992).

How treatments are performed

For decades, if not centuries, fillings of oils and resins with a viscosity low enough to penetrate into fractures have been used to seemingly improve the quality of the stones. The lower the viscosity of the filling medium, the more complete is the penetration into the fissure. Sometimes vacuum techniques are used to improve the result. The range of fillers encompasses numerous substances: apart from those such as vegetable and mineral oils with volatile components (Figure 2), there are the more durable fillers like fats and resins. Compounds such as synthetic epoxy resins are frequently used today (Themelis, 1990); these possess the advantage of a

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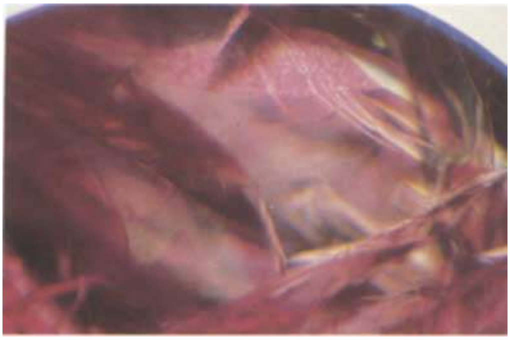


Fig. 1. Fractures stained red do not make a ruby! this picture shows part of one button shaped bead in a necklace. The material was originally near-colourless corundum. Magnification 25x.

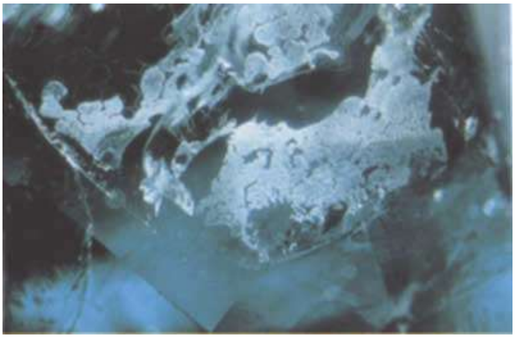


Fig. 2. Emerald with oil-treated fracture. Extensive 'lakes of air' form their lobular patterns near the fracture opening when the oil dries out. Magnification 20x.

more stable adhesion to the stone. This leads to a longer lasting improvement in appearance which is not possible with volatile compounds like oil and paraffin used traditionally. The latter are released quite easily due to their solubility in soaps, detergent and solvents.

The most stable fracture filler material is glass, which is introduced into fractures in its molten state. For the moment, diamond and corundum are the only gemstone species treated by this method. Only these species resist the required high temperature without being seriously damaged (Kane, 1984; Hänni, 1986). All other stones like quartz, tourmaline, beryls, jade, lapis lazuli etc are normally treated with natural or artificial organic compounds.

Emeralds

Before a filler is applied to an emerald, a cleaning process should be used to remove all dirt and residual filler material from any former treatments. This may be done by prolonged immersion in solvents and/or acids, possibly with the assistance of ultrasonics or steam. The use of a vacuum may extract previously inserted 'oil'. The procedure of cleaning may, depending on the intended filler to be used, take many hours or even days (Themelis, 1991).

For a good penetration into the fractures, a low viscosity filler is essential. This objective is reached with oil, paraffin (Figure 3) or resin by slightly heating these and using a vacuum to assist in the treatment. Special additives are sometimes used to lower the viscosity as far as to 260 centistokes.

A well known product name is sometimes used for a group of epoxy resins with similar characteristics: Opticon. Most emeralds in the trade today are treated in the rough or cut state with 'Opticon' or a similar product. Other epoxy resins such as Araldite NU 471, Dobeckot 505, Novogen P40 etc have similar effects as fillers. Their refractive indices are in the range 1.5 to 1.6.

Fig. 3. Resin treated fracture in an emerald, with spectral colour flashes and dendrite-shaped gas bodies. Opticon treated fractures may look like this. Magnification 20x.

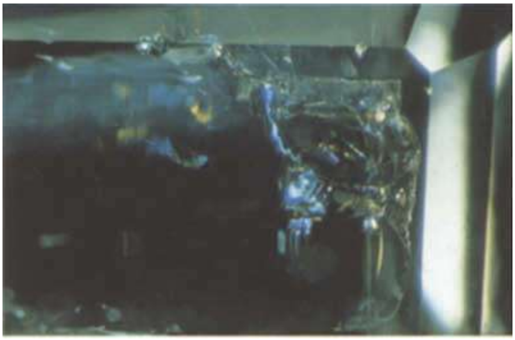
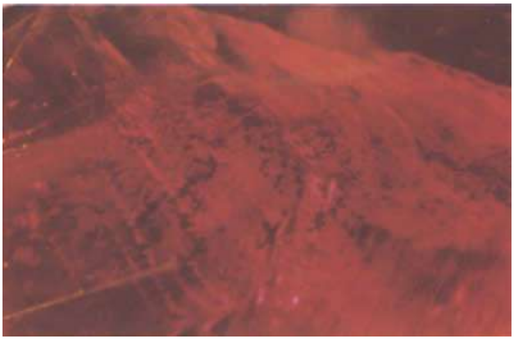


Fig. 4. Ruby with a fracture, probably treated with wax or paraffin. A typical dendrite-like pattern is visible.



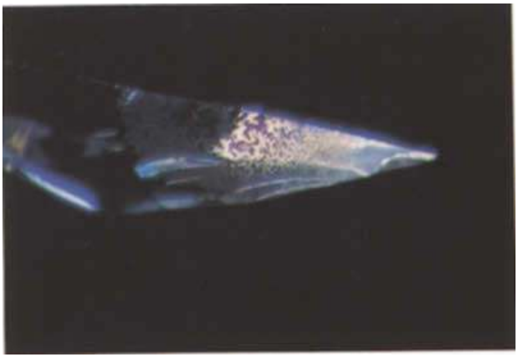


Fig. 5. Sapphire with a filling of artificial resin, showing dendrite-like patterns of gas bodies. In UV light the filling has a whitish fluorescence. Magnification 40x.

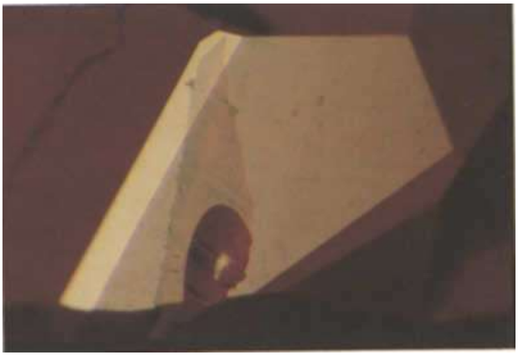


Fig. 6. A facet of a heat and glass treated ruby. A cavity (and all open fractures) have been filled with glass, identifiable by its lower lustre compared with corundum. Within the glass part an air bubble is cut by the surface. Magnification 20x.

Epoxy resins can be used with or without a hardener. If the resin is used without a hardener, it remains soft and usually entirely fills the fracture. Gas bubbles and other structures like viscous fingering are rare in the fissure planes. When the artificial resin is mixed with a hardener, polymerisation takes place. A shrinking effect causes fine fissures and pseudo-dendritic patterns to occur in the filler plane, making it easier to detect.

Corundum

Although some historical filling substances are encountered today (most probably wax or paraffin) the majority of fractures in ruby and sapphire are treated with a boro-silicate melt. Before treatment, a process of cleaning is performed to remove all dirt and residual filler material from any former treatments. Also natural deposits like iron hydroxide or clay minerals must be dissolved. A cleaning treatment is normally carried out by using hydrofluoric acid, which attacks all silicate minerals that may still adhere on rough stones. Sulphuric or hydrochloric acid may also be used to remove foreign material on and in the open fractures of corundum.

The treatment requires the presence of boron or lithium to lower the melting point of the silica-compound forming the melt. The melt, besides filling the fractures, also acts as a solvent or flux respectively and enables some recrystallization of the fracture planes.

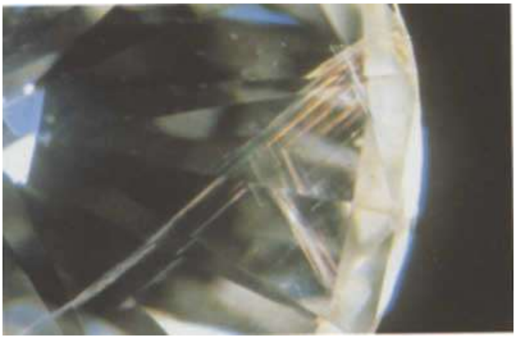
Treatments with glassy substances today appear to be performed faster and/or at lower temperatures than some time ago, since the included rutile 'silk' may not be affected during the glass infilling treatment.

How treatments are identified

Some of the filler materials contain air or gas bodies, forming individual bubbles or dendrite-like patterns. Such patterns, when present, prove the existence of two different phases on a fissure plane. Many of the organic fillings show a bright fluoresc-

Fig. 7. Artificially healed fracture in a ruby. Under the flux effect of the glass the fracture plane has recrystallized. In newly formed crystalline cells, the glass has been trapped, devitrified and formed bunches of white radiating crystals. Magnification 40x.

Fig. 8. Treated cleavage fractures in a brilliant-cut diamond. Yellow and violet interference colours together with gas bodies are characteristic for the Yehuda treatment.



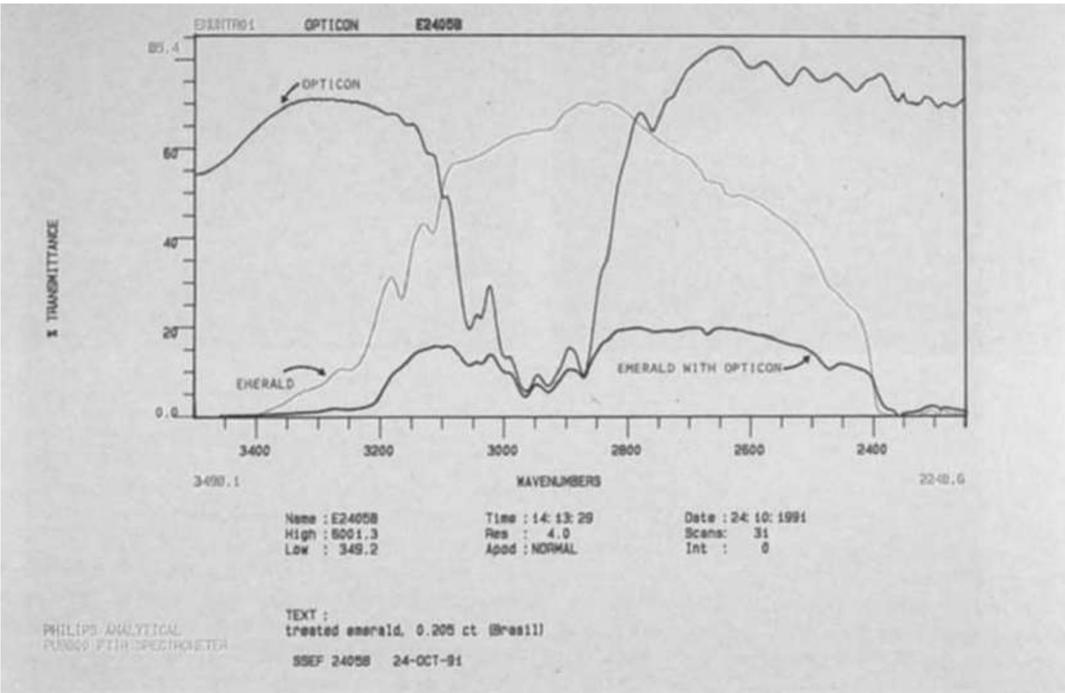


Diagram 1. Infrared spectra of untreated emerald, Opticon (artificial epoxy resin), and emerald treated with artificial epoxy resin. FTIR-Spectrum recorded by E. Jegge, SSEF laboratory, Zurich.

ence under ultraviolet light which is visible either with the unaided eye or a loupe.

The presence of oil can be indicated by bathing the stone in a solvent such as acetone or hexane for a short period. The soluble oil is diluted by the solvent. Under a microscope the drying out of the solvent which has replaced some of the oil is easily visible. Lobular air dendrites develop at the fracture openings. Such a reaction does not appear with resin treated fractures, since resins are less soluble.

Artificial resin fillings are often apparent by their orangy or violet colour flashes (Figures 4 & 5). A further proof for a foreign organic filling is possible by means of the hot needle. If the needle is put next to the fracture opening, the filling turns to a liquid state and moves slightly. The examination should be observed through the microscope and performed very carefully. The 'observation' of a foreign filling in a fracture by microscopic inspection may be quite easy, but the 'identification' of a particular filler may be difficult. Organic fillers, can be detected by infrared spectroscopy (see Diagram 1). The infrared spectrometer appears to be the most reliable tool for an identification, but owing to the numerous varieties of organic compounds, and the difficulties due to the superimposition of the stone's spectra over the filler spectra, this may prove to be a handicap for an exact identification of a particular filler. Also, if stones were subjected subsequently to different treatments without proper cleaning, the IR spectrum may be difficult to interpret.

Glassy substances, at the surface of a stone may be recognized by their different lustre compared with that of corundum (Figure 6, Hänni, 1986). If glassy fillings are to be identified within the stone, Raman spectroscopy may be the most useful method. In many cases, voids filled with artificial glass are whitish. The glass has served as a flux, recrystallized the fracture plane and sealed itself into a newly formed geometric void. In some instances devitrification starts, resulting in the appearance of radiating fibrous crystals that emerge from trapped gas bubbles (Figure 7).

Heavy liquids possess a high refractive index. This property is utilized for the Yehuda fracture treatment of diamond (Figure 8). Also with this fracture treatment, the filler shows vivid colour flashes, and the fracture planes contain gas bubbles and 'lakes' (see Koivula *et al.*, 1989). The heavy elements are identifiable by X-ray spectroscopy (Scanning Electron Microscope SEM or Energy Dispersive X-ray Fluorescence Analysis EDS-XFA). Glassy fillings in corundum show the presence of silica and Yehuda treated diamonds indicate the presence of lead and occasionally bismuth.

Outlook

Although the above mentioned treatments are not new, it appears that many trade members have little knowledge of some of them or do not wish to complicate their business by acknowledging their presence on the market. The use of colourless oiling is accepted as a common enhancement practice. This rather historic treatment method is being increasingly replaced by more stable treatments that utilize modern filler substances. Whilst the newer treatment methods in no way represent single cases, it is unfortunate that only a small number of stone dealers, jewellers or goldsmiths have the time, the knowledge, the motivation or the equipment to check or confirm these treatments. So it will probably take a long time for trade opinions about this kind of treated stone to change and make an impact on the market place.

At present time the CIBJO rules require only a disclosure of fracture treatments performed with substances other than colourless oil. This means that almost all emeralds, an important number of rubies and many sapphires should be labelled or sold respectively as treated gemstones. The exact identification of the numerous more or less viscous oils (vegetal, animal or synthetic), fats, paraffins, natural and artificial resins is rarely simple and often impossible. The analyses might be expensive and finally come only to the result that the stone is treated and has a foreign organic substance in its fissures. Because of the multitude of organic compounds which could serve as fillers it may be more appropriate not to draw an arbitrary line between 'permitted' treatments and those which are not tolerated without declaration.

This would mean a change in the CIBJO rules that govern this problem. To the author it seems advisable to handle all fracture treatments in the same way, either to disclose all fracture filled stones or to consider fracture filling as a common practice (whatever substance is used) and omit any comment to individual stones. However, the author considers that disclosure of the glass filling of any gemstone should be mandatory.

In any case the final consumer should be informed of the commonly used practices by his gemstone specialist to prevent damaging action by people with unfair goods.

Acknowledgement

The author thanks Kenneth Scarratt and Alan Jobbins for their very helpful editing of the manuscript.

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[*Manuscript received 22 November 1991; revised 14 June 1992*]

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Symmetrical polyhedra for gemstones

Jos Lurie, Ph.D., FGA

Technikon Witwatersrand, School of Mines, PO Box 3293,
Johannesburg, South Africa

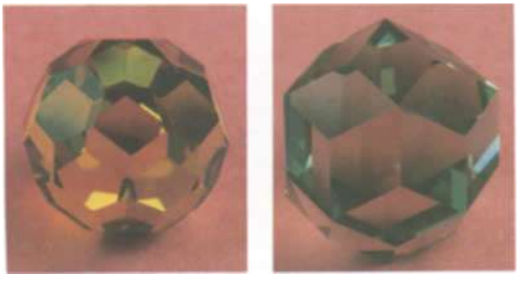
Abstract

Faceted 'spheres' cut recently are described. Regular convex polyhedra including platonic solids, rhombic forms and other equidimensional forms are discussed with respect to face shape and number, and their inter-relationships. They are placed into symmetry classes. The well-known crystallographic hexoctahedral class with its two platonic solids, one rhombic form and four variable forms is discussed. Combinations of the first three forms and also of the seven forms with faceting angles are given. The platonic dodecahedron and icosahedron are variously combined. The little known rhombic triacontahedron with faceting angles is given. Combinations of these three closely related forms are given. The virtually unknown four variable forms with the same symmetry were derived theoretically and a combination of the seven forms with its 362 faces is illustrated.

Introduction

The gemstone collection of a talented amateur faceter, Dick Rothkugel, was recently examined. Possibly the most intriguing of the items of an interesting collection is a 'sphere' of smoky quartz with 32 symmetrically arranged facets weighing 20 carats and 15mm in diameter. This, together with an article by Paul C. Smith on making a sphere of this sort, provided inspiration to investigate the fascinating realm of symmetrical polyhedra in order to produce alternate designs that would challenge the enthusiastic faceter. Findings included several forms related to the pentagonal dodecahedron and the icosahedron. Having cut another sphere on the previous design but of amber cubic zirconia of 45 carats, Dick Rothkugel subsequently produced a 47-carat triacontahedron on my calculated data. These two gem polyhedra are illustrated in Figure 1. The beauty of these cuts is in the symmetry of the facets and the light pattern reflected from them.

Fig. 1. Faceted spheres: A – a combination cubic zirconia sphere; B – a smoky quartz triacontahedron.



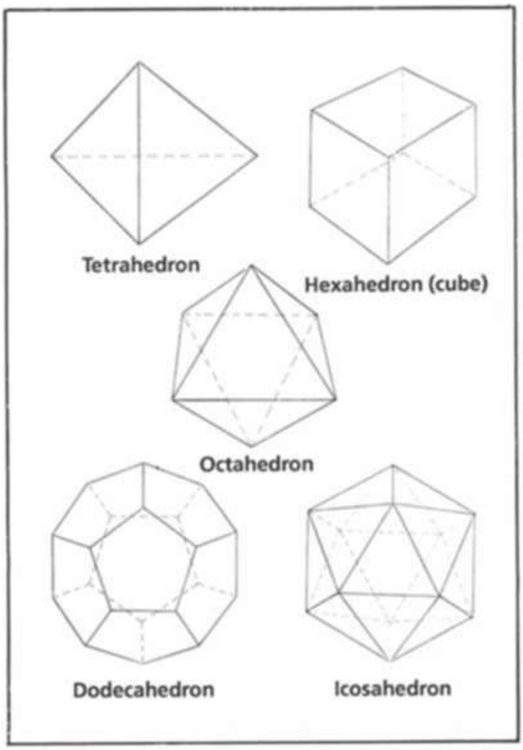


Fig. 2. The platonic polyhedra.

Regular polyhedra

There are only five convex polyhedra each of identical faces that are regular polygons with equal internal angles. This fact was known by the Greek philosophers and the polyhedra are therefore referred to as the platonic solids. These are: the tet-

Table 1: Some equidimensional polyhedra

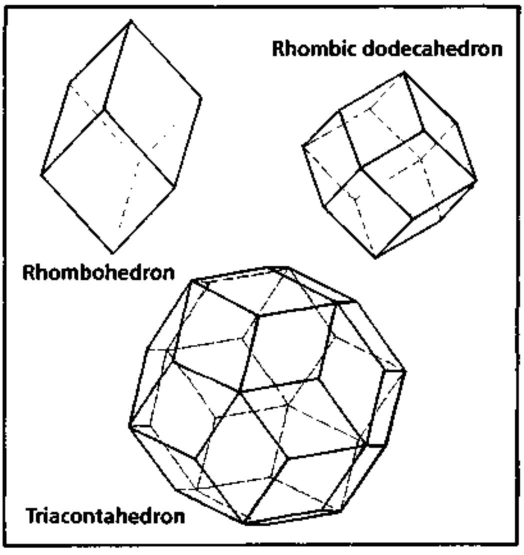
	Non-crystallographic	Crystallographic		Face form
Class	Hexicosahedral	Hexoctahedral	Hextetrahedral	
Symmetry*	$6A_5$ $10A_3$ $15A_2$ 15P C	$3A_4$ $4A_3$ $6A_2$ 9P C	$4A_3$ $3A_2$ 6P	
Platonic forms	Trigonal icosahedron 20	Trigonal octahedron 8	Tetrahedron 4	▲
	–	Square hexahedron (cube) 6	Square hexahedron (cube) 6	■
	Pentagonal dodecahedron 12	–	–	⬟
Non-platonic forms	Rhombic triacontahedron 30	Rhombic dodecahedron 12	Rhombic dodecahedron 12	♦
	Trigonal pentadodecahedron 60	Trigonal tetrahexahedron 24	Trigonal tetrahexahedron 24	▲
	Trigonal trisicosahedron 60	Trigonal trisoctahedron 24	Trigonal tristetrahedron 12	▲
	Trapezoidal hexcontahedron 60	Trapezoidal icosatetrahedron 24	Deltoid dodecahedron 12	♦
	Hexicosahedron 120	Hexoctahedron 48	Hextetrahedron 24	◢

* A denotes a rotation axis of symmetry, subscripts indicate repetitions/360°; P denotes a plane of symmetry; C denotes a centre of symmetry.

rahedron (four faces), the hexahedron (or cube with six faces), the octahedron (eight faces), the pentagonal dodecahedron (12 faces) and the icosahedron (20 faces). These are illustrated in Figure 2. Note that the only polygonal faces involved are the equilateral triangle, the square and the regular pentagon. These polyhedra all fulfil the Euler (18th Century Swiss mathematician) characteristic namely: Vertices + Faces − Edges = 2.

Because of the regular arrangement of their constituent faces and consequent symmetry such polyhedra are visually pleasing. Obviously the more component faces involved the more closely the polyhedron approaches a spherical form. Thus the dodecahedron and the icosahedron are the more interesting forms to investigate.

Fig. 3. Rhombic forms.



There are three additional symmetrical polyhedra with the rhombus as face form (Figure 3). They are: the variable rhombohedron (6 faces), the fixed rhombic dodecahedron (12 faces) and the variable triacontahedron (30 faces).

The closed forms of higher symmetry are classified in Table 1. The crystallography classes are well known; the proposed new symmetry class, the hexicosahedral, is now added. The author has constructed models of each of the seven forms of this new class.

Crystallographic polyhedra

Of the above platonic solids only the tetrahedron, the cube and the octahedron are encountered in crystallography (where faces are parallel to planes of atoms in their structure). There are actually several dodecahedra possible crystallographically but these do not have equilateral pentagonal polygon faces. For instance, the pyritohedron, a form in which the mineral pyrite sometimes crystallizes is, in fact, a pentagonal dodecahedron but the pentagon faces have a side of odd length and consequently the form has much lower symmetry. Interestingly, the so-called 'iron cross' interpenetrant twin form has higher symmetry. The tetrahedral pentagonal dodecahedron has irregular pentagonal faces and even lower symmetry. Garnets often crystallize as dodecahedra in which the faces are rhombs (Figure 4).

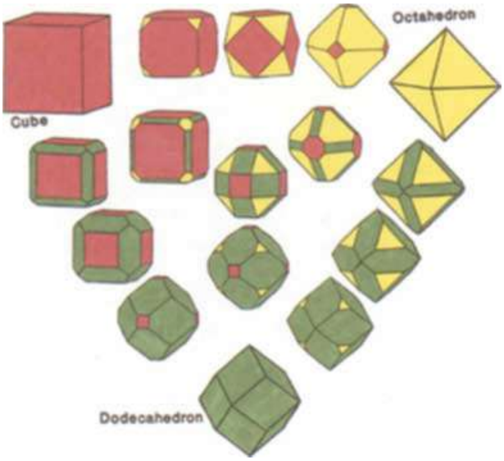


Fig. 4. Combinations of cube, octahedron and dodecahedron.

There are a large number of other polyhedra encountered in crystals but the faces of these are not regular polygons. Those of the most symmetrical crystal class (of 32) namely, the so-called Hexoctahedral Class, Isometric System, generally have the most faces and are equidimensional. They provide the best basis for the development of faceted spheres. They comprise the following forms: two platonic solids, namely, the cube (hexahedron) and octahedron; the rhombic dodecahedron (12 faces, the tetrahexahedron (24), the trisoctahedron (24), the icositetrahedron (24) and the hexoctahedron (48).

The cube and the octahedron have an interesting relationship in that the cube has 6 faces and 8 quoins, the octahedron 6 quoins and 8 faces. Furthermore, each of the cube and octahedron have 12 edges while the rhombic dodecahedron has 12 faces. Bevelled edges of both the cube and the octahedron would, in fact, produce the dodecahedron if these bevels were extended or symmetrically ground down. The three forms have the same symmetry and can be combined as illustrated (Figure 4). Note the relative development of the simple forms in each model.

Fig. 6. Model of a 146-faced 'sphere'.

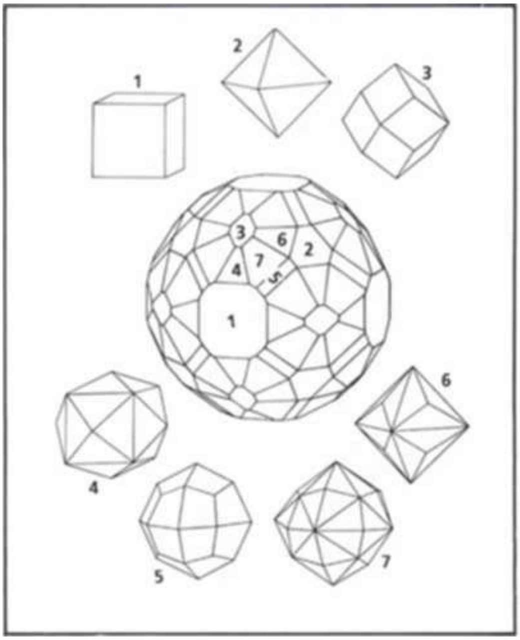


Fig. 5. Hexoctahedral combinations.

The remaining four forms of the class are not fixed in respect of inter-facial angles and intercepts with the crystallographic axes. There are, in fact, several variants of each form possible.

What may be regarded as the ultimate faceted sphere with pleasing symmetry in this class is produced by combining the seven forms of the hexoctahedral class to produce a 146-faced sphere. A result is shown in Figure 5. Those representatives of each of the variable forms have been chosen that have the simplest relationship with the crystallographic axes of the Isometric System, i.e. they have

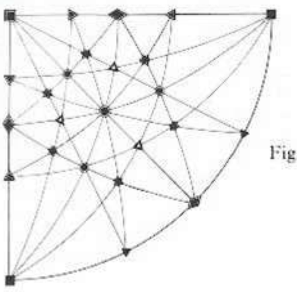


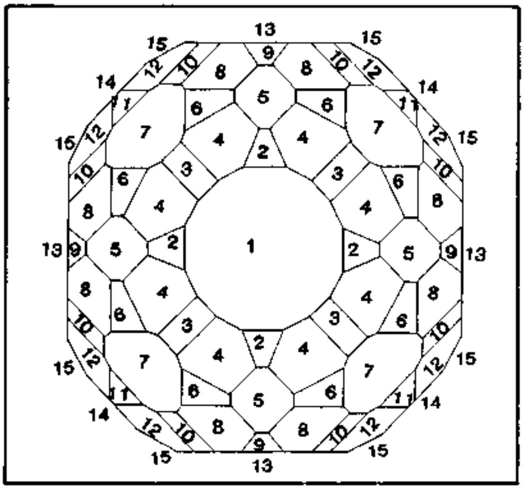
Fig. 7. Stereogram quadrant of model in Fig. 6.

the lowest Miller face symbols. These have the simplest relationship with one another and the fixed forms and the greatest degree of co-zonality. The parallel-perspective view of the combination was produced by means of a drawing technique using the stereographic projection of the poles of the faces.

The cube faces have been made dominant to serve as 'table' facets. A model in seven colours to represent the seven forms has been constructed out of sheet perspex. This is shown in Figure 6. One quadrant of the stereogram is shown in Figure 12. Construction of the model required the interfacial angles, the bevel angles for fitting adjacent faces together and also the plane face angles. Involved was considerable spherical trigonometry but the most formidable task was assembling the model.

This was accomplished after several unsuccessful attempts and by evolving a procedure for controlling angular distortion. The model obeys the Euler equation having 146 faces, 240 vertices and 384 edges. Parallelism of interfacial edges in the perspective view indicates the various zones in which faces lie and presents the faceter with a modus in respect of cutting order of facets. The angles for faceting are given in Table 2 below.

PLAN A



Hexicosahedral polyhedra

The first three polyhedra of this class have an analogous inter-relationship to that between the cube, the octahedron and the rhombic dodecahedron: the pentagonal dodecahedron has 12 faces and 20 coigns while the icosahedron has 20 faces and 12 coigns. In a sense, the one is the reverse of the other. Thus, in a particular orientation the spatial position of each face of the one would be in the position of a coign of the other. Thus each of a series of combinations of the two polyhedra consists of a total of 32 faces. Both have 30 edges. The triacontahedron has 30 faces and 32 (12+20) coigns. Interestingly, a crystalline form of boron has 20 atoms arranged at the coigns of an icosahedron. The symmetry of the three simple forms and the combinations are all the same, namely, six five-fold, ten three-fold, 15 two-fold rotation axes and 15 planes of symmetry and a centre of symmetry.

Table 2: Faceting angles for the construction of the 146-faced 'sphere'

Upper hemisphere					
Angle	Facet	Indices			
0	1. Cube	Any			
26.6	2. Tetrahexahedron	80	20	40	60
32.2	3. Trapezohedron	10	30	50	70
36.7	4. Hexoctahedron	6	14	26	34
		46	54	66	74
45.0	5. Dodecahedron	80	20	40	60
48.2	6. Trisoctahedron	6	14	26	34
		46	54	66	74
54.4	7. Octohedron	10	30	50	70
57.7	8. Hexoctahedron	4	16	24	36
		44	56	64	76
63.4	9. Tetrahexahedron	80	20	40	60
68.2	10. Trapezohedron	6	14	26	34
		46	54	66	74
70.2	11. Trisoctahedron	10	30	50	70
74.5	12. Hexoctahedron	7	13	27	33
		47	53	67	73
90	13. Cube	80	20	40	60
90	14. Dodecahedron	10	30	50	70
90	15. Tetrahexahedron	6	14	26	34
		46	54	66	74
Lower hemisphere					
Repeat of upper hemisphere in reverse order. Orientation controlled by facets 13, 14 & 15.					

Three of the two-fold axes which are normal to each other may be chosen as reference axes thus enabling the models to be viewed in analogous orientation (cf crystallographic axes).

A number of dodecahedral/icosahedron combinations are shown in Figure 8. The simple polyhedra, the dodecahedron and the icosahedron, are placed at the ends and the series of combined polyhedra illustrate a continuously increasing development of the one simple form and a simultaneous diminishing development of the other, depending on the order in which they are looked at.

The combination in which the two forms are in equilibrium or more or less equally developed, i.e. where they are reduced to regular pentagons and hexagons of equal side length (a design of the soccer football) is particularly pleasing. This is, in fact the sphere described by Paul Smith and made by Dick Rothkugel (see Figure 1). The 60 coigns of this combination also represent the relative positions of the atoms of the 3rd trimorph of carbon (the others: graphite and diamond) recently discovered and referred to as 'buckyballs' (see Figure 9). Thus, while none of the forms of this symmetry class are encountered in external morphology in crystallography some are nevertheless represented in molecular structure. For faceters who may be interested the interfacial angles which are applicable to each of the combinations illustrated and any others of different development are:

Dodecahedron/dodecahedron: 63.44°
Dodecahedron/icosahedron: 37.38°
Icosahedron/icosahedron: 41.81°

Combinations with the triacontahedron

Further designs involve bevelling the interfacial edges of the two forms (30 in each case). A dodecahedron modified in this manner has 42 faces (Figure 10, models 12, 11, 10) while the modified icosahedron has 50 faces (Figure 10, models 6, 7 and 8). The equilibrium combination of the former constitutes an alternative design for the soccer football (Model 11).

These bevels, in fact, constitute the positions of a triacontahedron, i.e. symmetrical grinding down of the bevels eliminating the other faces will produce a 30-faced triancontahedron in both cases. In fact this author was unaware of its existence and 'discovered' it by modifying the dodecahedron. The faces are all identical rhombs with plane face angles of 63.44° and 116.56° and interfacial angle of 36°. This form is illustrated in Figures 1 and 3. It is in fact one of a number of possible triacontahedra and is thus, in contrast to the pentagonal dodecahedron, the icosahedron and the other platonic solids, a variable form.

The various triacontahedra have sets of plane face

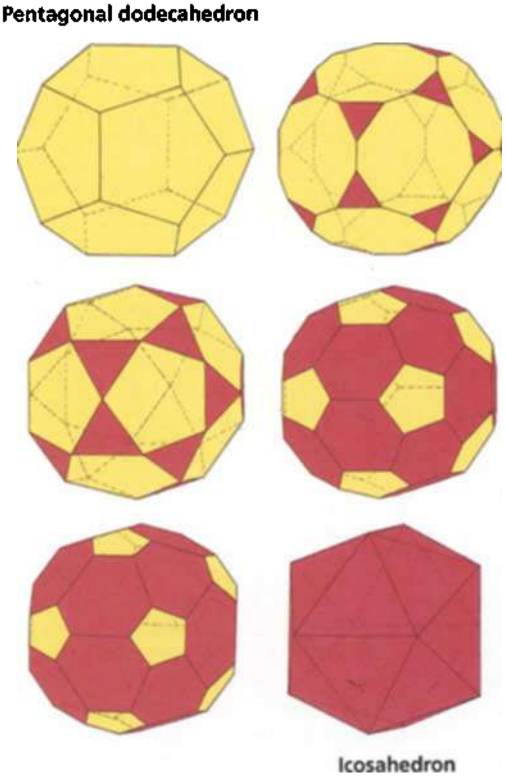


Fig. 8. Dodecahedron/icosahedron combinations.

Fig. 9. Arrangement of carbon atoms in a 'buckyball'.

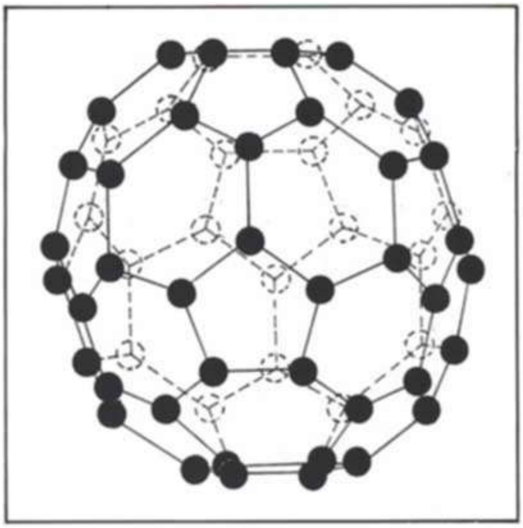
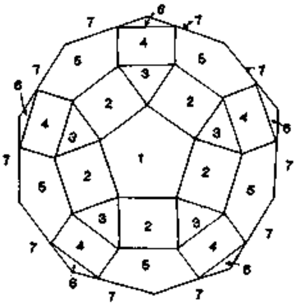


Table 3: Faceting angles for the construction of the triacontahedral 'sphere'

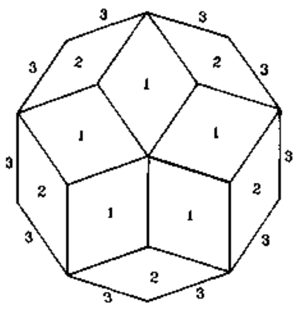


No.	Degree	Indices (80)				
1	0.0	Any				
2	31.7	8	24	40	56	72
3	37.4	80	16	32	48	64
4	58.2	80	16	32	48	64
5	63.4	8	24	40	56	72
6	79.2	80	16	32	48	64
7	90.0	4	12	20	28	36
		44	52	60	68	76

Lower hemisphere repetition in reverse order with 7 facets common. Ratio of diameter/side length = 4.

angles ranging between 108° and 120° (a) and between 72° and 60° (b). In each triacontahedron a + b = 180°. Although not a platonic solid since internal face angles are not the same the triacontahedron represents the ultimate of the forms possible consisting of identical rhombs. Another two are the crystallographic forms: the rhombohedron (a variable form typified by calcite) and the rhombic dodecahedron (a fixed form) both shown in Figure 3.

Table 4: Faceting angles for one of the variable forms of the triacontahedron



No.	Degrees	Indices (80)				
1	31.75	0	16	32	48	64
2	58.25	8	24	40	56	72
3	90.00	4	12	20	28	36
		44	52	60	68	76

Lower hemisphere: repetition in reverse order;
No. 3 facets common.
Ratio: Sphere diameter/rhomb side = 3.2

Examples of combinations of the three forms together of this symmetry class are also given in Figure 10 (models 13, 14, 15 and 16). 13 placed nearest the dodec has the dodec as the dominant form and the other two forms subordinate. Similarly, 14 represents the icosahedron dominant and 15 the triacontahedron dominant. Notice that throughout the two fixed forms have regular polygonal faces: equilateral triangles (icosahedron), regular pentagons (dodecahedron). The ultimate design in terms of symmetry, number of faces and aesthetics is, I believe, the equillibrium form where the triacontahedral faces become perfect squares and the polygons all have identical side lengths (model 16).

Faceting settings for this combination are given in Table 3.

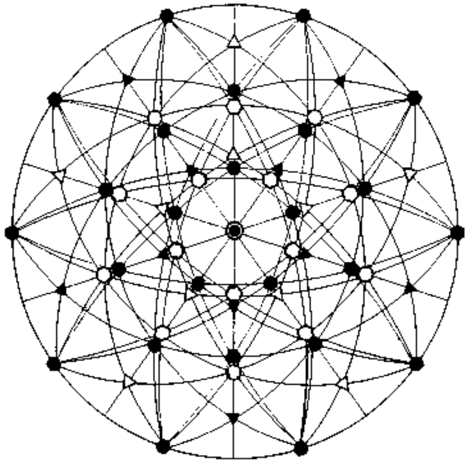


Fig. 11. Stereogram of triacontahedral forms.

Figure 11 is the stereogram of the combination projected with a dodec face horizontal. The combination fulfils the Euler equation (62 + 60 − 120 = 2).

The triacontahedron itself makes an attractive faceted sphere (Figure 1). Angular values of one of the variable forms are given in Table 4.

From purely theoretical considerations it was realised that a further four variable forms must exist to complete the seven entities of the symmetry group. These were first conceptualised from a stereographic projection, angles calculated and drawings produced by modifying those of the first three forms. Nomenclature was slightly problematical (see Table 1).

These four additional forms together with the three already discussed are shown in Figure 12. A

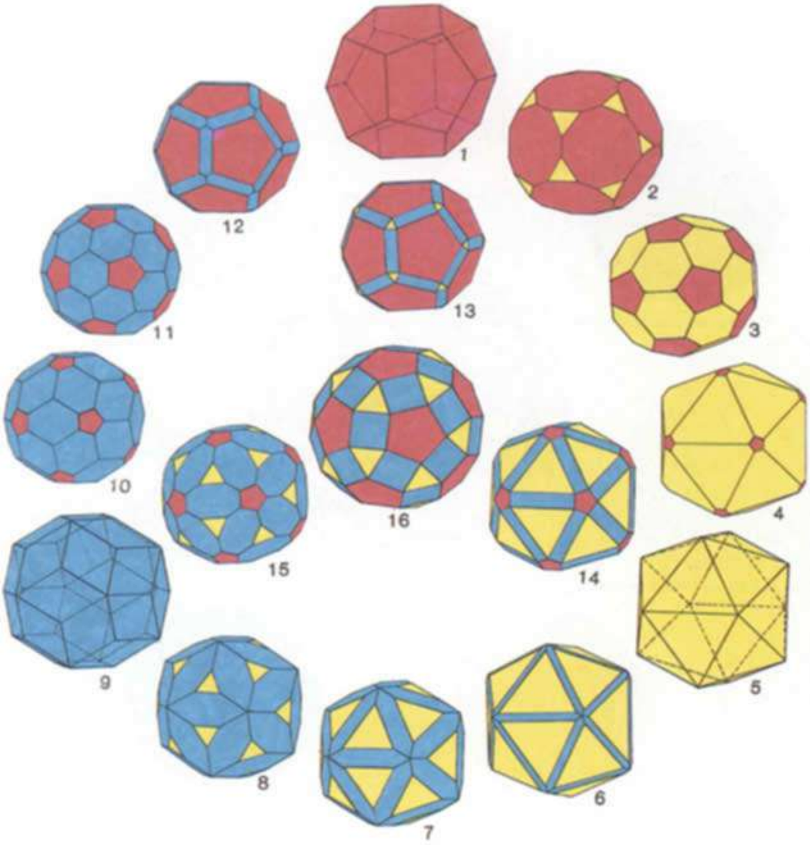


Fig. 10. Combinations of triacontahedral class.

combination of the seven forms with 362 faces is also shown. As before, examples of the variable forms with the simplest relationship to the fixed forms are shown. The entire group have been drawn in the same orientation – three orthogonal two-fold symmetry axes have been chosen as convenient reference axes (cf crystallographic axes) for this purpose. For the combination: vertices (360) + faces (362) − edges (720) = 2. Some mathematicians regard this as proof of the existence of the polyhedron!

Conclusion

Although there are an infinite number of polyhedra possible in consequence of the possibility of varying the relative development of the components of combined forms I believe that in respect of simple convex closed forms (those made of identical plane faces capable of independent existence) with maximum symmetry all the possibilities from a purely geometric point of view have been considered. Analysis reveals that:

1. All those symmetrical forms consisting of equilateral triangular faces have been considered: the tetrahedron, the octahedron, the icosahedron (all platonic solids). They involve respectively 3, 4 and 5 60° vertices meeting at a coign. One more (6) would total 360° and constitute a plane. Other forms consisting of equilateral triangles (there are five) have variable face numbers meeting at vertices and therefore lack or have low symmetry.

2. The only form possible consisting of square faces is the platonic cube. 3 90° vertices are a maximum.

3. The only form possible consisting of regular pentagonal faces is the platonic pentagonal dodecahedron. Only 3 vertices of 108° can form a coign.

4. The three non-platonic forms consisting of rhomb faces include the crystallographic rhombohedron (variable) and rhombic dodecahedron and also the triacontahedron (variable) now described in detail. Although the faces of these do not

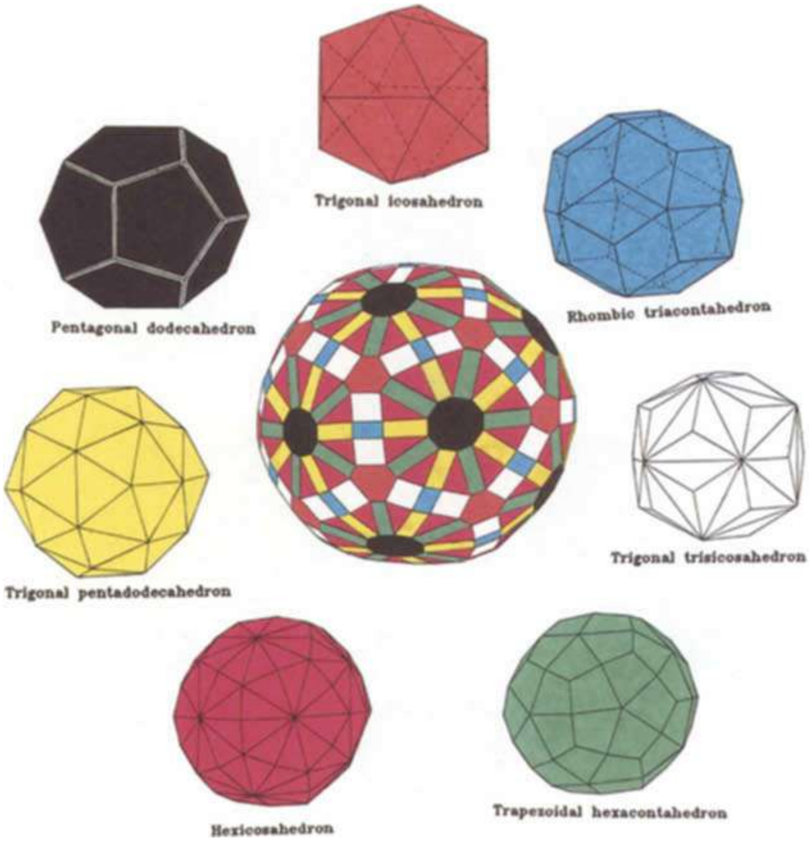
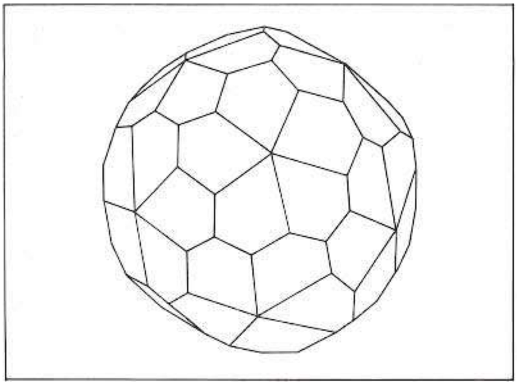


Fig. 12. Combination of the hexicosahedral polyhedra.

conform to platonic definition they do have twofold symmetry and the triacontahedron additionally has the full symmetry of the platonic pentagonal dodecahedron and the icosahedron. These rhombic forms involve 3, 4 and 5 acute vertices forming coigns and 3 obtuse vertices forming the other coigns.

Fig. 13. The pentagonal hexcontahedron.



5. The additional forms with the same symmetry as the foregoing have all been considered. Other multiple identical faced (60, etc.) forms exist but they have lower symmetry. An example is the pentagonal hexcontahedron which lacks planes of symmetry (Figure 13).

6. The four additional forms of the isometric hexoctahedral class (all variable) have been considered since they do represent the highest crystallographic symmetry.

7. Numerous other simple forms, some crystallographically possible, have not been considered because of relatively low symmetry.

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Notes from the Laboratory – 16

Kenneth Scarratt

Gemmological Association and Gem Testing Laboratory of Great Britain
London EC1N 8SU

An interesting large spinel

A client recently submitted 'for interest only' a cushion-shaped red spinel (Figure 1). The stone weighed 149.92ct, measured approximately 32.5 x 31.5 x 15.7mm, and was in a specially made case.

The gemmological properties were consistent with natural spinel. The refractive index was 1.716, and when the stone was bathed in light filtered through a solution of copper sulphate the typical organ pipe spectrum (Anderson, 1990) was observed with the hand spectroscope. The fluorescence under long-wave ultraviolet was an intense red and under short-wave the appearance was somewhat 'chalky'. The stone contained numerous, and well formed, crystal inclusions (Figure 2). Some needle-like inclusions were also present. When viewed between crossed polars the stone displayed strain birefringence.

At two points on the stone's girdle the remains of drill holes (Figure 3) were observed, indicating that the stone was ancient and had been recut from the old traditional style of fashioning for spinel – essentially a polished crystal in which the basic crystal form is retained; such stones are usually drilled in various directions to facilitate different settings, including the possibility for it to be worn in a turban.

Fig. 2. A closer view of the red spinel in Figure 1 and its well formed crystal inclusions. *(Photo K. Scarratt)*

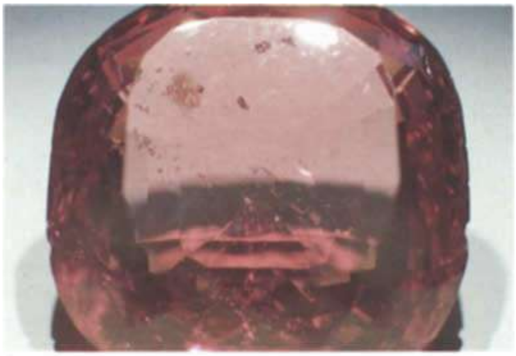

Fig. 1. The 149.92ct red spinel displaying the typical red colour. *(Photo K. Scarratt)*

Fig. 3. A side view of the spinel shown in Figures 1 and 2 showing the semi-circular remains of a drill hole at the girdle. *(Photo K. Scarratt)*

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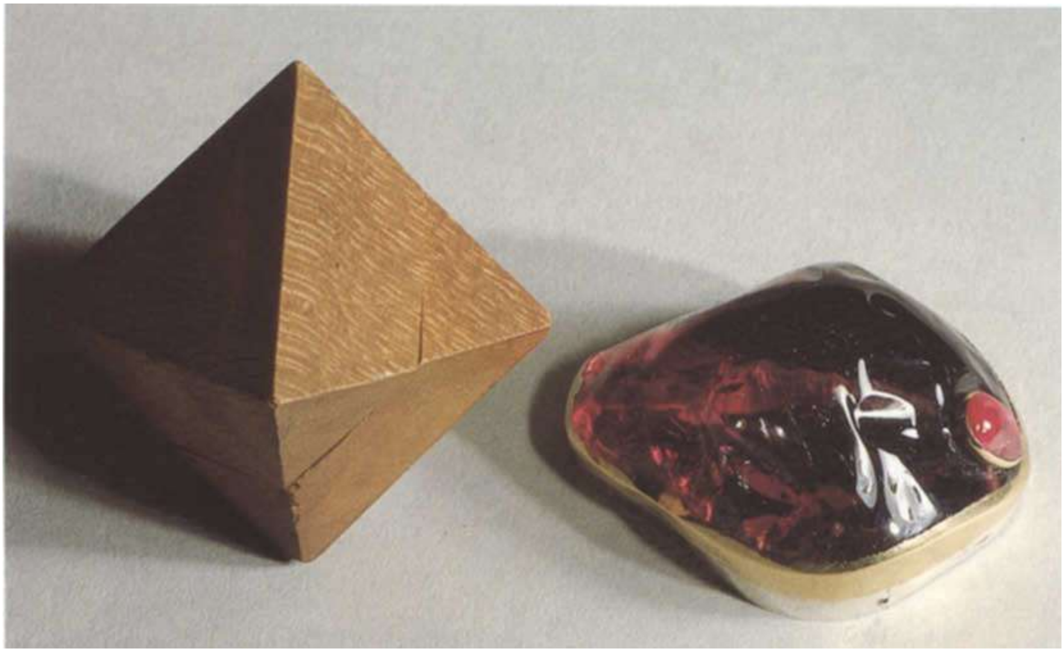


Fig. 4. The 'Black Prince's Ruby', a large spinel which is displayed in the front of the Imperial State Crown of the British Crown Jewels. The octahedron model has been positioned in a similar orientation with the faces of the 'Black Prince's Ruby'. *(Photo E.A. Jobbins)*

Originally the stone might well have been in a similar form to that of the 'Black Prince's Ruby' (an historical name for the large spinel displayed in the front of the Imperial State Crown of the British Crown Jewels). The 'Black Prince's Ruby' (with an octahedron model in similar orientation) is shown in Figure 4; it measures 43.3 x 33.8 x 20.1mm and weighs 220.50ct inclusive of its setting and inset cabochon-cut Burma ruby. There are four drill holes in the 'Black Prince's Ruby'. Given the present weight and dimensions of the two stones, it is possible that prior to recutting the 149.22ct cushion-shaped stone was originally larger than the 'Black Prince's Ruby'.

Fig. 5. 0.40ct treated blue diamond seen in reflected lighting conditions. *(Photo Jobbins/Scarratt)*

A Treated Diamond with an unusual blue colour

Whilst searching through the private coloured diamond collection of a New York dealer friend, I came across the treated diamond seen in Figure 5. The colour was unusual enough for me to want to examine the stone in more detail and the dealer was only too pleased for me to do so. He stated that he had had the stone treated in New York some years previously.

Infrared spectroscopy determined the diamond to be of the type Ia category and an examination of the stone's visible spectrum determined the presence of a strong 'General Radiation Band' and GR1. The normal face-up colour of the stone was an unusual shade of bright blue that tended towards turquoise (Figure 6). When viewed from a slight, and increasing angles, from the normal to the table, and also from the pavilion, much of the colour is lost (Figure 7). Peculiar yellow patches are also visible from certain angles (Figure 8).

The most interesting feature was the concentration of blue colour in the culet area (Figure 9) which is indicative of electron irradiation (Fritsch and Shigley, 1989). Whilst we have observed such colour concentrations in treated diamonds on many occasions, this must be one of the strongest examples recorded.

Fig. 6. The 0.40ct treated blue diamond in Figure 5 displaying the 'normal colour' seen by this stone. *(Photo Jobbins/Scarratt)*

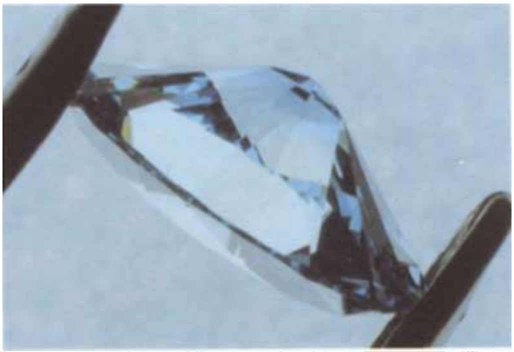
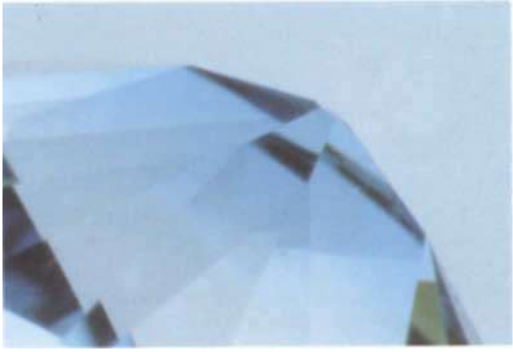


Fig. 7. Side view of the treated blue diamond showing the lack of colour in the body of the stone. *(Photo Jobbins/Scarratt)*

Fig. 8. The treated blue diamond viewed from the pavilion, and showing the lack of colour in the body of the stone. Peculiar yellow patches are also present. *(Photo Jobbins/Scarratt)*

Fig. 9. Enlarged view of the pavilion area of the treated blue diamond seen in Figures 7 and 8. The colour concentration in the culet area indicates electron treatment. *(Photo Jobbins/Scarratt)*



'Impregnated', 'Bleached' or 'B-Jade'

We have now had the opportunity to examine what is being termed 'bleached' or 'B-Jade' from two sources in Hong Kong. The first treated samples (a piece of rough and a fashioned disc or 'pi') were donated to the Laboratory by Dominic Mok of Hong Kong and the second set (treated rough and a treated cabochon) were provided by Mrs Anne Paul of Hong Kong, via Alan Hodgkinson in the UK (Figure 10).

The treatment process involves the removal of the brown 'iron stained' areas in lower quality jadeite samples, by soaking in hydrochloric acid and then impregnating the resultant material with a resin. The resin may be of the Araldite type or Opticon – the resin often used for the fracture filling of emeralds. The treated material appears to have a mugh higher lustre than one would expect for jadeite (Figure 11) and this may be the first indication that a piece of jadeite may have been treated in this manner.

Both the treated oval cabochon weighing 5.65ct

Fig. 10. Resin impregnated jadeite or 'B-Jade'. The disc on the right weighing 1.56ct and the cabochon on the left weighing 5.65ct. *(Photo K. Scarratt)*

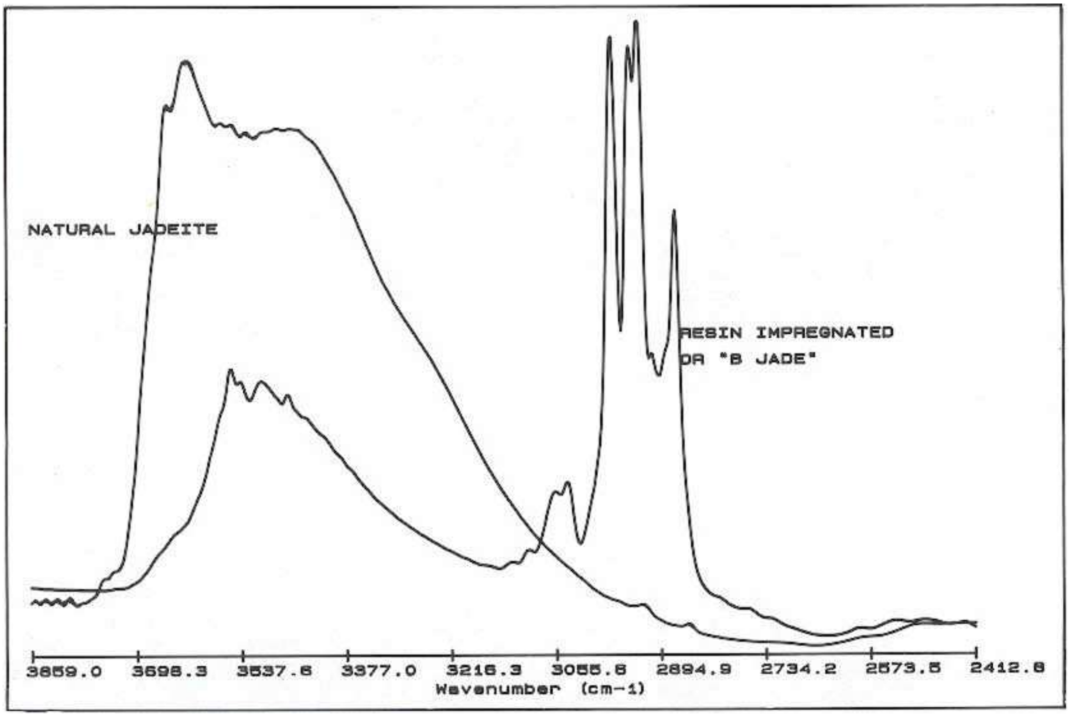
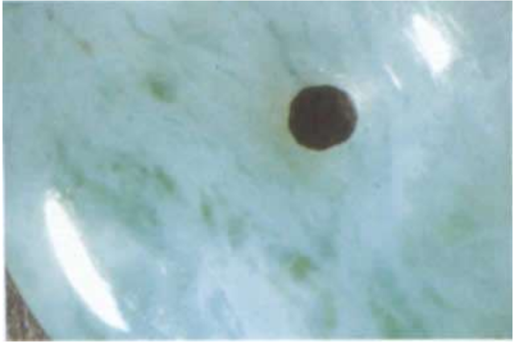


Fig. 12. Comparative infrared curves, in absorbence, of natural untreated jadeite and resin impregnated or 'B-Jade'.

and the disc weighing 1.56ct fluoresced a dull blue under short-wave ultraviolet light. The cabochon fluoresced an overall even blue under long-wave ultraviolet light whereas the disc was a more patchy blue. Of the two treated rough specimens, the larger weighing 40.71ct fluoresced a bright greenish-blue, whilst the smaller weighing 21.73ct fluoresced a bright blue under long-wave ultraviolet light. Under short-wave ultraviolet the two rough specimens fluoresced a more chalky version of their long-wave colour.

The refractive index taken from the flat back of the treated cabochon was 1.655, which is 'normal' for jadeite. The SG, obtained by hydrostatic weighing, was 3.31, which is also within the normal range for jadeite. Using the hand-held spectroscope, the normal jadeite absorption line at 437nm could be seen strongly in all the treated specimens. The normal jadeite 'chromium lines' were also readily apparent.

Fig. 11. A close view of the 1.56ct resin impregnated jadeite disc in Figure 14, showing the unusually high lustre. *(Photo Jobbins/Scarratt)*



A hot point was applied to the surfaces of the two fashioned specimens and the test areas examined through the microscope for signs of 'sweating' from the resin, but no signs of 'sweating' or any surface movement were observed. The two rough specimens both had a thick coating of the resin, and when the same test was applied to them the resin 'powdered'.

An infrared spectrum was taken of the treated cabochon (Figure 12) and compared with a piece of jadeite from the Laboratory collection. Additional features at 2969, 2942, 2928 and 2827cm^{-1} were noted in the cabochon's spectrum and these correspond with those reported for Opticon.

Cast polyester resin as an imitation of tortoiseshell, horn, ivory, bone and jet

Cast polyester resins in various colours and of differing internal structural patterns are being distributed by a company in West Sussex, (UK). The material is said to be of a quality suitable for machining, drilling, threading, boring, and specialized turning, and takes an exceptionally high polish. Rods are being supplied from 20mm to 128mm in diameter and 1.5 metres in length. Rectangular sections, also in 1.5 metre lengths, are available in sizes from 25 x 35mm to 45 x 75mm. The material is also available in sheet form.

Amongst others, the colours and textures manufactured are those of ivory, bone, tortoise-shell, horn and jet (Figure 13). Given that the sale, or production, of items of adornment from ivory, tortoise-shell and horn is unacceptable to many people and governments, it is likely that polyester resin as a substitute may make an increasing appearance on the market in the future.

All colour types have a similar refractive index, hardness, SG, and IR spectrum. Separation from the natural materials may be achieved by either refractive index or SG determination (see Table 1), or more simply by microscopic observations.

The structures seen in the ivory imitation bore a little resemblance to ivory itself. Slightly wavy structural lines may be observed along the length, and in cross-section a slightly swirled structure may be seen (Figures 14 and 15). However, these should not be mistaken for the more distinctive elephant ivory structures (Figures 16 and 17).

Very little is visible in the bone imitation in the way of structure (Figure 13, right) whereas the structure of bone itself is very distinctive, (see Figures 18 and 19). The tortoise-shell imitation has an interesting colour distribution which gives an overall impression of the imitated material (Figure 14) but the structure is sufficiently different from tortoise-shell (Figure 20) for it to cause no problems with identification.

The horn imitation has a structure quite different from the rhinoceros horn (Figure 21) it is supposed to imitate, with swathes of colour in cross-section (Figure 14) and a 'woodgrain' appearance along its length.

Fig. 14. The structures seen in the cast polyester resin imitations of: top row, left to right – horn and tortoise-shell (2), bottom row – 'onyx marble' and ivory. *(Photo E.A. Jobbins)*

Fig. 13. The 'varieties' produced in cast polyester resin to imitate (rods, from left to right) tortoise-shell, 'onyx marble', jet, ivory, tortoise-shell, horn and bone. *(Photo E.A. Jobbins)*

Fig. 15. The slightly swirly structure seen in the cross-section of the cast polyester resin imitation of ivory. *(Photo K. Scarratt)*

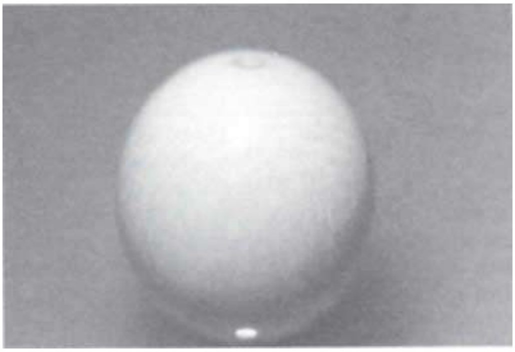


Fig. 16. An ivory bead showing the distinctive 'engine turning' structure common to elephant ivory. *(Photo K. Scarratt)*

Fig. 17. A thin section of elephant ivory showing the typical fine undulating structure seen on magnification – x10. *(Photo E.A. Jobbins)*

Fig. 18. The structure seen along the length of bone – x10. *(Photo E.A. Jobbins)*

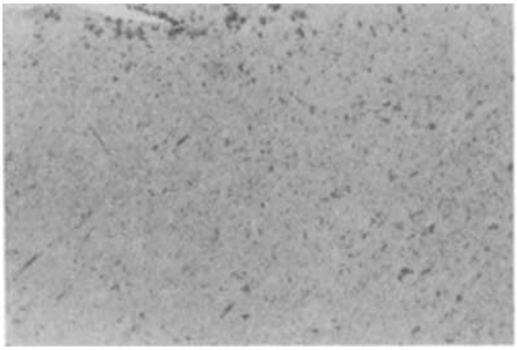


Fig. 19. The cross-section structure of bone – x10. *(Photo E.A. Jobbins)*

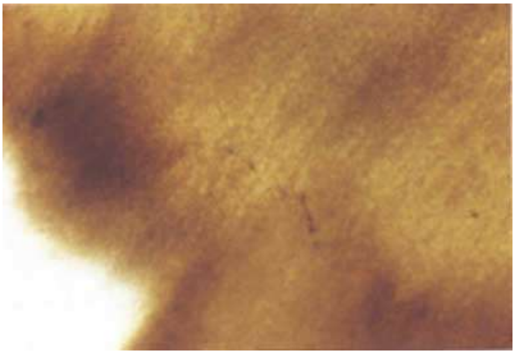


Fig. 20. Magnified view of the structure seen in natural tortoise-shell – x10. *(Photo E.A. Jobbins)*

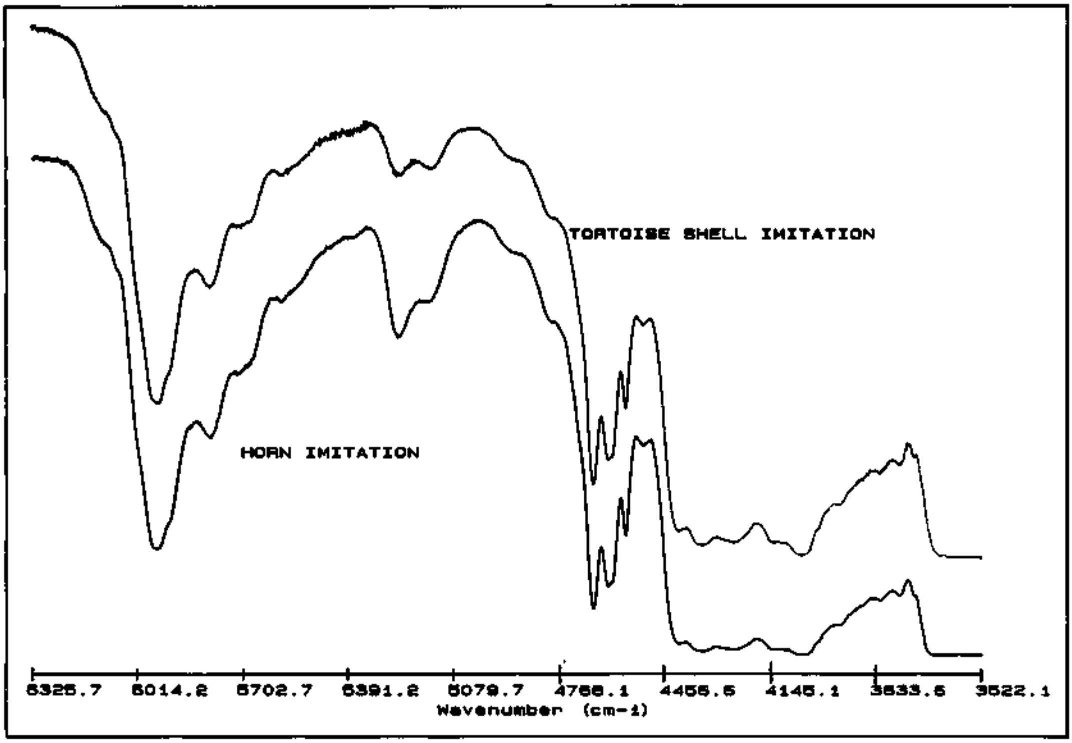


Fig. 24 Comparative infrared spectra, in transmission, of the cast polyester resin imitations of tortoise-shell and horn.

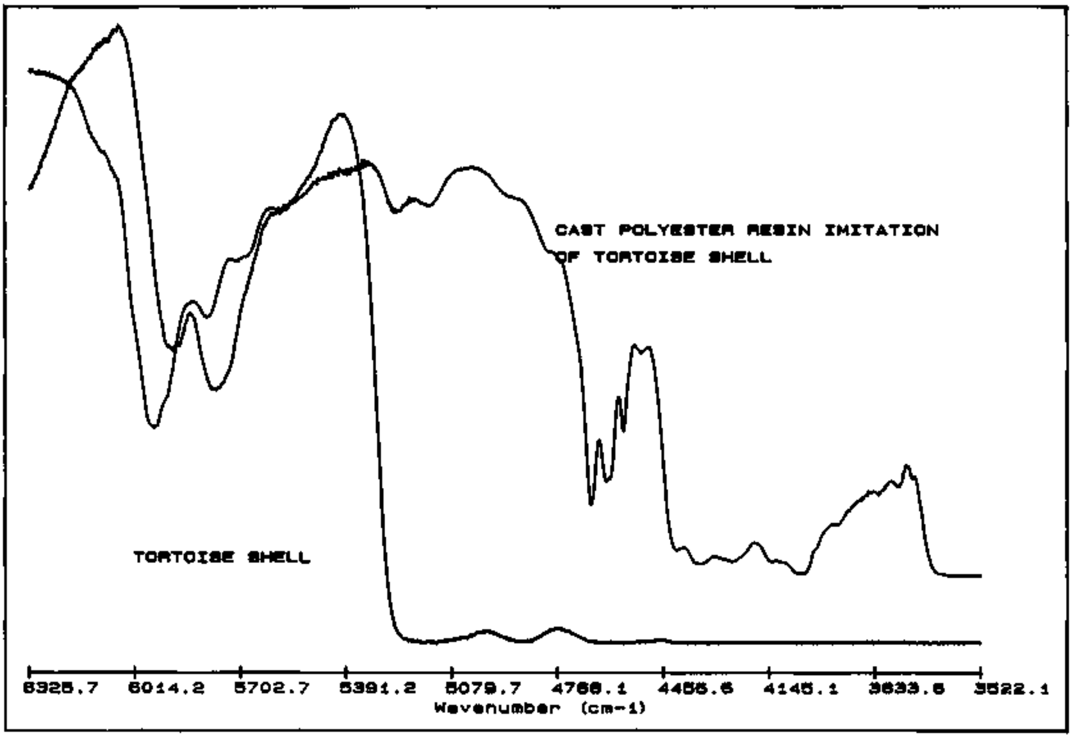


Fig. 25 Comparative infrared spectra, in transmission, of the cast polyester resin imitation of tortoise-shell and natural tortoise-shell.

Fig. 21. Section of rhinoceros horn showing the 'congealed hair-like' structure. *(Photo E.A. Jobbins)*

Table 1

Material	RI	SG	H
Ivory (elephant)	1.54	1.7 – 1.9	2¼ – 2¾
Bone	1.54	2.00	2½
Horn (rhinoceros)	–	1.29	–
Tortoise-shell	1.55	1.29	2½
Jet	1.66	1.33	2½
Cast Polyester Resin	1.548	1.20 – 1.22	1½

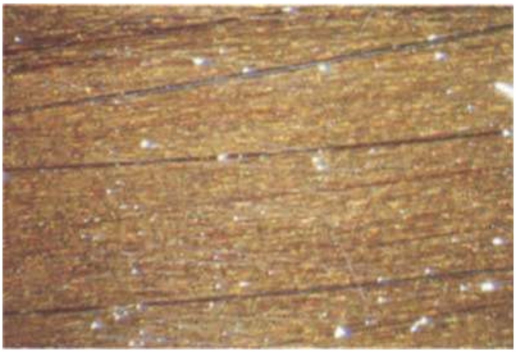


Fig. 22. Polished section of natural jet, showing 'wood grain' structure (moistened with light oil) – x25. *(Photo E.A. Jobbins)*

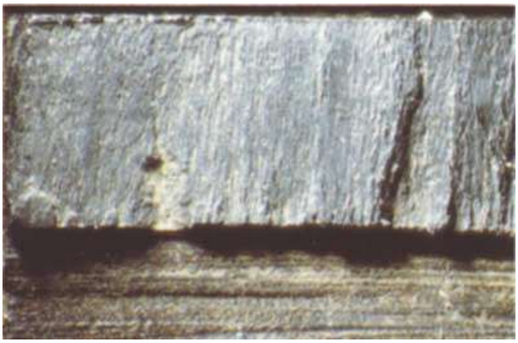


Fig. 23. Dry fracture surface of natural jet (above) with sawn section below – x25. *(Photo E.A. Jobbins)*

A high magnification examination of the surface structure of jet will sometimes reveal a wood-like structure with brownish reflections (Figures 22, 23) whereas the polyester resin imitation shows no structure at all. A hot point placed on the surface of jet will give off the characteristic smell of burning coal, whereas the polyester resin gives off a 'sweet' and somewhat 'sickly' odour.

Positive identification of cast polyester resin may be achieved by infrared spectroscopy. Figure 24 compares the tortoise-shell and horn imtations whilst Figure 25 compares natural tortoise-shell with the resin imitation. The principal infrared features for cast polyester resin are situated at 5957, 5799, 5245, 5153, 4668, 4621, and 4574cm^{-1}.

A Note from the Bahrain Laboratory*

Although the Laboratory receives a much greater proportion of pearls for testing than gems, it does see more amber and its simulants than the London Laboratory. One of the reasons for the popularity of amber in Bahrain is that, owing to its light weight and 'pleasant feel', it is a material ideally suited for fashioning into 'worry beads'.

Seeing this quantity and variety of amber, inevitably means that the Bahrain Laboratory encounters various forms of enhancement in the course of testing. Some of these enhancements reveal clear identification features that allow for a straightforward description, whilst others are not so co-operative.

Recently an example of the type of problem encountered when testing amber arrived in the Laboratory. A necklace consisting of 47 yellow/orange faceted beads (see Figure 26) was submitted for examination.

The usual tests associated with the identification of amber were carried out. The necklace floated in saturated brine, hot needle tests applied to a number of beads produced the characteristic aromatic odour of amber, and sectility tests revealed that the material splintered in the manner normal for amber (these last two tests may only be applied with extreme care and only to an 'inconspicuous area' of the sample, e.g. inside the drill hole of a bead).

The problems began to arise when the necklace was examined with the aid of a microscope. The colour appeared to be confined to the surface and formed a symmetrical pattern on the facets of each bead. Detailed examination revealed that the surface colour was concentrated in the centre of each facet with the edges only showing the much paler underlying colour. However, the lustre of the surface was even and no form of 'coating' could be seen.

When the necklace was immersed, the colour pattern bore a similarity to that normally seen on the facets of an immersed diffusion-treated corundum (Nassau, 1981), but in reverse. In this instance the beads were pale or colourless at the facet edges with the concentration of colour being in the central area of each facet.

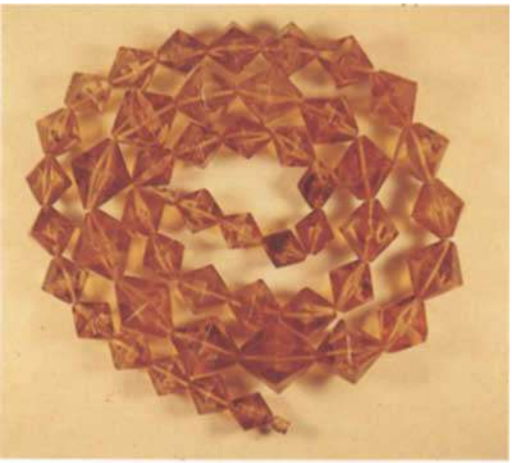


Fig. 26 A necklace of 47 surface colour enhanced amber beads. *(Photo N. Sturman)*

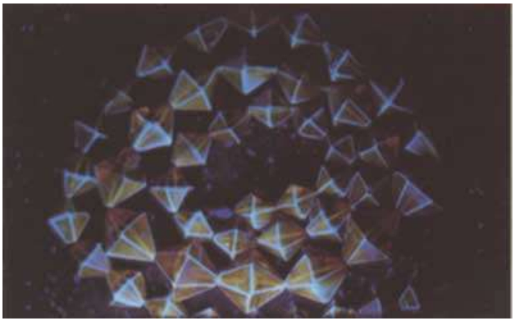


Fig. 27 The effect seen when the amber necklace seen in Figure 26 is bathed in ultraviolet light. *(Photo N. Sturman)*

In addition to the unusual colour distribution, the beads revealed a peculiar and striking fluorescence (Figure 27) when exposed to both long-wave and short-wave ultraviolet light. Where the colour was concentrated the fluorescence was one of a dull chalky greenish-brown, whilst in the areas of no colour it was a very bright chalky bluish-white.

Inclusions such as plant-life, bubbles, swirls and thread-like tubules indicated that the material was

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*The Gem and Pearl Testing Laboratory of Bahrain is a government laboratory set up and operated with the assistance of GAGTL. Ahmed Bubshait is the head of the Laboratory and currently Nick Sturman is the GAGTL officer on secondment. This is the first note from Ahmed and Nick to be included in 'Notes from the Laboratory', and we look forward to more in the future.

Fig. 28 Examples of surface enhanced amber showing the deep yellow exterior contrasting with the colourless to near-colourless interior. Each specimen has been specially sectioned and polished to display the effect of the treatment. *(Photo K. Scarratt)*

not pressed amber. This was confirmed by the absence of the characteristic strain patterns normally associated with some forms of pressed amber.

The nature of this enhancement is not certain but it may be similar to the heat-treated amber discussed by Scarratt (1986) and in Burland (1992). In such cases the surface colour concentration is a by-product of the 'clarification process'. Cloudy amber which has already been fashioned into the desired form, is gradually heated by 50° steps up to approximately 200°C in an ordinary domestic type oven. This process clarifies the amber but sometimes lessens the interior colour to a point where it is almost colourless, whilst at the same time producing a much darker exterior (Figure 28). The Laboratory's conclusion was 'surface colour enhanced amber'.

Acknowledgements

It is with thanks that the author acknowledges the assistance of his colleagues in the Laboratory, in particular Steve Kennedy who produced the visible spectrum of the treated blue diamond, and confirmed the SG's of the impregnated jadeite and cast polyester resin. He also wishes to record his appreciation of the tremendous assistance given by Alan Jobbins in the production of the photomicrographs.

Also acknowledged is the generosity of Mr Peter Kaplan for allowing the author to examine his coloured diamond collection. The author also wishes to thank Mrs M.E. Hutchinson of the Ancient Monuments Laboratory (English Heritage) for bringing the cast polyester resin imitations to his notice. Both Ahmed Bubshait and Nick Sturman acknowledge, with grateful thanks, the assistance of their colleagues in Bahrain and London.

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[*Manuscript received 3 August 1992*]

The Chemical Properties of Colombian emeralds

Dr Dietmar Schwarz

Institute for Geosciences,
Johannes Gutenberg University, Mainz, Germany

Abstract

Ninety emeralds from different mining regions (Muzo, Coscuez, Yacopí, Chivor/Somondoco, and Gachalá) in the Cordillera Oriental/Colombia were examined by micro-X-ray-spectroscopy (microprobe). The results of the chemical analyses are discussed using the correlation diagrams Al_2O_3/MgO, Al_2O_3/Na_2O, Al_2O_3/FeO_{tot}, Na_2O/MgO, Na_2O/FeO_{tot}, and FeO_{tot}/MgO.

1. Introduction

The Colombian emerald occurrences are situated in the so-called 'emerald-belt' of the Cordillera Oriental. Within this belt two mineralized zones can be distinguished: the Western zone containing the mining regions of Muzo, Coscuez, and Yacopí (Figure 1) and the Eastern zone with the mining regions Chivor/Somondoco and Gachalá (Figures 1 and 2).

2. Chemical data

In the course of our examinations a total of 90 emeralds originating from different mining regions of the Cordillera Oriental/Colombia were chemically analyzed by micro-X-ray-spectroscopy (microprobe). In detail, emeralds from the following localities were examined (number of samples in parentheses):

Muzo	(20)
Coscuez	(07)
Yacopí	(11)
Chivor	(14)
('Polpito' and 'El Oriente' areas)	
Gachalá	(08)
('Vega de San Juan', 'El Diamante' and 'Las Cruces' areas)	

For another 30 samples the mines of origin could not be exactly determined, these are designated in a general manner as 'Colombian emeralds'.

Table 1 gives the chemical data (width of variations and mean concentrations) for emeralds from the Western mineralization zone (covering the regions of Muzo, Coscuez and Yacopí). The chemical data for emeralds from the Eastern mineralization zone with the regions of Chivor/Somondoco and Gachalá are compiled in Table 2 (including the data from Kozlowski *et al.*, 1988, for emeralds from Achiote-Somondoco). The chemical data of 4 samples showing colour zoning are given in Table 3. Table 4 contains a compilation of literature data

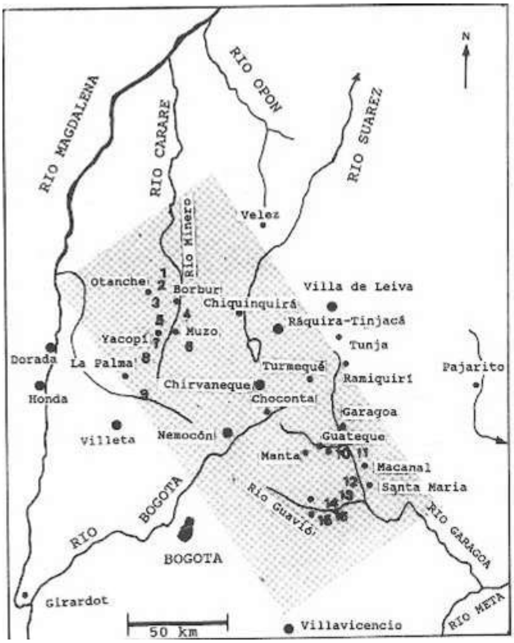

Fig. 1. The 'emerald belt' of the Cordillera Oriental/Colombia with the Western (Muzo-Coscuez-Yacopí) and the Eastern (Chivor/Somondoco-Gachalá) mineralization zones.

1 = Penas Blancas
2 = La Chapa
3 = Coscuez
4 = Santa Rosa
5 = Muzo
6 = Maripí/Coper
7 = Yacopí
8 = La Mina (Glorieta) /Aposentos
9 = El Penon
10 = Achiote/Somondoco
11 = Sagrada Familia/ Pavaranado
12 = Chivor
13 = Buenavista
14 = Mundo Nuevo
15 = Las Cruces/El Toro/ El Diamante
16 = Vega de San Juan

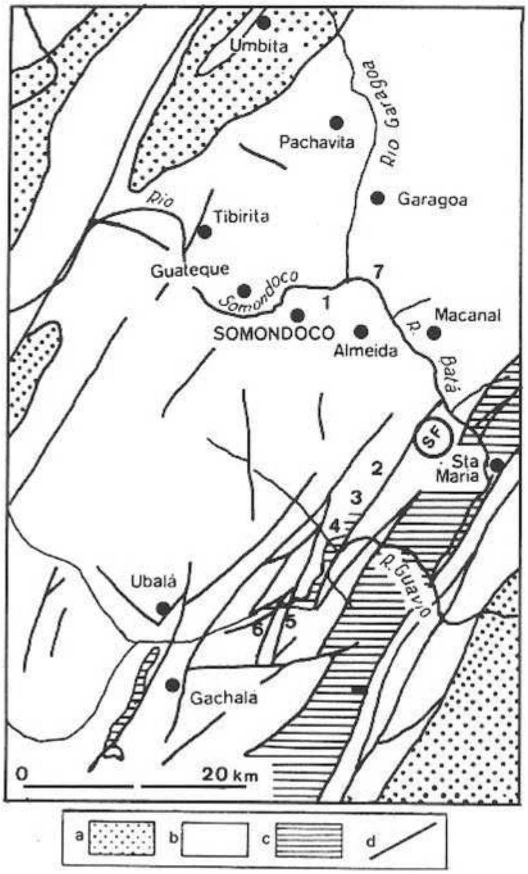

Fig. 2. The Colombian emerald occurrences (geographic situation) in the region Chivor/Somondoco-Gachalá. (Modified after Kozlowski *et al*, 1988).
1 = Achiote/Somondoco
2 = Chivor
3 = Buenavista
4 = Mundo Nuevo
5 = Las Cruces/El Toro/El Diamante
6 = Vega de San Juan
7 = Sagrada Familia/Pavaranado
a = Tertiary
b = Cretaceous
c = pre-Cretaceous
d = faults
SF = San Fernando fault

from earlier studies (Zambonini, 1928; Tsherepivskaya, 1971; Hänni, 1980; Hänni, 1982; Schrader, 1987, and Aurisicchio, 1988) and also the values for width of variations and mean concentrations of 26 emeralds from different (but not exactly known) mining areas in the Cordillera Oriental that were examined by the author.

Partial analyses of Colombian emeralds can be found in Staatz *et al.* (1965), Barriga & Villalba (1973), Schrader (1981) and Landais (in Gübelin, 1982).

Emerald as a member of the beryl group has the chemical formula $Be_3Al_2Si_6O_{18}$. The oxide concentrations that correspond to this ideal composition are SiO_2 = 67.07%, Al_2O_3 = 18.97% and BeO = 13.96%. But it has been known for a long time that natural beryls only in rare cases come to this standard composition, mostly they show distinct deviations from it (this is a well-known behaviour that can be observed also in many other minerals). These discrepancies go back to the fact that certain lattice components can substitute for each other and some additional ('extraneous') elements (that do not appear in the chemical formula) may enter the crystal structure.

As we can see from the chemical data of Tables 1-4, in the case of emerald these 'extraneous' elements are mainly magnesium, sodium, iron, and, naturally, the colouring agents chromium and vanadium. Therefore, the discussion of the chemical characteristics of the beryl variety emerald may be restricted initially to these 5 elements. But in view of geochemical-genetic considerations it is certainly of interest to include in future certain trace elements.

Our investigations, realized on emeralds from different localities (Brazil, Schwarz, 1990; Norway and Australia, Schwarz, 1991a; Habachtal and Ural Mountains/USSR, Schwarz, 1991b) have clearly shown that the contents of the 'extraneous' elements present, in part, considerable widths of variations. This is valid not only for samples coming from the same mining region, but also for the (mean) concentrations in emeralds from different localities (see also Section 3). It is a factor that in many former studies was not taken into account sufficiently. Sometimes, inadmissible or generalized conclusions based only on a few chemical data have been drawn to characterize the chemical properties of emeralds originating from a certain mining field or a certain geographic region.

With regard to magnesium and sodium our studies show that the contents of these elements in Colombian emeralds are low.*

The lowest mean concentrations (0.25% Na_2O and 0.34% MgO) were observed in the emeralds from the mining region of Gachalá. The highest contents of these oxides (about 1% MgO and 0.7-0.8% Na_2O) are shown by crystals from Yacopí

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*The concentration bands for the elements chromium, vanadium, iron, sodium and magnesium were delimited empirically by the following values (in wt% Cr_2O_3, V_2O_3, FeO, Na_2O and MgO; Schwarz, 1988 and 1990):

	low	medium	high
chromium	<0.2	0.2-0.4	>0.4
vanadium	<0.2	0.2-0.4	>0.4
iron	<0.5	0.5-1.0	>1.0
sodium	<1.0	1.0-2.0	>2.0
magnesium	<1.5	1.5-2.5	>2.5

Table 1: Chemical data (width of variations and mean concentrations for the number of samples given in parentheses) of Colombian emeralds from the mining regions of Muzo, Coscuez and Yacopí.

	Muzo	(20)	Coscuez	(07)	Yacopí	(11)
SiO_2	65.47-67.63	67.07	66.81-67.81	67.31	66.10-67.08	66.65
Al_2O_3	16.24-18.11	17.23	15.40-17.02	16.19	16.54-17.67	16.98
Cr_2O_3	0.06- 0.69	0.27	0.02- 0.08	0.05	0.02- 0.09	0.06
V_2O_3	0.05- 0.81	0.29	0.03- 0.08	0.05	0.02- 0.10	0.08
FeO	0.03- 0.16	0.07	0.05- 0.40	0.19	0.04- 0.25	0.17
MnO	‹ - 0.05	0.02	‹ - 0.03	0.02	‹ - 0.06	0.02
MgO	0.44- 1.10	0.65	0.59- 1.48	1.00	0.67- 1.27	0.98
Na_2O	0.24- 1.02	0.53	0.53- 1.03	0.72	0.56- 1.04	0.80
CaO	‹ - 0.02	–	‹ - 0.01	–	‹ - 0.01	–
K_2O	‹ - 0.02	0.01	‹ - 0.02	0.01	‹ - 0.02	–
TiO_2	‹ - 0.02	0.01	‹ - 0.02	0.01	‹ - 0.03	–

Obs.: ‹ = element concentration below detection limit of the analytical method

Table 2: Chemical data (width of variations and mean concentrations for the number of samples given in parentheses) of Colombian emeralds from Chivor and Gachalá (including the data of Kozlowski *et al.*, 1988, for emeralds from Achiote/Somondoco).

	Chivor	(14)	Gachalá	(08)	Somondoco	(07)
SiO_2	66.22-68.20	67.59	66.77-67.55	67.22	64.18-65.55	64.96
Al_2O_3	16.64-17.71	17.11	16.69-17.48	17.15	17.04-18.84	18.25
Cr_2O_3	0.01- 0.50	0.18	0.02- 0.43	0.10	0.01- 0.34	0.17
V_2O_3	0.03- 0.23	0.08	0.02- 0.15	0.09	0.01- 0.13	0.08
FeO	‹ - 0.50	0.10	0.03- 0.12	0.07	0.14- 0.60	0.30
MnO	‹ - 0.03	0.02	‹ - 0.03	0.02	0.0 - 0.05	0.02
MgO	0.32- 0.85	0.63	0.15- 0.48	0.34	0.74- 1.65	1.11
Na_2O	0.20- 0.54	0.39	0.14- 0.29	0.25	0.70- 1.50	1.01
CaO	‹ - 0.02	–	‹ - 0.02	0.01	0.0 - 0.02	0.01
K_2O	0.01- 0.08	0.02	‹ - 0.01	0.01	0.03- 0.09	0.05
TiO_2	‹ - 0.04	0.02	‹ - 0.02	0.01	0.0 - 0.03	0.01

Obs.: ‹ = element concentration below detection limit of the analytical method

Table 3: Chemical data of Colombian emeralds showing colour zoning.

	(A)		(B)		(C)		(D)	
	R	K	R	K	R	K	R	K
SiO_2	66.50	66.19	66.31	66.67	65.84	65.40	64.63	64.19
Al_2O_3	17.27	17.52	17.44	16.99	17.04	16.93	16.44	17.51
Cr_2O_3	0.28	0.05	0.16	0.03	0.17	0.01	0.64	0.01
V_2O_3	0.11	0.04	0.21	0.06	0.20	0.05	0.56	0.03
FeO	0.06	0.06	0.05	0.10	0.05	0.13	0.06	0.03
MnO	‹	‹	–	–	–	–	–	–
MgO	0.71	0.69	0.41	0.87	0.46	0.89	0.67	0.84
Na_2O	0.58	0.55	0.32	0.91	0.45	0.88	0.54	0.70
CaO	‹	‹	‹	0.01	0.02	‹	0.01	‹
K_2O	0.01	0.01	‹	‹	0.03	0.02	0.03	0.03
TiO_2	‹	‹	0.01	0.02	‹	‹	‹	0.02

Obs.: R = green border zone
K = colourless central zone
‹ = element concentration below detection limit of the analytical method
– = no data for this element

Table 4: Chemical data of Colombian emeralds: compilation of literature data from Zambonini (1928), Tsherepivskaya (1971), Hänni (1980), Hänni (1982), Schrader (1987), and Aurisicchio (1988). The width of variation and mean concentrations of 26 emeralds analyzed by the author coming from different (but not exactly known) localities in the Cordillera Oriental are also given.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
SiO_2	65.26	65.07	65.8	66.0	66.4	66.6	65.2	64.6	67.15	64.98	64.39	65.95	65.34	65.23-68.48	66.58
Al_2O_3	17.60	18.51	16.7	16.9	16.9	17.7	16.3	16.3	17.94	17.43	17.55	17.19	16.51	15.54-18.33	17.17
Cr_2O_3	–	0.13	0.8	0.6	0.2	0.3	0.2	0.2	0.58	0.32	0.22	0.03	0.37	0.01- 0.93	0.15
V_2O_3	–	–	–	–	0.3	0.4	0.8	0.6	0.10	0.11	0.06	0.05	0.64	< - 1.27	0.24
FeO	0.08	0.65	0.1	0.0	0.0	0.0	0.0	0.0	0.05	0.07	0.04	0.10	0.31	< - 0.23	0.08
MnO	0.06	0.02	0.0	0.1	0.0	0.0	0.0	0.0	–	–	–	–	<	< - 0.07	–
MgO	0.77	0.24	0.5	0.4	1.4	1.0	1.0	1.2	0.31	0.34	0.17	0.97	0.67	0.13- 1.52	0.66
Na_2O	0.50	0.43	0.4	0.4	1.0	0.6	0.8	0.8	0.27	0.18	0.07	0.74	0.49	0.11- 1.16	0.46
CaO	0.09	0.65	0.0	0.0	–	–	–	–	0.01	0.01	0.01	0.01	–	< - 0.02	–
K_2O	0.22	0.16	0.0	0.0	–	–	–	–	–	–	–	–	<	< - 0.05	–
TiO_2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	–	–	–	–	<	< - 0.04	–

Obs.:
(1) = Zambonini (1928) (Muzo)
(2) = Tsherepivskaya (1971) (Muzo)
(3), (4) = Hänni (1980)
(5)-(8) = Hänni (1982)
(7), (8) = 'Trapiche' emeralds
(9)-(12) = Schrader (1987) (9, 10, 11 Chivor)
(13) = Aurisicchio (1988) (Muzo)
(14) = width of variations of 26 Colombian emeralds (this paper)
(15) = mean concentrations of 26 Colombian emeralds (this paper)
< = element concentration below detection limit of the analytical method
– = no data for this element

and Coscuez. Comparing the Na and Mg concentrations of emeralds coming from the two mineralized emerald zones of the Cordillera Oriental, it is obvious that there are no distinct differences. This fact indicates that the geological-geochemical processes that are responsible for the introduction of the elements sodium and magnesium in the two mineralization zones are basically of the same nature. Besides this it shows that regional mineralization processes (e.g. with the participation of the evaporites present in the whole region) are more than probable locally restricted events (as is, for example, the case when contact metamorphism is related to the emplacement of pegmatites).*

The iron contents in Colombian emeralds are low to very low throughout. The highest iron concentration of the samples examined by the author was observed in a Chivor emerald (0.50% FeO). The Somondoco emeralds examined by Kozlowski *et al.* (1988) exhibited FeO concentrations from 0.14-0.60% with a mean concentration of 0.30% FeO. Barriga and Villalba (1973) and Landais (in Gübelin, 1982) report FeO contents of 0.9% and up to 0.72% respectively for emeralds from Muzo.

The elements responsible for the brilliant green colour of the Colombian emeralds are chromium and vanadium. Contents of these vary widely. This behaviour is also known of emeralds coming from other (genetically different) localities. Frequently in the literature it has been pointed out that emerald crystals found immediately side by side in the same vein may show quite different shades of green. Besides this, many emeralds (from the most different occurrences) distinguish themselves by a distinct colour zoning (compare also Table 3). This clearly shows that the supply of chromium in the emerald 'mother liquor' suffered strong variations through time and space.

As can be seen from the analytical data, all these considerations are valid in an analogous manner also for the element vanadium. It must be emphasized that the samples from Colombia are amongst those with the highest vanadium concentrations of all emeralds analyzed by the author up to the present. They are surpassed only by the Norwegian emeralds from the Eidsvoll/Lake Mjosa deposit (mean concentration of four samples = 1.29% V_2O_3; Schwarz, 1991) and the so-called 'V-beryls' from Salininha/Bahia, Brazil. At this point we should like to emphasize again the fact that the mean concentrations of vanadium and chromium in Colombian emeralds are of the same order of magnitude (the mean concentrations of the 90 emeralds examined by the author during the present investigation are 0.16% Cr_2O_3 and 0.18% V_2O_3 respectively). In many samples the vanadium content is even distinctly higher than the chromium concentration. On the other hand there are many emeralds that show a more or less pronounced dominance of chromium. A third 'type' of Colombian emeralds contains comparable amounts of these colouring

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*A detailed compilation and a discussion of the different hypotheses used to explain the genesis of the Colombian emerald occurrences is given by Schwarz, 1991(c).

Table 5: Chemical data of some Colombian emeralds showing different ratios of the colour-influencing elements chromium, vanadium, and iron.

	Cr_2O_3	V_2O_3	FeO_{tot}
Yacopí	0.02	0.10	0.25
Chivor	0.11	0.04	0.50
	0.34	0.08	
Gachalá	0.43	0.15	0.09
	0.02	0.10	0.03
Muzo	0.69	0.59	0.05
	0.34	0.81	0.08
	0.51	0.52	0.09
Coscuez	0.02	0.03	0.40
Mining region not known	0.31	1.27	0.13
	0.06	0.69	0.43
	0.93	0.54	0.10

elements (see also Table 5). Surely, the significance of the element vanadium as agent for the green colour of emerald has not been taken into consideration adequately in the past. It would be desirable with regard to a future discussion on the definition of the term 'emerald' to give more importance to the element vanadium. From the mineralogical point of view it is surely not justified to consider the chromium content as only criterion for the delimitation emerald-green beryl.

Table 3 shows the chemical data of four Colombian emeralds presenting a distinct colour zoning with an almost colourless central part and a green border zone ('rim'). As can be expected, the colour zoning is clearly related to the concentrations of the colouring elements chromium and vanadium. The contents of these elements are distinctly higher in the border zone. On the other hand the iron concentrations are in the same order of magnitude in the different parts of the crystals. It seems that there is no correlation between the content of this element and the intensity of the green colour. The concentrations of the elements sodium and magnesium are much higher in the central zones of three samples, however, in the fourth one these concentrations show almost no variation. By this, we can conclude that for the crystals examined the incorporation tendency of the elements sodium and magnesium is contrary to that observed for the colouring agents chromium and vanadium!

Emeralds from Colombia showing a colour zoning are relatively common. Crystals with a colourless or a weakly coloured greenish central core and a deep green border zone ('rim') have been described, among others, by Scheibe (1926) and Ringsrud (1986) from Muzo. MacFadden (1934) describes an emerald from Somondoco with several concentric 'colour-rings' around a colourless central core that becomes increasingly darker from the inner to the outer regions.

Sinkankas (1981) and Kozlowski *et al.* (1988; a crystal from the Juntas mine in Achiote/Somondoco) mention stones with a distinct colour zoning consisting of a green emerald core surrounded by a colourless border zone.

Among the data of former investigations (compiled in Table 4) the high CaO content of a Muzo emerald (analyzed by Tsherepivskaya, 1971) is just as striking as the high concentrations (compared to the data published by other authors) of K_2O in emeralds from Muzo reported by Zambonini, 1928 (0.22%) and Tsherepivskaya, 1971 (0.16%).

3. Discussion of element correlation diagrams

3.1 *Correlation diagram Al_2O_3/MgO*

In the diagram of Figure 3, the representative points of the chemical analyses (mean concentrations) of emeralds from Colombia, Brazil, Australia, Norway, Austria, and the USSR are marked. For comparison purposes the data for pegmatite beryls from the mining regions of Governador Valadares and Araçuai-Salinas, Minas Gerais, Brazil, are also shown.

It is interesting to note in this diagram, the large variation of the contents of Al_2O_3 and MgO in emeralds from different occurrences. The lowest mean concentrations of MgO (0.05%) of all samples examined by the author up to the present are shown by the emeralds from the Emmaville mining region in New South Wales, Australia. The highest mean concentrations of this oxide (about 3%) were observed in Brazilian emeralds from the occurrences Salininha/BA, Santa Terezinha/GO, and Itaberaí/GO. The representative points for emeralds from the different Colombian deposits are placed, throughout, in the upper left part of the population area. This means that their magnesium contents are low and their aluminium concentrations are high. The distinctly developed diagonal distribution trend (with negative slope) of the population field verifies that the introduction of magnesium into the emerald-/beryl structure follows the substitution reaction (1).

$$(1)\ Al^{3+,VI} = Mg^{2+,VI}$$

3.2 *Correlation diagram Al_2O_3/Na_2O*

The representative points in the correlation diagram Al_2O_3/Na_2O (Figure 4) show a behaviour that is analogous to the one observed in the diagram Al_2O_3/MgO: the clearly developed diagonal trend with negative ascent shows that the rising Na content of the emeralds is accompanied by a decrease of the Al_2O_3 concentration. This behaviour is based on the following substitution reaction (2).

$$(2)\ Al^{3+,VI} = Me^{2+,VI} + Na^{1+\ (channel)}$$

Correlation diagrams for Al_2O_3/MgO (Fig. 3), Al_2O_3/Na_2O (Fig. 4), Al_2O_3/Fe_{tot} (Fig. 5), Na_2O/Fe_{tot} (Fig. 7), Fe_{tot}/MgO (Fig. 8), with the representative points (mean concentrations for emeralds from Colombia, Brazil, Australia, Norway, Austria and the USSR (data from this paper and from Schwarz, 1990; Schwarz, 1991a and Schwarz, 1991b).

(1)	Carnaíba/BA	(38)*	(13)	Eidsvoll, Norway	(04)*
(2)	Capoeirana/MG	(16)*	(14)	Ural Mountains, USSR	(11)*
(3)	Belmont Mine/MG	(48)*	(15)	Habachtal, Austria	(10)*
(4)	Socotó/BA	(63)*	(16)	Untersulzbachtal, Austria	(06)*
(5)	Tauá/CE	(11)*	(17)	'Colombia' (exact mines of origin not known)	(30)*
(6)	Pirenópolis/GO	(07)*	(18)	Yacopí, Colombia	(11)*
(7)	Salininha/BA	(05)*	(19)	Coscuez, Colombia	(10)*
(8)	Itaberaí/GO	(13)*	(20)	Muzo, Colombia	(20)*
(9)	Santa Terezinha/GO	(29)*	(21)	Somondoco, Colombia (Kozlowski *et al.*, 1988)	(07)*
(10)	Poona/Western Australia	(12)*	(22)	Gachalá, Colombia	(08)*
(11)	Menzies/Western Australia	(04)*	(23)	Chivor, Colombia	(14)*
(12)	Emmaville/NSW, Australia	(05)*			
(C1)	Pegmatite beryls from the Araçuai-Salinas region/MG (Correia Neves *et al.*, 1984)	(09)*			
(C2)	Pegmatite beryls from the Governador Valadares region/MG (Correia Neves *et al.*, 1984)	(05)*			
* =	number of analyzed samples				

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
●	☆	★	▲	□	△	◇	○	■	✷	✳	◆	▼	▽	◈	❖	⊙	◉	◬	⊛	⟐	⊲	✪

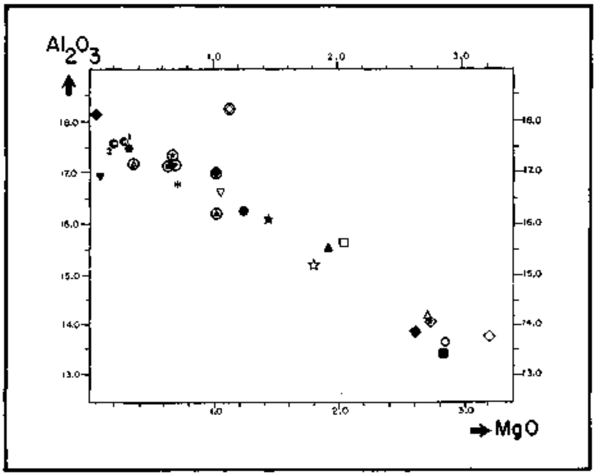


Fig. 3.

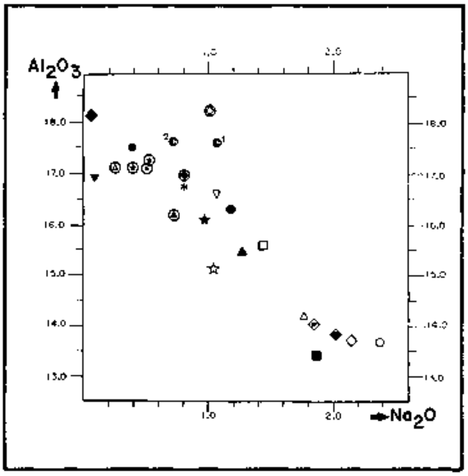


Fig. 4.

Fig. 5.

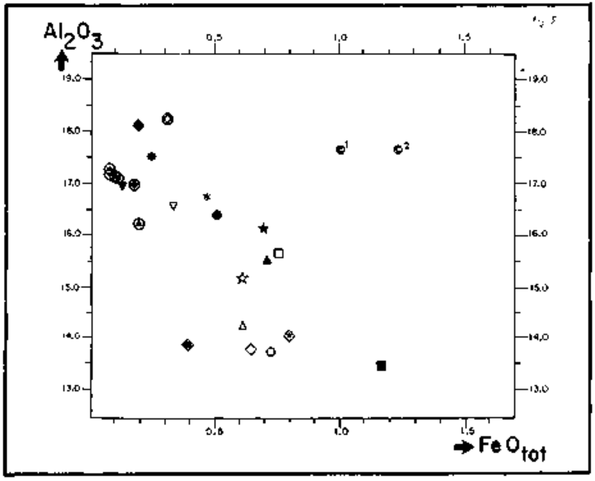


Fig. 7.

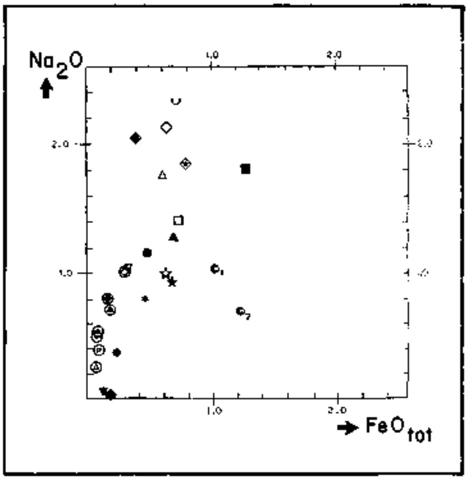


Fig. 8.

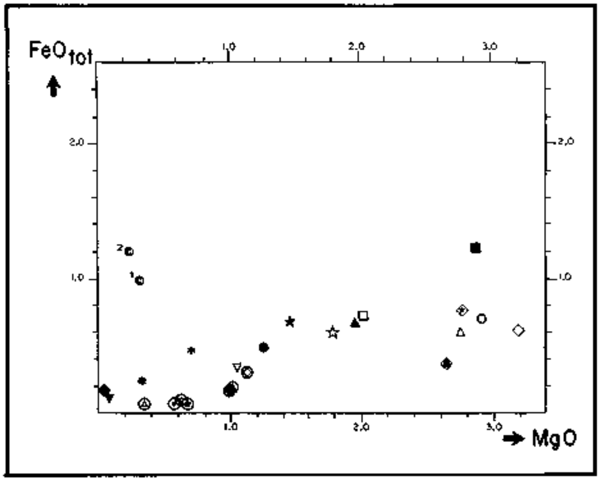
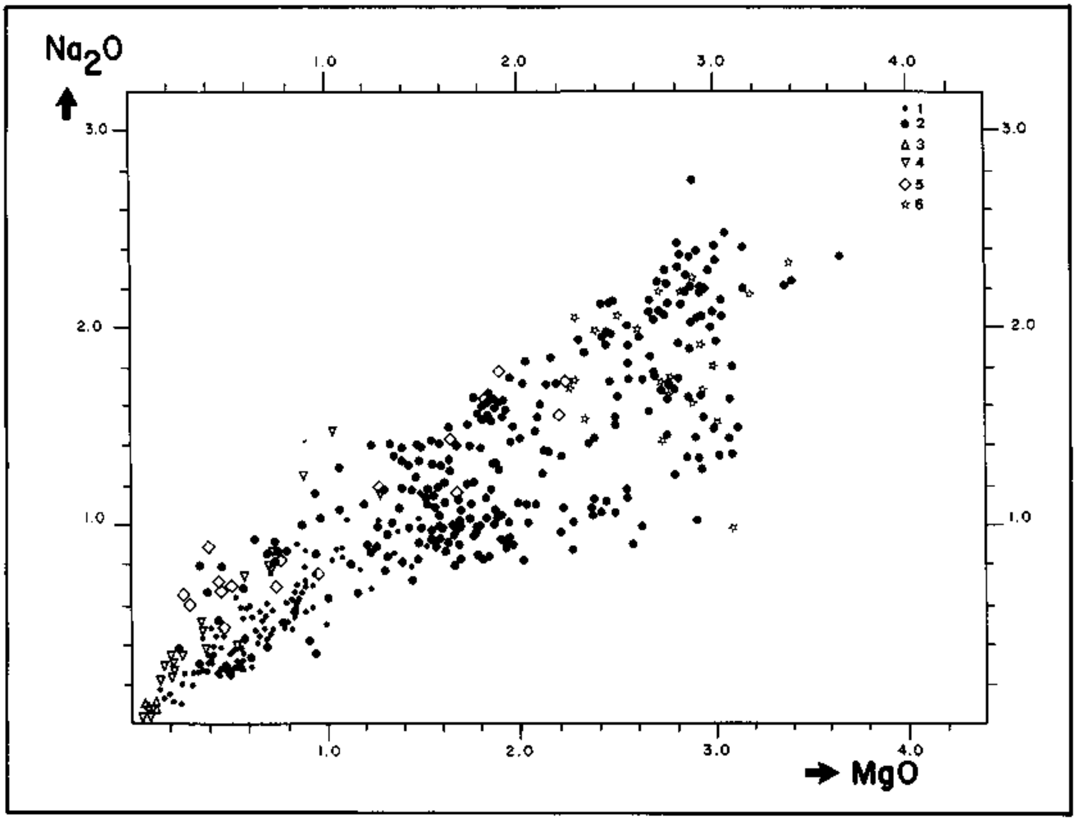


Fig. 6. Correlation diagram for Na_2O/MgO with the representative points (single analyses) for emeralds from Colombia, Brazil, Australia, Norway, Austria, and the USSR (data from this paper and from SCHWARZ, 1990; SCHWARZ, 1991a and SCHWARZ, 1991b).

1 = Colombia
2 = Brazil
3 = Norway
4 = Australia
5 = Ural Mountains
6 = Habachtal



The substitution of the trivalent aluminium by bivalent metal (Me) ions (in emerald predominantly Mg^{2+}) requires a charge compensation. This is achieved practically exclusively by the additional incorporation of monovalent sodium in channel positions.

The representative points for all Colombian emeralds in the Al_2O_3/Na_2O correlation diagram are situated in the upper left region of the population area: their mean Na concentrations are low, the mean concentrations of aluminium, however, are high.

3.3 *Correlation diagram Al_2O_3/FeO_{tot}*

The general trend of the representative points in the correlation diagram Al_2O_3/FeO_{total} (Figure 5) shows indeed a diagonal distribution pattern (with negative ascent). This is however far less well developed than in the correlation diagrams of Al_2O_3 with MgO and Na_2O. The absence of a clearly defined diagonal distribution trend indicates that the incorporation of iron into the emerald/beryl structure does not always follow the 'ideal' substitution reactions (3a) and (3b).

$$(3a)\ Al^{3+,VI} = Fe^{3+,VI}$$

$$(3b)\ Al^{3+,VI} = Fe^{2+,VI} + Me^{1+\ (channel)}$$

The Colombian emeralds with their low iron content (mean concentrations of emeralds from different occurrences <0.3% FeO_{tot}) are placed in the upper left part of the population field.

It is of particular interest that the pegmatite beryls examined by Correia Neves *et al.* (1984) are placed distinctly outside the 'emerald' population field.

3.4 *Correlation diagram Na_2O/MgO*

As can be seen from the data of the chemical analyses of Tables 1-4, magnesium and sodium are the only uni- and bivalent 'extraneous' elements present in higher concentrations in the Colombian emeralds (surely, emeralds from some other localities also contain, in part, higher contents of Fe^{2+}). Structural chemical considerations and the distribution patterns of the representative points in the different correlation diagrams confirm for these two elements the crystallochemical reaction (4).

$$(4)\ Al^{3+,VI} = Mg^{2+,VI} + Na^{1+\ (channel)}$$

The magnesium/sodium incorporation into the emerald/beryl structure follows practically completely this 'ideal' substitution reaction. This is shown by the very clearly developed diagonal distribution pattern (with positive ascent) of the representative points in the correlation diagram Na_2O/MgO (Figure 6).

3.5 *Correlation diagram Na_2O/FeO_{tot}*

The Na_2O/FeO_{tot} correlation diagram (Figure 7) shows a general diagonal distribution trend (with positive ascent) of the representative points, but this is developed less distinctly than we have seen in the correlation diagrams discussed before. This means that the processes controlling the incorporation of the elements iron and sodium into the emerald structure cannot always be directly correlated. Partly, this behaviour goes back to the fact that iron, at least in part, is present in the form of the trivalent ion which needs no charge compensation by sodium when introduced into the emerald structure. On the other hand, it must also be taken into consideration that the incorporation of sodium into emerald is largely controlled by the substitution of aluminium through magnesium.

Because of their low iron and sodium concentrations the representative points for the Colombian emeralds in the Na_2O/FeO_{tot} diagram are restricted to the lower left area of the population field.

3.6 *Correlation diagram FeO_{tot}/MgO*

At first sight the correlation diagram FeO_{tot}/MgO (Figure 8) doesn't show a definite distribution pattern. The variation of the mean magnesium concentrations in emeralds from different occurrences is very strong. On the other hand the mean FeO_{tot} contents are normally less than 1%. The only exception from this behaviour is shown by the samples from the Santa Terezinha de Goiás mining region. A special chemical feature of these emeralds is the poor variation of the (always high) magnesium content in combination with strongly varying iron concentrations (compare Schwarz, 1990).

Of special interest with regard to the chemical differentiation of emeralds on the one hand and pegmatite beryls on the other hand may be the fact that the representative points of the pegmatite beryls from the mining regions of Araçuai-Salinas and Governador Valadares (both in Minas Gerais state, Brazil) are situated completely outside the 'emerald' population field.

The Colombian emeralds are amongst the samples with the lowest iron and magnesium contents so far analysed by the author. Their representative points are placed within the lower left area of the population field in the FeO_{tot}/MgO diagram.

Acknowledgements

The author wishes to thank the following people and institutions for their kind co-operation during the visits to the emerald mines in the Cordillera Oriental, for the donation of material for examination and for making available bibliographic data, maps etc.: Vicente Giordanelli Duran, Adolfo Pacheco Hernandez and Diego Estrada Piedrahita from Ecominas, Jorge Alfonso Cabra Paez and Alvaro Tenjo Gutierrez (Coexminas Ltda.), Wilson

A. Quintero (Minas de Chivor Ltda.), Manuel Rubiano Lamouroux and Rubens D. Llinas Rivera (Universidad National de Colombia), Jaime Barajas B. and Andulfo Cepeda Q., Elizabeth Cortes Castillo (Ingeominas) and Maria A. Delgado Chaparro.

Mr J. Zang and Dr Schulz-Döbrick from the Institute of Geosciences, University of Mainz, kindly gave assistance during the microprobe investigations.

The author is also grateful to the following institutions for financial support and the provision of facilities: German Academic Exchange Service (DAAD), German Agency for Technical Cooperation (GTZ), German Research Association (DFG), and the Fritz Thyssen Foundation.

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[*Manuscript received 14 August 1991*]

Gemmological Abstracts

ANDERGASSEN, W., 1990. Inclusione a piò fasi in un corindone giallo. *La Gemmologia*, **15**, 3/4, 33-5, 4 photos in colour.

A yellow sapphire weighing 2.27ct contained a negative crystal in which liquid CO_2 was identified. The stone was Sri Lankan in origin. M.O'D.

ANDERSON, A.L., 1991. Curves and optics in non-traditional gemstone cutting. *Gems & Gemology*, **27**, 4, 234-9, 8 figs.

This author is getting some attractive effects by combining curved facets with crownless open-table cuts. The pavilion has a combination of large plane facets and curved ones which give a mobile pattern of reflections as the stone is moved. Generally more effective in closed settings and better for large stones of pale to medium colour than for those of deep colour. R.K.M.

BALFOUR, I., 1991. Famous diamonds of the world XLVII - The Centenary Diamond. *Indiaqua Annual 1991*, 255, 4 figs (2 in colour).

The 599 carat rough diamond from the Premier Mine was cut and polished under the supervision of Gabi Tolkowsky to produce a part heart-shaped, part shield-shaped gem of 273 carats which was unveiled at the Tower of London to commemorate the 100th anniversary of De Beers. P.G.R.

BALFOUR, I., 1991. Famous diamonds of the world XLVI - Some notable diamonds in 1990. *Indiaqua Annual 1991*, 251-4, 9 figs (7 in colour).

Contains details of recent diamonds plus new information on older diamonds which has come to light since the author's book *Famous Diamonds* was published three years ago. Recent diamonds include the shield-shaped 89.01 carat 'Guinea Star', a 101 carat pear-shaped stone and an emerald-cut light pink 28.67 carat gem. P.G.R.

BROWN, G., 1992. Trade embargo on coral. *Australian Gemmologist*, **18**, 1, 5-6.

Export and import of native corals is now prohibited in Australia, including black coral harvested since 1981 and some other types since 1990. Precious white, pink and red corallium corals are exempt at the moment and gold and bamboo corals are also excluded from the order. Leaves many non-gem species protected and problems are anticipated when it comes to separating banned species from those which may still be traded. Do not rely on assurances from vendors. R.K.M.

BROWN, G., LINTON, T., 1992. Halogen lamps - a warning. *Australian Gemmologist*, **18**, 1, 2-4, 2 figs.

Tungsten-halogen lamps emit UV light strongly from about 300nm which is passed freely by the quartz glass envelope and can cause serious damage to skin, eyes and other tissues. All such lamps should include lead glass or other filters to eliminate these harmful rays. Photographic filters are less useful since they are damaged by heat. R.K.M.

CASSEDANNE, J.-P., 1991. L'aigue-marine au Brésil. *Revue de Gemmologie*, **108**, 3-7, [second part], 8 photos (3 in colour), 1 fig.

Geological and mineralogical details are given for the more important Brazilian aquamarine gem deposits. Techniques of recovery are described. M.O'D.

CAVENEY, R.J., 1991. De Beers Diamond Research Laboratory Report, Part V: Now for the backroom ... *Indiaqua Annual 1991*, 246, 3 figs.

A 14.2 carat good-quality industrial monocrystal diamond was synthesized at the De Beers Diamond Research Laboratory in Johannesburg. The synthesis took over five hundred hours of high temperature/high pressure running, and required prolonged maintenance of the delicately balanced conditions necessary for successful synthesis. The production of a synthetic diamond of this size is extremely expensive, and would not normally be commercially viable. However, this stone was produced for experimental purposes to test the technology and equipment. The 14.2 carat stone is yellow in colour, a characteristic of synthetics containing nitrogen. Synthetic mono crystals are generally sliced into industrial products and are not suitable for use in jewellery. P.G.R.

Collyer, T., Rodrigues, E.G., Machado, J.I.L., 1991. Das Malachitvorkommen der Serra Verde, Curionopolis, Pará, Brasilien. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 99-102, 2 illustrations (one in colour), bibl.

The malachite is mined in the municipality of Curionopolis in the south-east of Para. It is the first mineable deposit of gem quality malachite in Brazil. Mining is connected with the neighbouring gold deposits and found in hydrothermally formed veins. The material is suitable for cabochons, beads and objets d'art. At times it is found together with chrysocolla and other Cu materials, similar to the 'Eilat' stones. E.S.

Duda, R., Molnar, J., 1992. DieMineralien aus den slowakischen Edelopal-Lagerstätten. *Lapis*, **17**, 4, 23-8, 9 photos in colour, 2 maps.

Details of some of the types of precious and common opal, with brief descriptions of accompanying minerals and general geology are given for the classic Czechoslovakian location of Cervenica-Dubnik. M.O'D.

Ediriweera, R.N., 1991. Scientific Aspects of Geuda Beneficiations. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 149-54, 1 graph, 1 table, 1 diagram, bibl.

Milky-white corundums with a slight yellow or blue hue are named 'geuda' in Singhalese. By heat treatment some of these corundums can be altered to blue or yellow sapphires. The heat treatment dissolves the rutile inclusions and alters the colour-influencing ions. The blue colour is caused by iron-titanium particles with a positive charge of 6, the yellow colour by iron ions with a positive charge of 3, at temperatures between 1600-1850°C. For blue sapphires one requires a reducing, for yellow sapphires an oxidizing atmosphere. The treatment is conditional on the presence of sufficient iron and titanium particles. E.S.

Fryer, C.W., Crowningshield, R., Hargett, D., Moses, T., Hurwit, K., Kane, R.E., 1991. Gem trade lab notes. *Gems & Gemology*, **27** 4, 248-53, 14 figs.

A large (13cm) yellow-brown clinochlore IIb carving was thought to be a Tang Dynasty, Chinese sceptre, about 1200 years old; a green diamond confirmed by uniform colour and spectrum as neutron-treated also had natural radiation burns on the girdle suggesting that it was a pale natural green enhanced by artificial irradiation; a large Oriental brownish-yellow carved hardstone vase with spot RI of 1.74 was grossular, confirmed by X-ray diffraction analysis; a fine green jadeite had heat damage around the girdle after a repair to the ring mount, suggesting that it was waxed - stone should have been removed before using heat; a lapis lazuli with narrow curved banding is described; an X-ray of a 96 carat baroque pearl revealed a large interior cavity partly filled by a small shell bead and cement; fashionable black jewellery is exceeding available black onyx supplies and various substitutes are being offered including a black dolomite/quartz which is illustrated.

An orange-yellow sapphire had no relevant absorption, no reaction to LUV, no pleochroism and a purplish iridescence unknown in sapphire and was identified as a coated stone, soaking in warm HCl removed the colour - other coatings, similar to 'Aqua-Aura', are anticipated; two sapphires with repeated twin layers were thought natural until curved banding and gas bubbles were detected, such twinning, probably due to heating to reduce the banded structure, can be confusing and careful immersed examination of stones is called for. R.K.M.

Garzon Jiménez, J., 1991. Esmeraldas sintéticas e imitaciones. *Boletin del Instituto Gemológico Español*, **33**, 9-29, 76 photos in colour, 8 figs.

The whole field of emerald synthesis and imitation is covered, with many photographs of characteristic inclusions. Those of composite stones are particularly effective. Notes on chemical composition and on infra red spectra are also given. M.O'D.

Godovikov, A.A., Ripinen, O.I., 1991. Wunderschîne Achate von den Fundstellen der Mongolei. *Lapis*, **16**, 12, 35-9, 11 photos (9 in colour).

Among minerals reported from the north-western Gobi, Mongolia, are ornamental quality agates. From the photographs the specimens include a wide range of colours. M.O'D.

Gübelin, E., 1991. Dans la vallee des rubis. *Revue de Gemmologie*, **109**, 7-9, 1 map, 3 photos (1 in colour).

The first part of a review of the ruby deposits of Myanmar (Burma) covering the journey to the site and the area geology. M.O'D.

Gurney, J.J., Levinson, A.A., Smith, H.S., 1991. Marine mining of diamonds off the West Coast of southern Africa. *Gems & Gemology*, **27**, 4, 206-19, 16 figs.

The raised beaches of marine deposits inland in this area have already yielded about 100 million carats of mostly gem quality diamond. Similar deposits are known to exist off-shore and new techniques have been developed to exploit these at depths of up to 100 metres and are expected to increase in yield. The deposits have been swept northward by prevailing coastal currents for millions of years and extend far along the shores of Namibia where they are also exploited under lease mainly by South African based companies. The off-shore leases on the South African coast extend north from a point above Lamberts Bay to the present mouth of the Orange River. These southerly beaches were deposited at a time when that river reached the sea at what is now the mouth of the Olifants River. The source of these stones is the vast Orange River basin which eroded most of the region's known diamond bearing kimberlite pipes some thousand miles to the east over the past millions of years.

Submarine deposits of diamonds in potholes at shallow depths enable them to be worked with vacuum hoses operated by divers, while deposits up to 100 metres deep are vacuumed up by a large machine known [amusingly] as a 'robotic bottom crawler', which can raise up to 100 cubic metres of suspended solids an hour. There is no significant production from deep water yet, but that is expected to change if the Namaqualand (SA) De Beers sampling is successful. These off-shore diamond reserves are probably the largest known - 1.5 billion carats are estimated - but large scale recovery from the sea- bed presents major engineering problems, although prognosis would appear to be good. R.K.M.

HANNI, H.A., 1992. Blue-green emerald from Nigeria. (A consideration of terminology.) *Australian Gemmologist*, **18**, 1, 16-18, 4 figs.

Discusses the distinction between green beryl and blue-green emerald from Nigeria, which contains iron as well as chromium and vanadium, altering the colour from the normally expected green of emerald. Dr Hanni justifies calling these stones by the more prestigious name on several counts. He suggests 'blue-green emerald' is sufficient distinction. R.K.M.

HARDER, H., 1992. Vom Steinbeil bis zur Smaragde - Jade ('Imperial - Jade'). *Aufschluss*, **43**, 65-82, 16 photos (14 in colour).

Despite the title, the paper deals with both jadeite and nephrite, reviewing the colour varieties, mineralogy and substances imitating jade. The imitations are conveniently listed together in a table which gives composition, specific gravity and refractive index. M.O'D.

HENN, U., BANK, H., 1991. Geschliffener, klar durchsichtiger Hackmanit von Mount St. Hilaire in Kanada. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2-3, 93-7, 4 photomicrographs, 1 table, 1 graph, bibl.

The hackmanites were found at Mount St Hilaire in Quebec; the same locality has yielded blue willemite in the past as well as beloeilite, a sodalite with albite and nepheline. The examined ten faceted hackmanites vary in weight from 0.27ct to 31ct. They are Cl-sodalites and show distinctive photochroism. RI 1.485-1.487, SG 2.30- 2.32. E.S.

HENN, U., BANK, H., 1991. Sternbronzit aus Sri Lanka. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 145-8, 2 photomicrographs, (one in colour) 1 graph, bibl.

Bronzite is an orthopyroxene, between enstatite and orthoferrosilite. The star bronzite cabochon from Sri Lanka weighed 0.79ct and showed a six-rayed star caused by needle-like inclusions filled with a liquid. RI 1.680-1.693, DR 0.013, SG 3.41. E.S.

HENN, U., BANK, H., 1992. Examination of an unusual alexandrite. *Australian Gemmologist*, **18**, 1, 13-15, 5 figs.

Underlines problems of distinguishing natural Brazilian alexandrite from the synthetic product since inclusions and growth patterns are similar in each. Present stone was first thought to be synthetic on the evidence of a triangular tabular inclusion. Further investigation by infrared spectrum proved it was genuine, and the inclusion was identified as hematite, typically natural. [Difficult] R.K.M.

HURWIT, K.N., REINITZ, I., MOSES, T., KAMMERLING, R.C., 1991. Untersuchung von Salzwasserzuchtperlen mit künstlichen, farbigen Kernen. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 81-8, 1 photograph, 4 photomicrographs, 4 graphs, bibl.

The nucleus seems to have been produced from powdered oyster shells and an inorganic pigment. The 'beads' are dark grey-green and have a diameter of 8mm. Other pearls were found to have a nucleus of some synthetic substances which started to melt when drilled. Comparative X-rays illustrate the difference. E.S.

Johnston, C.L., Gunter, M.E., Knowles, C.R., 1991. Sunstone labradorite from the Ponderosa mine, Oregon. *Gems & Gemology*, **27**, 4, 220-33, 17 figs.

This mine produces labradorite sunstone in colours ranging from yellow through orange, pink to deep red, with green as the rarest colour. Yield of cuttable quality seems high but much is pale in colour and the best stones are generally small in size. Mining, in summer and autumn only, is open-cast by a small staff using a back-hoe and bulldozer; estimated ore reserves so far mined is 1.5 tonnes; high grade material about 500 grams a day in small sizes. Spangling is due to copper platelets distributed randomly parallel to two possible crystal directions (001) and (010). RIs 1.563-1.572; SG av. 2.71, as expected for labradorite. Ponderosa claims to be the premier location for this type of sunstone. There appear to be considerable reserves. R.K.M.

Kammerling, R.C., Koivula, J.I., Kane, R.E., Fritsch, E., Muhlmeister, S., McClure, S.F., 1991. An examination of nontransparent 'CZ' from Russia. *Gems & Gemology*, **27**, 4, 240-6, 6 figs.

CZ is available in a wide variety of transparent colours and is now coming from Russia in opaque white, pink and black forms, the first two being cabochon cut and marketed as 'Pearl CZ'. Under intense lighting all are to some extent translucent with evidence of a banded or striated growth. Lustre of polished specimens was high and a faceted black stone resembled black diamond. Pink exhibited a fine line spectrum suggesting a rare-earth dopant. RI beyond the range of the refractometer, SG from 5.93 black, to 6.15 pink, probably varying with different stabilizer percentages. R.K.M.

Kammerling, R.C., Koivula, J.I., Weldon, R., 1991. Identificación de ghemas sintéticas fabricadas por fusión a la llama (método Verneüil). *Boletin del Instituto Gemológico Espanol*, **33**, 32-7, 8 photos and 2 figs in colour.

Features of the Verneuil flame-fusion growth process are illustrated and discussed with particular attention paid to inclusions and absorption spectra. The coverage is limited to corundum and spinel. M.O'D.

Kammerling, R.C., Koivula, J.I., 1992. Novel assembled opals from Mexico. *Australian Gemmologist*, **18**, 1, 19-21, 5 figs.

Assembled opal made by part filling cabochon shaped mould with acrylic resin before placing a sliver of black-backed opal face down and completing the filling. Bubbles were apparent in plastic, and viewed from side these looked like triplets. R.K.M.

Kampf, A.R., 1991. Taaffeite crystals. *Mineralogical Record*, **22**, 5, 343-7, 6 photos in colour, 2 figs.

Taaffeite has been reported from five places on earth. Most crystals are pyramidal or bipyramidal and are often truncated by basal pedions. Taaffeite crystals from Sri Lanka (the only ones of gem potential so far found) are most commonly mono-pyramidal (the mineral is hemimorphic). Crystals from the Pitkäranta district, Karelian USSR, are reported to occur as epitactic overgrowths on spinel; bipyramidal crystals from Sianghwaling, China, appear to be twinned by reflection on {0001}. Bipyramidal crystals from eastern Siberia and from Mount Painter, South Australia have not yet been described in detail but may also represent twins on {0001}. M.O'D.

Kohout, K., 1991. Die Mineralien des Hartsteinbruchs Rockenhausen in der Nordpfalz. *Lapis*, **16**, 10, 41-4, 8 photos in colour.

Fine agates and other minerals are found in the Hartsteinbruch area of the German Nordpfalz. M.O'D.

Koivula, J.I., Fryer, C.W., Kammerling, R.C., 1991. Almandine garnet in Montana sapphire. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 89-92, 4 photos, bibl.

Sapphire crystals with a slightly brownish-orange inclusion of almandine garnet are found in Dry Cottonwood Creek in Deerlodge County northwest of Butte in Montana, along the Continental divide. The alluvial corundum found here varies from colourless to yellow, blue, purple and red. They are of gem quality. The host sapphire crystal is yellowish, 3.55ct and measures 9.81 x 9.11 x 3.74mm. The inclusion measures 0.8mm in diameter and is of brownish-orange colour. Identification was made by X-ray diffraction analyses. E.S.

Koivula, J.I., Kammerling, R.C., 1991. Gem news. *Gems & Gemology*, **27**, 4, 254-65, 20 figs.

DIAMONDS

News of diamond cutting in Botswana; a large diamond found in China; proposed diamond cutting in Shanghai. Diamond demand in U.S. remains strong in 1991 exported stones rose 16 per cent, imports also increased; a diamond factory is to open in Dubai for melee up to half carat sizes. General Electric announce synthesis of large carbon-13 crystals, expected to be harder than normal diamond and of exceptional structural perfection suggesting uses for new electronic devices; Indonesian Diamond Corp reports a yield of 1 carat per $10m^3$ of treated gravel with substantial reserves; low-calcium/high- chrome garnet has been used as an indicator of diamond potential in exploration, but the nickel content of high calcium pyrope now seems to be more reliable. Raphaeli- Stschik, Israeli diamond cutters have unveiled their Royal Line diamond cuts - the Duchess, the Baroness and the Empress - reported to take advantage of flatter rough, giving straight-edged well-spread shapes [remarkably similar to the Maico 'Dream-cuts' illustrated in this column in the last issue of *Gems & Gemology*].

COLOURED STONES

A 'hairy bug' in amber is described and illustrated; Czechoslovakian Conference revealed recently discovered ruby deposit north of Magnitogorsk, Russia, high quality expected; synthetic malachite displayed and synthetic opal from Russia discussed. Dr Edward Gübelin has a 'cross' chrysoberyl cat's-eye, the normal eye being crossed by a growth band of different colour; an attractive Tanzanian green diopside is illustrated and described; Mike Ridding draws attention to finds of large emerald and green beryl crystals at Jos, Nigeria, in 1990; demantoid garnets are being mined again in the Urals; yellow manganese garnets are reported from Tanzania and a 23.56ct tsavorite is illustrated. The ban on ivory and tortoiseshell has led to search for suitable substitutes, including 'fossil' mastodon and mammoth tusks and vegetable ivory; 'recycled' ivory was said to be from old tusks but proved to be thin veneers from old piano-keys. Peruvian opal in blue and pink self-colours is coming from a mine near Arequipa - a copper mining area.

A 19th Century chalcedony ring had a sepia portrait of George Washington printed or stained on it by a photographic process.

Five out of six fragmentary rubies bought as natural in Vietnam proved to be synthetic when cut; several instances of synthetics from that country have been reported but these were the first synthetic 'rough' examined; terrorism is hampering exploration in Sri Lanka but good deep red corundum has been found at Hambatota and at Matara; good red star spinels from Ratnapura; yellow-green andradite and sundry colour-change stones and kornerupine and sillimanite also found, cat's-eye kornerupine is becoming scarce.

Intergrowths of sunstone and iolite are reported from India, the iolite usually of the 'bloodshot' type [which I named in 1955]; an update on tanzanite mining reports competition for workable zones over the gem rich area; a pink-yellow bi-colour tourmaline is reported as unusual.

SYNTHETICS AND SIMULANTS

Laser '91 exhibition in Los Angeles included chrome-doped alexandrite, padparadscha colour synthetic corundum, erbium-doped YAG and erbium-doped yttrium lithium fluoride; saturated emerald green YAG doped with chromium, thulium or holmium; chrome-doped LiCaF and chrome-neodymium gallium scandium gadolinium garnet; a star sapphire with a centre void in its star is illustrated.

ENHANCEMENTS

Editors have experimented with Opticon filled cracks in quartz and report all were low relief needing careful microscopy to detect them; dark-field showed characteristic violet/blue flashes, probably the most reliable diagnostic feature. An emerald crystal was found to contain cavernous oil-filled areas; cracks in synthetic emeralds from Swat, Pakistan were filled with a substance which fluoresced strong yellow under LUV; demand for yellow sapphire in Sri Lanka has led to heat treatment of pale stones and the import of synthetic yellows, surface coating with organic compounds, boiling with vegetable dyes which are then covered by wax to defeat the acid immersion test. Pink sapphire is similarly faked; some are chewed with a local berry [betel nut?] and then a cigarette is smoked to improve the colour. Paraiba tourmalines continue to be simulated; Drs Henn and Bank list apatite, irradiated topaz, beryl triplets, tourmaline and glass doublets and blue apatite cat's-eyes all offered as Paraiba tourmalines. R.K.M.

Koshil, I.M., Vasilishin, I.S., Pavlishin, V.I., Panchenko, V.I., 1991. Wolodarsk-Wolynskii: geologischer Aufbau und Mineralogie der Pegmatite in Wolynien, Ukraine. *Lapis*, 16, 10, 24-40, 2 maps, 5 figs, 30 photos (27 in colour).

The pegmatites of the Wolodarsk area of the Ukraine, USSR, are remarkable both for their green (non-emerald), yellow and blue beryl crystals and for equally fine crystals of topaz.

The beryl crystals display characteristic etching. A list of the other minerals found in the area is given with notes on the pegmatites and their formation. M.O'D.

NOACK, R., 1991. Die Achate aus den sekundären Fundstellen der Lausitz. *Lapis*, **16**, 12, 22-4, 1 map, 5 photos in colour.

Fine ornamental agates are found at Lausitz in the eastern part of Germany. The agates are locally known as 'Elbe-agates'. M.O'D.

O'DONOGHUE, M., 1991. Industrial review - Gemstones. *Britannica Book of the Year* 1991, p. 217.

Retail, production and saleroom details of the gemstone market are reviewed with notes on new species and varieties and on further developments in colour alteration and gemstone enhancement. Sales in the retail sector held up reasonably well in the period under review. M.O'D.

OSTROOUMOV, M.N., 1991. L'amazonite. *Revue de Gemmologie*, **108**, 8-12, 1 map, 2 figs, 1 photo in colour.

Occurrences of amazonite throughout the world are reviewed with observations on the cause of colour, ascribed to a colour centre including Pb and Fe ions. M.O'D.

PONAHLO, J., 1991. Diferenciación entre piedras preciosas naturales ysinteticas por catodoluminiscencia. *Boletin del Instituto Gemológico Espanol*, **33**, 47-52, 7 figs in colour.

Cathodoluminescence is advocated as a means of distinguishing between natural and synthetic gemstones. Corundum and chrysoberyl varieties are discussed together with Afghan and Chilean lapis lazuli. M.O'D.

READ, P.G., 1990. The threat of the look-alikes. *Canadian Jeweller*. October 1990, 34, 1 fig.

Although the main thrust of gemmological research is to do with methods of identifying the latest synthetic gem products, and we are alert to the possibility of a synthetic when checking out the potentially more valuable stones, when it comes to the 'semi-precious' materials we may not exercise the same degree of suspicion. The article instances amethyst, and various composite look-alike stones, including garnet-topped doublets (which were still being listed in Swarovski's catalogue in the 1970s). Details of simple identification methods are included. (Author's abstract) P.G.R.

ROBERT, D., 1991. La zircone, pourquoi cubique? *Revue de Gemmologie*, **108**, 14-17, 2 photos in colour, 2 figs.

The relationship between natural monoclinic zirconia and the cubic artificial product is described. M.O'D.

RÖTTERMANN, C., 1991. Argyle Diamonds - Ein australisches Abenteuer. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 155-6.

A short survey of the development and production of the world's largest diamond mine. The Argyle mine, situated in the Kimberley region in the north of Western Australia, is named after an artificial lake nearby. It started full production in 1986 (29.2 million carats) yielding in 1990 35 million carats. 5% are of gem quality, amounting to 3% of world gem production. The best of the gem diamonds are pink and very expensive. 75% of the production is marketed by the CSO. E.S.

SAADI, J.A., 1991. Monumento geológico: diatremas, únicas en el mundo, portadoras de formaciones estalactíticas de rodocrosita. *Boletin del Instituto Gemológico Espanol*, **33**, 38-43, 19 photos in colour, 1 map.

The rhodochrosite mine at Minas Capillita, Andalgala, Catamarca, Argentina, is described with notes on the geology and mineralogy. Photographs graphically illustrate the rhodochrosite occurrence as stalactites. M.O'D.

SCHWARZ, D., 1991. Die chemischen Eigenschaften der Smaragde. III. Habachtal/ôsterreich und Uralgebirge/UdSSR. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **40**, 2/3, 103-43, 12 graphs, 1 table, 2 geological maps, bibl.

The regional, geological and genetic aspects of the Habachtal, Austria, and the Urals, USSR, are discussed, as are the chemical properties of emeralds from both localities. Variations and average concentrations of chromium, iron, magnesium and sodium are analysed. E.S.

SCOVILL, J.A., 1992. The Gillette quarry, Haddam Neck, Connecticut. *Mineralogical Record*, **23**, 1, 19-28, 3 maps, 14 photos (11 in colour).

Gem quality crystals of elbaite and beryl have been recovered over the years from the Gillette quarry, Haddam Neck Connecticut, USA. Prospects for future collecting are not good. M.O'D.

SUN, X.R., 1992. A note on corundum veinlets in rubies from China and Australia. *Australian Gemmologist*, **18**, 1, 22-3, 3 figs.

In rubies from Huo Shan, China and Harts Range, Australia, geological conditions have caused shatter-like cracks which have subsequently been healed by darker corundum infillings, or at a later date by sericite [a fibrous form of mica]. Such inclusions may affect quality and value. R.K.M.

TOWNSEND, I.J., 1992. The Mintabie opalfield. *Australian Gemmologist*, 18, 1, 7-12, 9 figs and map.

A remote area of South Australia 290km from Coober Pedy and 450km from Alice Springs, first discovered about 1920 but too arid (rainfall average 10" per annum) and too difficult of access to be worked seriously until 1976 when bull-dozers and pneumatic drills were brought in. Matrix is a hard quartz sandstone and mechanical open cast mining and explosives are used until opal traces found when hand working is employed. Some Mintabie opal tends to crack if mined from below the water table, shallow drier veins are said to be free from this defect. Since 1985 output, including fine black, has increased dramatically. R.K.M.

TOGNONI, C., 1990. An automatic procedure for computing the optimum cut properties of gems. *La Gemmologia*, 15, 3/4, 23-32, 2 figs.

The optimum ray path inside a simple shaped transparent body is evaluated by an automatic computing method. M.O'D.

TROSSARELLI, C., 1990. Use of the inverted microscope in gemmology. *La gemmologia*, 15, 3/4, 7-21, 2 figs, 24 photos in colour.

Microscopes which display the underside of metallurgical, biological or opaque mineral specimens can be adapted for the examination of inclusions in gemstones. Examples of some uses are given. M.O'D.

WALMSLEY, J.C., LANG, A.R., 1992. Oriented biotite inclusions in diamond coat. *Mineralogical Magazine*, **56**, 108-11, 3 photos, 1 fig.

Coated diamonds have a clear, often gem-quality octahedral core with a coat shell in which the diamond matrix is densely populated by sub-micrometre-size non-diamond bodies. Flakes of brown biotite mica have been discovered in the coat of some diamonds from Zaire, and may have a preferred orientation with biotite (001) parallel to a diamond octahedral plane, for example (111) with diamond [110] parallel to biotite [110] or to an equivalent direction. M.O'D.

WATERMEYER, B., 1990. Colour retention and distribution. *Diamond International*, 4, March-April, 97-101, 4 figs.

Summarizes the principles of the passage and absorption of light in a polished diamond, and outlines the steps which can be taken to solve problems of colour concentration and colour dilution. Taking into account the relationship between colour concentration and the geometry of the stone, it is shown how the quality of colour in a number of diamond cutting styles can be improved. This can result in an upgrade from a normal to a fancy colour. Colour distribution can also be improved; pale stones can be deepened in colour, and darker colours can be enriched by introducing more light. P.G.R.

WEERTH, A., 1991. Neufunde aus dem Himalaya und Karakorum. *Lapis*, **16**, 10, 45-6, 4 photos (3 in colour).

Some recently reported minerals from the Pakistan Karakoram/Himalaya include emerald from Gujar Killi where crystals up to 5cm length have been found; spessartine from Haramosh, hematite from Skardu, epidote from Turmik near Skardu, aquamarine, apatite and herderite from the Dusso area. M.O'D.

YACOOT, A., MOORE, M., 1992. An unusual octahedral diamond. *Mineralogical Magazine*, **56**, 111-13, 6 photos.

A clear colourless diamond weighing 0.35ct showed small dodecahedra on the six vertices of the octahedron and laue pictures showed that the specimen was a single crystal. X-ray topographs show that crystal growth started from an imperfect and highly strained nucleus, growth banding confirms that growth was on {111} planes. A history of the crystal's mode of growth is suggested. M.O'D.

I.C.A. Laboratory Alerts. 1992. *Australian Gemmologist*, **18**, 1, 18.

Valuable warnings of 'Swat emerald rough' which yielded two synthetic cabochon emeralds; synthetic flux-grown red and blue spinels from Sri Lanka; 'Malaya Jade' which is green dyed quartzite; and crackle quenched red-dyed natural corundum which resembles some East African rubies, no trace of chromium spectrum and a yellow fluorescence under LUV betray. R.K.M.

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

OBITUARIES

Denis Inkersole, FGA, for a generation the leading gemmology evening class teacher, died after a short illness on 11 August 1992. Living all his life in the East London borough of Hackney it was fitting that his teaching work took place at what is now the City Polytechnic whose premises are in an adjacent borough.

Born in 1931, Denis took a Higher National Certificate in a variety of subjects but worked mainly as an industrial chemist until the early 1970's when the move of his then employers out of London gave him the chance to set up on his own as a mineral dealer, lapidary and, later on, lapidary teacher. His firm, Mineral Associates, dealt in a wide range of the less expensive but more commercial gem and ornamental minerals and his lapidary work complemented his dealing, using similar species.

As the years went on, however, Denis was increasingly asked to provide faceted and sawn materials for some important commissions; his skills and patience as a lapidary teacher were recognized by other countries and he instituted lapidary classes in more than one. While all this was going on his Polytechnic classes continued in his characteristically chatty and friendly way.

Denis was always ready to take on the bread-and-butter work associated with class teaching and this perhaps unspectacular consistency marked his whole life; outside gemstones he worked with the Scout movement and must have given an inspiring start in life to many boys from a poor area of London.

We extend love and sympathy towards his wife and children who will sadly miss so kind and unassuming a man, as we do. M.O'D.

R.W. (Ron) Yeo, FGA, on Wednesday 26 February 1992 aged 81.

Ron Yeo's career as a jeweller and gemmologist spanned six decades, Ron himself qualifying as a Fellow of the Gemmological Association in 1929, passing with Distinction. Later he assisted I.G. Jardine with his gemmological lectures at Chelsea Polytechnic.

The opening of the Tech. in March 1963. The 'usher' on the right is the late Robert (Bobby) Blott of Waters & Blott; probably at one time the biggest jobbing jewellers around, R.W. worked there for a time.

In the early thirties Ron worked for Barnetts in the Burlington Arcade and later he established his own business in the same arcade.

During the war the business suffered badly when Burlington Arcade was bombed. On 10 September 1940 a 500lb bomb scored a direct hit on the shop. Ron always said that he was the first jeweller in the country to suffer bomb damage. He was always very proud of the fact that he and the staff sorted through the remains of the business and managed to salvage about 40% of the total stock themselves during a 12 week 'sweep up'. Later Ron was in great demand from jewellers elsewhere in the country whose businesses had suffered similar fates during the bombing of provincial towns and cities. His practical advice enabled many to resurrect their companies.

After the war Ron ran two shops in the West End of London and then opened another shop in Burlington Arcade. The Company which bore his name expanded to own a number of businesses from Penzance to London, and is still in existence today with its head office in Exeter.

His passion for gemmology remained with him throughout his life and his lasting legacy is the South Western Trust in Exeter. He started the Trust in 1962 and developed a museum, a gem testing laboratory and a teaching centre. In its own premises near the centre of Exeter, the Trust runs the courses of both the Gemmological Association and the National Association of Goldsmiths.

He is survived by his wife and children and those who knew the larger than life personality of Ron will surely miss him. D.G.

Elma H. Evans, FGA (D.1988), Spring Valley, California, USA, died recently.

Kenneth Holmes, FGA (D.1969), Edgware, died on 31 August 1992.

James Walter Hudspith, FGA (D.1976), Leatherhead, died recently.

Janet A. Marriott, FGA (D.1988), died recently.

Father John W. O'Rourke, FGA (D.1973), Australia, died recently.

GIFTS TO THE GAGTL

The Association is most grateful for gifts of gems and gem materials for research and teaching purposes donated by the following:

Mr L.J. Fifield, FGA, of A. Sechaud & Co Ltd., London for two specimens of synthetic quartz;

John Kessler for emeralds from various localities;

Marcus McCallum, FGA, for spessartine garnet from Namibia;

Elizabeth MacGregor, FGA, of Teresopolis, Brazil, for crystal specimens and gem gravels;

Mrs C.M. Ou Yang, FGA, for peridot from China;

Professor Chen Zhonghui and Vice Professor Yan Weixuan, FGA, for turquoise from China;

Professor Guoping Zhou and Mr Huang Sheng for feldspar (moonstone) and saussurite from China.

MEMBERS' MEETINGS

London

On 22 September 1992 at the Ironmongers' Hall, London EC2, the annual Trade Luncheon was held.

On 30 September 1992 at 27 Greville Street, London EC1N 8SU, the Annual General Meeting of GAGTL was held. A full report will be published in the next issue of *The Journal*.

Midlands Branch

On 25 September 1992 at Dr Johnson House, Bull Street, Birmingham, an Open Forum was held, at which questions were answered by a panel.

North West Branch

On 16 September 1992 at Church House, Hanover Street, Liverpool 1, Adrian Klein gave a talk on emeralds.

GEM DIAMOND EXAMINATION 1992

In the 1992 Gem Diamond Examination 39 candidates sat for the Gem Diamond Diploma examination. Of these 31 (79%) passed, 1 with Distinction. The names of the successful candidates are as follows:

Qualified with Distinction

Tees, Audrey, Glasgow.

Qualified

Argyrakou, Joulia, London.
Baker, Paul Ronald, Ringmer, Lewes.
Barratt, Claire A., Gillingham.
Fromming, David Erwin, Gerrards Cross.
Georgiadou, Elizabeth, London.
Ghisi, Maria K., Athens, Greece.
Hall, David James, London.
Houseago, James A., Lowestoft.
Jordan, Lynn Pamela, Manchester.
Kejriwal, Bindu, London.
King, Margaret A., Scotland.
Levine, Richard John, Leeds.
Lilley, Elaine, London.
Lupton, Elaine, Paddock Wood.
MacLennan, David Jack, Glasgow.
Martin, Julie, Glasgow.
McConnachie, David Charles, Glasgow.
Ng, Soon Hoh, London.
Patel, Jagdish Ishverbhai, Wimbledon Village.
Patel, Pankaj, London.
Pattison, Rebecca Ann, Meopham.
Scott, Michael A., London.
Thatcher, Alison, Woking.
Thomas, Richard, Bridgend.
Vannet, Mary A., Dundee.

MEMBERSHIP '93

The new magazine *Gem and Jewellery News* has been well received by members during 1992. Also many have now taken the opportunity to apply for use of the Coat of Arms or Laboratory logo on their business stationery.

Overseas members benefit from the new arrangements to pay by credit card or sterling draft and will pay less in 1993 than in 1992; also in 1993 their *Journals* will be sent by airmail. All other membership rates are held at 1992 levels, as set out below:

Subscription Rates 1993

	UK	Overseas
Ordinary Member Fellow Diamond Member	£45.00	£65.00
Laboratory Member	£210.00 +VAT	
Gold Laboratory Member	£525.00 +VAT	£525.00

Members, Fellows and Diamond Members receive *The Journal of Gemmology* and the *Gem and Jewellery News* quarterly. Fellows may use FGA after their name and Diamond Members the title DGA, and both may also apply for use of the Coat of Arms on their stationery.

Laboratory Members receive *The Journal of Gemmology* and *Gem and Jewellery News* quarterly, and may apply for use of the Laboratory logo on their business stationery. Gold Laboratory Members may enjoy the benefits of Laboratory Members together with lower fees for diamond reports, assistance with temporary import of stones for testing, and special facilities on pearl and coloured stone reports.

Walter, Keith David, Peebles.
Young, Gabrielle E.M. Wareham.

EXAMINATIONS IN GEMMOLOGY 1992

In the 1992 Examination in Gemmology 515 candidates sat the Preliminary examination, 338 (66%) of whom qualified, 420 candidates sat the Diploma examination and 191 (45%) qualified, 16 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 Michael Tse Kwok Wing from Hong Kong.

The **Anderson/Bank Prize** for the best non-trade candidate of the year in the Diploma examination was awarded to Mr Michael Tse Kwok Wing from Hong Kong.

The **Rayner Diploma Prize** for the best candidate of the year who derives her main income from activities essentially connected with the Jewellery trade, was awarded to Miss Anne Bailey from Rugby, UK.

The **Anderson Medal** for the best candidate of the year in the Preliminary examination was awarded to Miss Sarah Hue-Williams from London, UK.

The **Preliminary Trade Prize** for the best candidate under the age of 21 years on 1st June 1991 who derives his main income from activities essentially connected with the Jewellery trade was awarded to Mr Alexander Hammond from Sandy, UK.

DIPLOMA

Qualified with Distinction

Bailey, Anne Margaret, Rugby.
Beckett, Shona-Maria Ferguson, London.
Boote, Caroline Marguerite Elizabeth, London.
Cheung Chi Ho, Hong Kong.
Dharmaratne, Pannipitiye Gamaathi Ralalage, Colombo, Sri Lanka.
Drowley, Brigitte, London.
Goddard, Valerie J., Alfold.
Grossman, Julie Frances, London.
Kesheng, Chen, Guilin, P.R. China.
Lang, Bernard, Basel, Switzerland.
Magara, Yoshiaki, Fukui Pref., Japan.
Marsh, Leona Claire, Harare, Zimbabwe.
Patel, Rekha Mahesh, Nairobi, Kenya.
Tse Kwok Wing, Michael, Hong Kong.
Tucker, William J., Douglas, Isle of Man.
Tun, Maung Win Myint, Bangkok, Thailand.

Qualified - UK

Balter, Jonathon, London.
Barrie, Lindsay, London.
Bedwell, Victoria Lynsee, London.
Bendel, Helle, London.
Bindon, Julie Ann, Taunton,
Birrell, Andrew Tierney, Edinburgh.
Bradford, Nikki, Hassocks.
Burrow, Denis, Gravesend.
Christian, Helen Elizabeth, Bolton.
Clayton, Josephine A., London.
Cooper, Carolyn, London, England
Day, Brynley John, Oldham.
Downing, Lucy N., London.
Emslie, Gail, Harrogate.
Fox, Rosemary, London.
Gemmell, James, Durham.
Geoghegan, Noel R., Wellesbourne.
Hardeman, Sonia L., Alton.
Harper, Jonathan, London.
Henn, C. John W., Wolverhampton.
Hering, Peter, Cambridge.
Hopper, Geoffrey C., Harrow.
Hughes, Helen, London.
Kneebone, Garfield David, Penzance.
Koetsier, Anya Kristina, London.
Ku, Sarah Joy, London.
Larkins, Barry, London.
Leathley, A.B.D.A., York.
Lodge, Sara Anne-Marie, Birmingham.
Lowe, David J., London.
Ludlow, Andrew Philip, London.
McDonald, Suzanne M., Edinburgh.
McFarlane, Neil R., Alloa.
McQueen, Janet E., Lurgan.
Mildenhall, Caroline, Brighton.
Nandha, Manoj, Nottingham.
Ng, Soon Hoh, London.
O'Brien, Gillian M., North Berwick.
Oldfield, Gemma, London.
Panlilio, Regina S., London.
Patel, Jagdish Ishverbhai, Wimbledon Village.
Prior, Louise Charlotte, London.
Quinton, Sarah, Oxford.
Read, Julian, Goole.
Reffell, Keith C., Rainham.
Sancroft-Baker, Raymond, London.
Spanbok, Gary, London.
Stewart, Robert Miller, Bishops Waltham.
Strachan, Elizabeth, London.
Taylor, David John, Isle of Wight.
Travis, Peter John Booth Charles, London.
Van Papen, Lorraine F.M., Guildford.
Vannet, Mary A., Dundee.
Vaughan, Michael, Chester.
Wakefield, Melanie, Horsham.
Wootton, Angela B., Sheffield.
Wu, Mei Wan, Harlow.

Qualified - Overseas

Alwicher, Terrence, Nijmegen, The Netherlands.
Anantwatanapong, Angkana, Bangkok, Thailand.
Araki, Kazuo, Hyogo Pref., Japan.
Arnau Graus, Concepcion, Barcelona, Spain.
Asanis Nikolaos, Athens, Greece.
Bakker, F.C.S., Zwaagdijk, The Netherlands.
Ball, Pamela, Hong Kong.
Bierlein, Chari L., Paris, Tex., USA
Blanch Papaceit, Gloria, Barcelona, Spain.
Chan Siu Chan, Lily, Canada.
Cheang Chong Nun, Macau, China.
Cheng Chi Chung, Hong Kong.
Cheng Sau Chun, Hemans, Hong Kong.
Cheung, Liann, Mei Ping, Hong Kong.
Cho, Hang Sun, Daejon, Korea.
Chow, Kenickie Tze Joak, Hong Kong.
Chow Chun Hung, William, Hong Kong.
Chow Shui Wah, Hong Kong.
de Gruyter, Barbara, Houwaert, Belgium.
de Jongh, Laurentia Melissa, Den Haag, The Netherlands.
De La Torre Lopez, Luisa, Tarragona, Spain.
de Ruiter, J.E., Waddinxveen, The Netherlands.
de Wit, Lambertus, Den Haag, The Netherlands.
Deraniyagala, Isanth R., Colombo, Sri Lanka.
Dharmaratne, Rosemary Olivia, Colombo, Sri Lanka.
Eguchi, Yukio, Osaka, Japan.
Engel, Nora, Geneva, Switzerland.
Falco Rovira, Joaquim, Llanca, Spain.
Friedland, Melissa R., Omaha, Nebr., USA
Galopim De Carvalho, Rui, Portugal.
Groeneveld, Pauline, Giessenburg, The Netherlands.
Haberli, Sabine Maya, Bottmingen, Switzerland.
Harjula, Katri, Helsinki, Finland.
Harman, Bronwen, Brisbane, Australia.
Hawrelko, Donna P., West Vancouver, Canada.
Ho Po Mi, Avis, Hong Kong.
Hoso, Sadayuki, Osaka, Japan.
Hui Chak Lun, Hong Kong.
Hwang, Mi Hee, Daejon, Korea.
Jayasekera, M.C. de S., Negombo, Sri Lanka.
Jewitt, Laura Kathleen, Vancouver, Canada.
Kang, Hyun Sook, Daejon, Korea.
Kariya, Tomoko, Tokyo, Japan.
Karkkainen, Niilo, Espoo, Finland.
Karlsson, Andreas, Lannavaara, Sweden.
Khudhairy-Gaylani, Bann, Toronto, Canada.
Kim, Gum Jo, Pusan, Korea.
Kim, Hei Jong, Seoul, Korea.
Kim, Jong Pil, Seoul, Korea.

Kim, Sang-Ki, Seoul, Korea.
Klumpes, Eric, Veere, The Netherlands.
Ku Kai Leung, Hong Kong.
Kuwahara, Rie, Hong Kong.
Kwong Yi Hang, Agnes, Hong Kong.
Lai Sai Mui, Hong Kong.
Lau, Grace Tin-Kwan, Richmond, Canada.
Lau, Ying Chi, Hong Kong.
Lau Sau-Kuen Heddy, Hong Kong.
Lau Yuen Mee, Hong Kong.
Lee, Du Hee, Seoul, Korea.
Lee, Hyeon Jin, Inchon, Korea.
Lee Siu Yin, Ann, Hong Kong.
Leung Chee Wing, Hong Kong.
Leung Lai Ping, Florence, Hong Kong.
Li Chi Man, Hong Kong.
Lum Yin Kew, Samantha, Singapore.
Matsumoto, Naoko, Chicago, Ill., USA
McCrary Weinberg, Dianna, Madrid, Spain.
Mollari, Seppo, Lannavaara, Sweden.
Nakamura, Haruji, Kyoto, Japan.
Ng Hung Lai, Floria, Hong Kong.
Ng Kwok Yin, Hong Kong.
Nishimura, Tadahiro, Osaka, Japan.
Ohira, Shino, Japan.
Park, Kyung Ok, Seoul, Korea.
Pawlyna, Andrea G., Hong Kong.
Peh, Angeline, Hong Kong.
Quek Cho Siang, Jessie, Hong Kong.
Ramboarison, Anita, Hong Kong.
Ravona, Haim, Hadera, Israel.
Rubio Barris, Ignasi, Olot, Spain.
Safar, Ali Mohd, Bahrain.
See Yat Sun, Hong Kong.
Serra Molla, Clara Ma, Valencia, Spain.
Sharma, Kul Bhushan, Lusaka, Zambia.
Siew Lai Ngoh, Georgette Williams nee, Kuala Lumpur, Malaysia.
Siu Wai-Chung, Norman, Hong Kong.
Slui, C., Krimpen A/D Ijsse, The Netherlands.
So Ying Yin, Hong Kong.
Sohn, Jeong Sun, Seoul, Korea.
Takarada, Michiko, Tokyo, Japan.
Tanaka, Mariko, Hyogo Pref., Japan.
Te Velde, Maja C., Langerak, The Netherlands.
Thorbjornsen, Bjorn Tore, Bergen, Norway.
Torregrosa Guirao, Inocencia, Guardamar Del Segura, Spain.
Trathen, John E., Stoney Creek, Canada.
Tse On Na, Anna, Hong Kong.
Tsui, Vincent Kam Luen, Hong Kong.
Van Hillo, G.J., Almere, The Netherlands.
Van Keulen, Simone, Amsterdam, The Netherlands.
Van Lamoen, H.T., Rosmalen, The Netherlands.
van Soest, Ingrid, Hoofddorp, The Netherlands.
Weissenborn, Maria, Den-Bosch, The Netherlands.
Wijne, Lieke, Schoonhoven, The Netherlands.
Winkelmolen, Karin, Beesel, The Netherlands.
Wong, Queenie, Hong Kong.
Wong Miu Wan, Mueller, Hong Kong.
Yabin, Zhang, Harbin, P.R. China.
Yamagami, Mayumi, Tokyo, Japan.
Yamamoto, Atsuko, Hyogo Pref., Japan.
Yu, Frankie, Sum-Pui, Hong Kong.
Yu Yim Tong, Hong Kong.
Yuen Chai Hung, Teresa, Hong Kong.
Yumoto, Atsuko, Osaka, Japan.
Yung Tak Yi, Hong Kong.
Zaveri, Pragnesh H., Bombay, India.
Zhao, Liu, Harbin, P.R. China.
Zinzuvadia, Jaydeep Amritlal, Bombay, India.

PRELIMINARY

Qualified - UK

Bastians, Anthony, London.
Bawden, Karen Alison, Weston-Super-Mare.
Beckett, Shona-Maria Ferguson, London.
Bertorelli, Andrea Elsbeth Louisa, London.
Bladbjerg, Tine, Rochester.
Boote, Caroline Marguerite Elizabeth, London.
Boulding, Philip, London.
Boyd, Derek Stephen, Didsbury.
Brown, Elizabeth, Lindford.
Campbell Pedersen, Maggie, Chiswick.
Carson, Michael Joseph, Boston.
Chambers, Jenny Lisa, Warwickshire.
Clay, Gretchen Fleur, Boston.
Close, Helen Jane, Selby.
Cook, Bridget Rosemary Tomlin, Brighton.
Cook, Stewart, Maidstone.
Cooper, Simon Paul, Hadfield via Hyde.
D'Arcy-Evans, Julie Anne, Little Chalfont.
Dale, Sharon Jean, Sutton.
Daniels, Razia, Chester.
Davidson, Clare Jane, Newcastle-upon-Tyne.
Day, James, Royal Tunbridge Wells.
de Villiers, Patricia Aileen, London.
Dinnis, Simon John, Burton on Trent.
Donkin, Jeffrey John, Surbiton.
Drowley, Brigitte, London.
Earby-McFarlane, Iain Scott, Chesham.
Fielding, Catherine, Avon.
Forrest, Jacqueline Alison, Bishopsbriggs.
Fox, Nigel Timothy, Leeds.
Fox, Rosemary, London.
Godfrey, Irmfried Adelheid, Glasgow.
Goliama, Teddy Francis, London.
Graham, Jennifer J., Glasgow.
Green, Kimberly Helen, Melton Mowbray.
Grossman, Julie Frances, London.

Gunnigan, Jane Carmel, Dartford.
Haddock, Brendan, Edinburgh.
Hammond, Alexander Malcolm, Sandy.
Hanna, Margaret Ann, London.
Hardeman, Sonia L., Alton.
Hardman, Joyce, Preston.
Harper, Jonathan, London.
Hawes, Rona Margaret, Redhill.
Hue Williams, Sarah Georgina, London.
Humphrey, Mary Sylvia, London.
Jarek, Raymond Vincent, London.
Johnson, Philip, Pensby.
Joly, Sandra Elizabeth, Rochester.
Jones, Amanda Melanie, Stourbridge.
Jones, Jason, Hull.
Joseph, Denise Taouk, London.
Jozwiak, Samantha Jane, London.
Kassam, Sultan Mohammed, London.
Kennedy, Lisa, Cambridge.
Kimber, Sarah, Aldershot.
Knowles, Louise Carole, Chatburn.
Kumar, Visuvalingam Krishna, Morden.
Lakhtaria, Yashwin, London.
Linde, Pamela A., Crewe.
Livingstone, Sheena, Dundee.
Lu, Jei-Chih, London.
Lysons, Jon David Eric, Sunderland.
MacKenzie, Hilary Morag, Greenock.
Martin, Jennifer Frances, Hanham.
Massow, Kenneth John, Rochford.
McCarthy, Emily, London.
McCormack, Susan, Aintree.
McLean, Grace Lesley, Dundee.
McNally, Angela, Edinburgh.
Misk, Mirna, London.
Molyneux, Peter Jeremy, York.
Morris, Patricia Elizabeth Jane, Crewe.
Nicholson, Charles James Rupert, London.
Nicoll, Douglas John, East Lothian.
O'Connell, Helen Maree, Kingston.
Orner, Miri, London.
Ozlati, Kathryn, Northampton.
Panlilio, Regina S., London.
Phillips, Lisa Wendy, South Harrow.
Pout, Margaret Elizabeth, Guildford.
Raphael, Menachem, Leeds.
Reilly, Clare, Sutton Coldfield.
Ritchie, Susan Jennifer, Edinburgh.
Roberts, Keri Jane, Radstock.
Rodrigues, Lourdes, London.
Saccoh, Boulaye Doughan, London.
Sagir, Yoram, Hendon.
Sandum, Mark Antony, Ramsgate.
Saunders, Frank, Spennymoor.
Saxton, Carol Anne Lesley, Alton.
Slater, Richard Mark, Bath.
Smith, Penelope Ann, Cirencester.
Sokhal, Jaswender, Staffordshire.
Sondack, Julia Ruth.
Spicer, Alison Joy, Chester.
Stapenell, Julia Carol, Birmingham.
Starkey, Julia Ruth, Burnham.
Taylor, Christopher, Staines.
Terras, Fay, Newton Abbot.
Thompson, Graham, Grimsby.
Thompson, Jane Margaret Devereux, Melton.
Thomson, Joanne Lesley, Peebles.
Turner, Stephen Jeffrey, Glasgow.
Wadia, Aneeta, London.
Wakefield, Melanie, Horsham.
Walker, Averil Lorraine, London.
Wiley, Christopher, Banstead.
Wilkinson, Cleotilde Socorro, London.
Windwick, William, Moray.
Withers, Justine Marguerite, Redhill.
Yasin, Abdel Nasser, St. Albans.

Qualified - Overseas

Adamali, Kunj, Nairobi, Kenya.
Alaniva, Orvokki, Kannonkoski, Finland.
Alteen, Michael Louis, Sydney, Nova Scotia, Canada.
Anandarajah, Dr Kandiah, Toronto, Canada.
Anantwatanapong, Angkana, Bangkok, Thailand.
Antzoulakos, George, Athens, Greece.
Astrom, Mikko Tapani, Helsinki, Finland.
Bandara, Rupasingha Mudali Navaratna, Sri Lanka.
Bartfai, Tunde, Schoonhoven, The Netherlands.
Batis, David, Athens, Greece.
Beili, Zhang, Hubei, China.
Berruex, Cedric, La Chaux-de-Fonds, Switzerland.
Bevers-Reinders, L.M., Rotterdam, The Netherlands.
Blorstad Pedersen, Berit, Oslo, Norway.
Bombeke, Sonja, Bergambacht, The Netherlands.
Boyens, Christine Patricia, Hong Kong.
Brom, Reinier, Wassenaan, The Netherlands.
Buxani, Naina Mahesh, Hong Kong.
Cham Wai Hing, Hong Kong.
Chan, Shuk Yu, Hong Kong.
Chan Ka Fung, Louisa, Hong Kong.
Chan Mei Wah, Carol, Hong Kong.
Chan W.K., Sunny, Hong Kong.
Chansrichawla, Luxmi, Bangkok, Thailand.
Chedta-Thaiyawong, Kanitha, Bangkok, Thailand.
Cheng, Chi Chung, Hong Kong.
Cheng, Sau Chun, Hemans, Hong Kong.
Cheung, Chi Keung, Hong Kong.
Cheung, Shuk Mei, Hong Kong.

Cho, Jin-Ho, Seoul, Korea.
Choi, Eun-Young, Busan, Korea.
Choi, Gyeng Hye, Seoul, Korea.
Chokhani, Durga Vishwanath, Bombay, India.
Chow Wing Yuen, Hong Kong.
Choy, Wai Ping, Daisy, Hong Kong.
Chui, Wai Chun, William, Hong Kong.
Chung, Young Hee, Seoul, Korea.
Coughlin, Donald George, Colombo, Sri Lanka.
de Groot-van der Ham, L., Utrecht, The Netherlands.
de Gruyter, Barbara, Houwaert, Belgium.
de Wit, Lambertus, Den Haag, The Netherlands.
Del Barrio Lazaro, Pedro A., Valencia, Spain.
Dimitropoulos, Kostas, Athens, Greece.
Duigan, Ingeborg, Hong Kong.
Durand, Douglas D., Toronto, Canada.
Eames, Lucy, Nairobi, Kenya.
Eetgerink-Hamel, Martien, Abcoude, The Netherlands.
Ettila, Annamari, Helsinki, Finland.
Farnsworth, Colleen, Hong Kong.
Farrimond, Thomas, Cambridge, New Zealand.
Fok, David, Hong Kong.
Fowle, Michael John, Nairobi, Kenya.
Fung Lai Yi, Hong Kong.
Garcia Garcia, Amelia, Valencia, Spain.
Garcia Moreno, Pedro, Valencia, Spain.
Gemin Cherkaoui, Nadine, Indonesia.
Goyal, Hariprasad, Jaipur, Rajasthan, India.
Granlund-Jarvinen, Ingalill Maria, Kasnas, Finland.
Griffiths, Mary, Canada.
Grimster, Melanie, Toronto, Canada.
Halme, Sini Pirjetta, Lahti, Finland.
Hamza, Mohamed Hassan Mohamed, Kandy, Sri Lanka.
Hawrelko, Donna P., West Vancouver, Canada.
Higo, Kenji, Osaka, Japan.
Hong, Suk, Seoul, Korea.
Hui, King Chuen, Hong Kong.
Hui Wing Chiu, Ernest, Hong Kong.
Hung, Suet Fung, Josephine, Hong Kong.
Hung Ching Ting, Hong Kong.
Im, Sung-Sik, Seoul, Korea.
Jang, Young-Rim, Seoul, Korea.
Jayarajah, Aravandy Pillai, Colombo, Sir Lanka.
Jegge, Erich Peter, Zurich, Switzerland.
Jeong, Hyun Hee, Daejon, Korea.
Jeong, Seok-Ran, Busan, Korea.
Jewitt, Laura Kathleen, Vancouver, Canada.
Jin, Soo Eun, Seoul, Korea.
Jingzhi, Li, Hubei, China.
Joo, Woong-Hyun, Seoul, Korea.
Ju, Young Ok, Pusan, Korea.
Jun, Huang, Hubei, China.
Kandamulla, Anuruddhika Priyadarshani, Colombo, Sri Lanka.
Kang, So Yean, Daejon, Korea.
Karlsson, Andreas, Lannavaara, Sweden.
Kauppinen, Sirpa, Helsinki, Finland.
Kelloniemi, Katri Irene, Helsinki, Finland.
Kervezee, Robert Louis, Berkel-Rodenrijs, The Netherlands.
Kiji, Michio, Osaka, Japan.
Kim, Gye Hong, Daejon, Korea.
Kim, Kyoung-Soo, Taegu, Korea.
Kim, Kyung Sook, Pusan, Korea.
Kim, Meong Hee, Kyunggi-do, Korea.
Kim, Mi Jung, Pusan, Korea.
Kim, Mi-Ae, Busan, Korea.
Kim, Taek Joong, Seoul, Korea.
Kim, Young Ju, Daejon, Korea.
Kinda, Yumiko, Osaka, Japan.
Ko, Kyung Hai, Seoul, Korea.
Kostovetsky, Evgeny, Toronto, Canada.
Krommenhoek, Celine Coaine, Amsterdam, The Netherlands.
Ku Kai Leung, Hong Kong.
Kuosmanen, Jussi Tapio, Vantaa, Finland.
Kuwahara, Rie, Hong Kong.
Kwan Wai Shun, Hong Kong.
Kwong Yi Hang, Agnes, Hong Kong.
Lam Tai Sing, Denys, Hong Kong.
Lanko, Jantine, Amsterdam, The Netherlands.
Lau, Chung Long, Hong Kong.
Lau, Grace Tin-Kwan, Richmond, Canada.
Lau, Paul, Hong Kong.
Lau, Teresa Sauwan, Hong Kong.
Lau Kit Yee, Kitty, Hong Kong.
Lau Yuen Mee, Hong Kong.
Lee, Eun-Ju, Busan, Korea.
Lee, Gang-Ho, Daejon, Korea.
Lee, Heui-Yeol, Chung Cheong nam-do, Korea.
Lee, Hye-Jeong, Seoul, Korea.
Lee, Jin Ah, Daejon, Korea.
Lee, Jum Sook, Pusan, Korea.
Lee, Mi Kyung, Seoul, Korea.
Lee, Moung-Hee, Seoul, Korea.
Lee, Nam Joo, Seoul, Korea.
Lee, Sang Yen, Daejon, Korea.
Lee, Tonny Song, Taipei, Taiwan, China.
Lee Siu Yin, Ann, Hong Kong.
Leung, Irene Yuk Ping, Hong Kong.
Lie, Torgunn, Oslo, Norway.
Lo, Teresa K.Y., Toronto, Canada.
Lo Shuk Lan, Hong Kong.
Lum Yin Kew, Samantha, Singapore.
Lundsrud, Berit, Sandvika, Norway.
Ma Siu Lam, Hong Kong.
Mathiopoulou, Regina Moser, Athens, Greece.
Mathon, Andries Peturs Theresia, Ammerstol, The Netherlands.
Meerdink, Handrika Catharina, Aalten, The

Netherlands.
Metzidie, Vassiliki, Athens, Greece.
Michaelides, Maria, Athens, Greece.
Mitchell, Gisela Charlotte, Hong Kong.
Miyamoto, Kiyomi, Osaka, Japan.
Mollari, Seppo, Lannavaara, Sweden.
Mommers, Ilse, Oss, The Netherlands.
Nadarajah, Veeragathy, Colombo, Sri Lanka.
Nakagawa, Yuko, Toronto, Canada.
Nam, Song-Ja, Daejon, Korea.
Nayer, Kuldeep Singh, Nairobi, Kenya.
Nayer, Ranjit Kaur, Nairobi, Kenya.
Ng Sau Lan, Annie, Hong Kong.
Ng, Siu-Ling Brenda, Hong Kong.
Niblock, Simon Guy, Whakatane, New Zealand.
Nissila, Ari Jukka, Oulu, Finland.
Odawara, Hiroko, Osaka, Japan.
Oele, Kees, Schoonhoven, The Netherlands.
Oey M.D., W.S., Z.O. Beemster, The Netherlands.
Oh, Sook-Hoe, Busan, Korea,
Orrite Jimenez, Paquita, Valencia, Spain.
Palme, Martina, Stockholm, Sweden.
Park, Han-Jin, Daejon, Korea.
Pattni, Mamta C.G., Nairobi, Kenya.
Perera, C.S.A., Colombo, Sri Lanka.
Pervolaraki, Anna, Athens, Greece.
Puhakainen, Petter Juhana, Helsinki, Finland.
Punchihewa, Yohan Laksiri, Colombo, Sri Lanka.
Ramboarison, Anita, Hong Kong.
Ranasinghe, Ranasinghe Liyanage D.S., Sri Lanka.
Romero Paya, Oscar, Valencia, Spain.
Roos, Stephan, Bienne, Switzerland.
Roubin, Ernest, Athens, Greece.
Rouleau, Jocelyne, Quebec, Canada.
Ruts, Willem Gerardus, Den Helder, The Netherlands.
Sagiv, Lihi, Hong Kong.
Schembri, Joseph Michael, Toronto, Canada.
Schuivens, Chantalle, Geleen, The Netherlands.
Sharma, Rashmi, Lusaka, Zambia.
Shouguo, Guo, Hubei, China.
Siew Lai Ngoh, Georgette Williams nee, Kuala Lumpur, Malaysia.
Sillanpaa, Heli Marianne, Kaustinen, Finland.
Silvonen, Nanna Kaarina, Helsinki, Finland.
Sivakumar, Periyasamy, Colombo, Sri Lanka.
Song, Kyong-Mi, Seoul, Korea.
Sorensen, Torfinn, Lannavaara, Sweden.
Stahl, Elone, Lannavaara, Sweden.
Stratmann, Rudolf Walter, Den Haag, The Netherlands.
Suh, Dae-Yeol, Seoul, Korea.
Suhaib, M.H.M., Colombo, Sri Lanka.
Summanen, Sari Irene, Helsinki, Finland.
Sÿren, Riitta Anneli, Tampere, Finland.
Taeed, Amelia, Apeldoorn, The Netherlands.
Tai Yuet Wan, Hong Kong.
Takahashi, Masumi, Hong Kong.
Takarada, Michiko, Tokyo, Japan.
Tanabe, Hiroko, Toronto, Canada.
Tanaka, Kazuhide, Osaka, Japan.
Tarkkanen, Mika, Helsinki, Finland.
Toft, Peter Christian, Copenhagen, Denmark.
Tonn, Heleen, Rotterdam, The Netherlands.
Trifaud, Guillaume Nicolas, Bangkok, Thailand.
Tse Siu Ling, Hong Kong.
Tsui, Vincent Kam Luen, Hong Kong.
Tun, Maung Win Myint, Bangkok, Thailand.
Tuovinen, Annikki, Aanekoski, Finland.
Tzerbou, Helen, Athens, Greece.
Vader, Leonoor, Den Haag, The Netherlands.
Valk, Bert-jan, Schoonhoven, The Netherlands.
van Gils, Heleen, Overveen, The Netherlands.
van Vliet, Wim, Haastrecht, The Netherlands.
Vinkka, Susanna, Hameenlinna, Finland.
von Redlich, Anna Britta Andrea, Den Haag, The Netherlands.
Vreeling, Jacqueline, Schoonhoven, The Netherlands.
Wilcox, Kimberly Anne, New York, USA.
Wong, Queenie, Hong Kong.
Wong Chi Wing, Hong Kong.
Wong Chun Kwong, Hong Kong.
Wong Lai Fun, Alice, Hong Kong.
Wong Nim Chi, Phyllis, Hong Kong.
Xianfeng, Zhang, Hubei, China.
Yamasuga, Ryoji, Hyogo Pref., Japan.
Yan, Gao, Hubei, China.
Yan, Kam Tim, Hong Kong.
Yang, Hye Keong, Pusan, Korea.
Yip Man Loong, Hong Kong.
Yun, Sun-Whoa, Seoul, Korea.
Zaveri, Pragnesh H., Bombay, India.
Zhang Ziang Dong, Hong Kong.
Zhi, Zhan, Hubei, China.
Zinzuvadia, Jaydeep Amritlal, Bombay, India.

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held on 20 May 1992 at Chapel House, Hatton Place, London ECIN 8RX, the business transacted included the election of the following:

Fellowship
Flint, Sara E., Leeds. D.1991

Ordinary Membership
Almudallal, Mohammad, Abu Dhabi, UAE.
Bosey, Pauline M., Eton.
Dansereau, Eva M., Anola, Manitoba, Canada.
Fricker, Rowena, Dulwich, S Australia.

Jones, Michael, Bournemouth.
Mifsud, Ivan, Sliema, Malta.
Nilaratanakul, Chiraphong, Bangkok, Thailand.
Pash, A., London.

Laboratory Membership
Nash Broad Wesson, 42 Upper Berkeley Street, London WlH 8AB.

At a meeting of the Council of Management held on 24 June 1992 at Chapel House, Hatton Place, London ECIN 8RX, the business transacted included the election of the following:

Ordinary Membership
Quinton, Sarah E., Byfield. 1992
Read, Julian, Goole. 1992
Sancroft-Baker, Raymond, London. 1992

Ordinary Membership
Ayles, Catherine, Edinburgh.
Branch, John Robertson, London.
Goh, Kok Chin Eric, Kuala Lumpur, Malaysia.
Hanna, David Mark, Inverness.
Jarek, Raymond Vincent, London.
Jindrich, Patricia Lynn, Trevor, USA.
McCormack, Susan, Liverpool.
Ronnie, Brenda, Leith, Edinburgh.
Saxton, Carol Anne Lesley, Alton.

Transfers to Fellowship and Diamond Membership
Barratt, Claire, Gillingham. 1992 (FGA, DGA)
Beckett, Shona-Maria F., London. 1992 (FGA)
Bendel, Helle, London. 1992 (FGA)
Blanch, Gloria, Barcelona, Spain. 1992 (FGA, DGA)
Boote, Caroline Margaret, London. 1992 (FGA)
Bradford, Nikki, Hassocks. 1992 (FGA)
Burrow, Denis, Gravesend. 1992 (FGA)
Day, Brynley John, Oldham. 1992 (FGA)
Drowley, Brigitte, London. 1992 (FGA)
Fox, Rosemary, London. 1992 (FGA)
Fromming, David Erwin, Gerrards Cross. 1992 (FGA, DGA)
Galopim de Carvalho, Rui, Portugal. 1992 (FGA)
Gemmel, James, Durham. 1992 (FGA)
Georgiadou, Elizabeth, London. 1992 (FGA, DGA)
Ghisi, Maria, Athens, Greece. 1992 (FGA, DGA)
Goddard, Valerie J., Alfold, Cranleigh. 1992 (FGA)
Grossman, Julie Frances, London. 1992 (FGA)
Hardeman, Sonia L., Alton. 1992 (FGA)
Harper, Jonathon, London. 1992 (FGA)
Hering, Peter, Cambridge. 1992 (FGA)
Houseago, James A., Lowestoft. 1992 (FGA, DGA)
Jordan, Lynn Pamela, Manchester. 1992 (FGA, DGA)
Kejriwal, Bindu, London. 1992 (FGA, DGA)
King, Margaret, Scotland. 1992 (FGA, DGA)
Kneebone, Garfield David, Penzance. 1992 (FGA)
Koundouros, Radka Lalovaska, Athens, Greece. 1992 (FGA, DGA)
Larkins, Barry, London. 1992 (FGA)
Lilley, Elaine, London. 1992 (FGA, DGA)
McConnachie, David Charles, Glasgow. 1992 (FGA, DGA)
McFarlane, Neil R., Alloa. 1992 (FGA)
Mildenhall, Caroline, Brighton. 1992 (FGA)
Ng, Soon Hoh, London. 1992 (FGA, DGA)
O'Brien, Gillian M., North Berwick. 1992 (FGA)
Oldfield, Gemma, London. 1992 (FGA)
Patel, Jagdish, Wimbledon Village. 1992 (DGA, FGA)
Patel, Pankaj, London. 1992 (FGA, DGA)
Prior, Louise Charlotte, London. 1992 (FGA)
Sergoulopoulos, Alexandros, Athens. 1992 (FGA, DGA)
Stather, Memory, Hong Kong. 1992 (FGA, DGA)
Stewart, Robert Miller, Bishops Waltham. 1992 (FGA)
Taylor, David John, Isle of Wight. 1992 (FGA)
Tees, Audrey, Glasgow, 1992 (FGA, DGA)
Travis, Peter J.B.C., London. 1992 (FGA)
Tucker, William J., Isle of Man. 1992 (FGA)
Van Papen, Lorraine, Guildford. 1992 (FGA)
Vaughan, Michael, Chester. 1992 (FGA)
Wakefield, Melanie, Horsham. 1992 (FGA)
Walter, Keith David, Peebles. 1992 (FGA, DGA)
Wu, Mei Wan, Harlow. 1992 (FGA, DGA)
Young, Gabrielle, Wareham. 1992 (FGA, DGA)

Gold Laboratory Membership
William Goldberg Diamond Corp. of 589 Fifth Avenue, NY, USA.

At a meeting of the Council of Management held on 23 September 1992 at 27 Greville Street, London ECIN 8SU, the business transacted included the election of the following:

Fellowship and Diamond Membership
Osborne, Sean J., Pimlico, London. 1989/1990.
Vannet, Mary A., Dundee. 1992
Webster, David E., Glasgow. 1988/1989

Fellowship

Bae, Sang-Duk, Seoul, Korea. 1991
Bindon, Julie A., Taunton. 1992
Christian, Helen E., Bolton. 1992
Coffin, Martin R., Carlisle. 1984
Hopper, Geoffrey C., North Harrow. 1992
Hughes, Helen Sylvia, London. 1992
Ku, Kai Leung, Hong Kong. 1992
Kwong Yi Hang, Agnes, Hong Kong. 1992
Lau, Grace Tin-Kwan, Richmond, Canada. 1992
Lodge, Sara, Birmingham. 1992
Jehu, A.G., Virginia Water.
Jones, Lloyd E., Gold Coast, Australia.
Kiernan, Janeien E., Cheddar Gorge.
Porter, Mark A., Hartley Wintney.
Sandy, Paul R., Bournemouth.
Smith, Richard S.N., Exmouth.
Van't Hooft, Jacobus A., Uught, The Netherlands.

Gold Laboratory Membership
Arthur Langerman, 62 Pelikaanstraat, 2018 Antwerp, Belgium.
Laboratory Membership
Andrew Diamonds Ltd, 11 Hatton Garden, London ECIN 8HA.
Ruppenthal (UK) Ltd, 3rd Floor, 20-24 Kirby Street, London ECIN 8TS.

At a meeting of the Council of Management held on 22 July 1992 at Chapel House, Hatton Place, London EC1N 8RX, the business transacted included the election of the following:

Fellowship
Tan, Ay Lin, Singapore. 1991

Ordinary Membership
Benjamin, Ronald, London.
Lai, Tai, Taiwan.
Passmore, Elizabeth Louise, Manchester.
Zagari, Paola, Italy.

Laboratory Membership
George Diamonds, L.D.B., 100 Hatton Garden, London EC1.
Lawrence Henry, 67 Clerkenwell Road, London EC1R 5BH.

At a meeting of the Council of Management held on 19 August 1992 at 27 Greville Street, London EC1N 8SU, the business transacted included the election of the following:

Diamond Membership
Scott, Michael A., Harpenden. 1992
Thomas, Richard, Bridgend. 1992

Fellowship
Bailey, Anne Margaret, Rugby. 1992
Carter, Angela Beverley, Sheffield. 1992
Fernandes, Shyamala, Jaipur.
Foo, Pui Man, Hong Kong. 1991
Geoghegan, Noel Richard, Wellesbourne. 1992
Henn, Christopher, J.W., Shropshire. 1992
Leathley, Adam B.D.A., Shiptonthorpe. 1992
Ludlow, Andrew Philip, Buckhurst Hill. 1992
McQueen, Janet E., Lurgan, Co. Armagh. 1992
Lowe, David J., Blackheath. 1992
McDonald, Suzanne M., Edinburgh. 1992
Nandha, Manoj, Nottingham. 1992
Ng, Hung Lai, Hong Kong. 1992
Pawlyna, Andrea G., Hong Kong, 1992
Ramboarison, Anita, Hong Kong. 1992
Reffell, Keith C., Gillingham. 1992
Thompson, Hugh D.R., Quebec, Canada. 1979
Webb, Malcolm H., Chatham. 1954

Ordinary Membership
Brown, Elizabeth A., Lindford.
David, Ian, London.
Einstein, Tamar S., Haifa, Israel.
Farrimond, Thomas, Cambridge, New Zealand.
Green, Kimberley H., Melton Mowbray.
Griffiths, Barry, Stanstead.
Harrington, Shaun T., Ross-on-Wye.
Kervezee, Robert L., Berkel Rodenrgs, The Netherlands.
Masson, Kenneth J., Rochford.
Maule, Natalie A., Alresford.
Palme, Martina, Stockholm, Sweden.
Plomp, Jean V., Rotterdam, The Netherlands.
Scott, Damian T., London.
Slater, Richard M., Bath.
Somprachayanan, Wanpen, Bangkok, Thailand.
Stratmann, Rudolf W., Den Haag, The Netherlands.
Wanputh, Dheeraporn, Bangkok, Thailand.

Transfers from Ordinary Membership to Fellowship
Araki, Kazuo, Hyogo Pref, Japan. 1992
Bedwell, Victoria L., London. 1992
Eguchi, Yukio, Osaka, Japan. 1992
Hoso, Sadayuki, Osaka, Japan. 1992
Kariya, Tomoko, Tokyo, Japan. 1992
Kim, Hei Jong, Seoul, Korea. 1992
Kim, Sang-Ki, Seoul, Korea. 1992
Ku, Sarah J., London. 1992
Magara, Yoshiaki, Fukui Pref, Japan. 1992
Matsumoto, Naoko, Chicago, Ill., USA. 1992
Nakamura, Haruki, Kyoto, Japan. 1992
Nishimura, Tadahiro, Osaka, Japan. 1992
Peh, Angeline, Hong Kong. 1992
Ravona, Haim, Hadera, Israel. 1992

Sharma, Kul Bhushan, Lusaka, Zambia. 1992
Tanaka, Mariko, Hyogo Pref, Japan. 1992
Thorbjornsen, Bjorn T., Bergen, Norway. 1992
Trathen, John E., Stoney Creek, Ont., Canada. 1992
Yamagami, Mayumi, Tokyo, Japan. 1992
Yamamoto, Atsuko, Hyogo Pref, Japan. 1992
Yumoto, Atsuko, Osaka, Japan. 1992

CORRIGENDA

On p.133 above, second column the Figure 7 illustration was omitted; a reprint of the page complete with Figure 7 is included with this issue so that it may be inserted in the correct place

On p.151 above, Figure 1, line 1, after 'system' add 'show prism (A), pinacoid (c), bipyramid (w, z, n) and rhombohedral (r) faces'; Figure 1, line 4, for 'c and d' read 'parts c and d'

On p.152 above, first column line 5, for 'Figure 1b' read 'Figures 1c and 1d'; line 21, for 'Vichit *et al* 1979' read 'Vichit *et al*, 1978'

On pp.153, 154, 155, 157 and 158, because of a printing error illustrations are shown as negatives; replacement pages are included with this issue.

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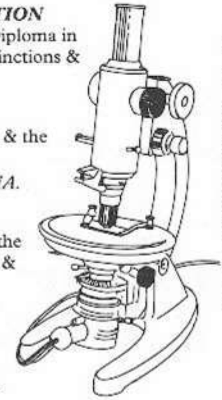

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Volume 23 No. 4. October 1992

The Journal of Gemmology

Contents

Registered Office: Palladium House, 1-4 Argyll Street, London W1V 1AD

ISSN: 0022-1252

Produced by Green Belt Studios: Printed by Quadrant Offset, Hertford, England.