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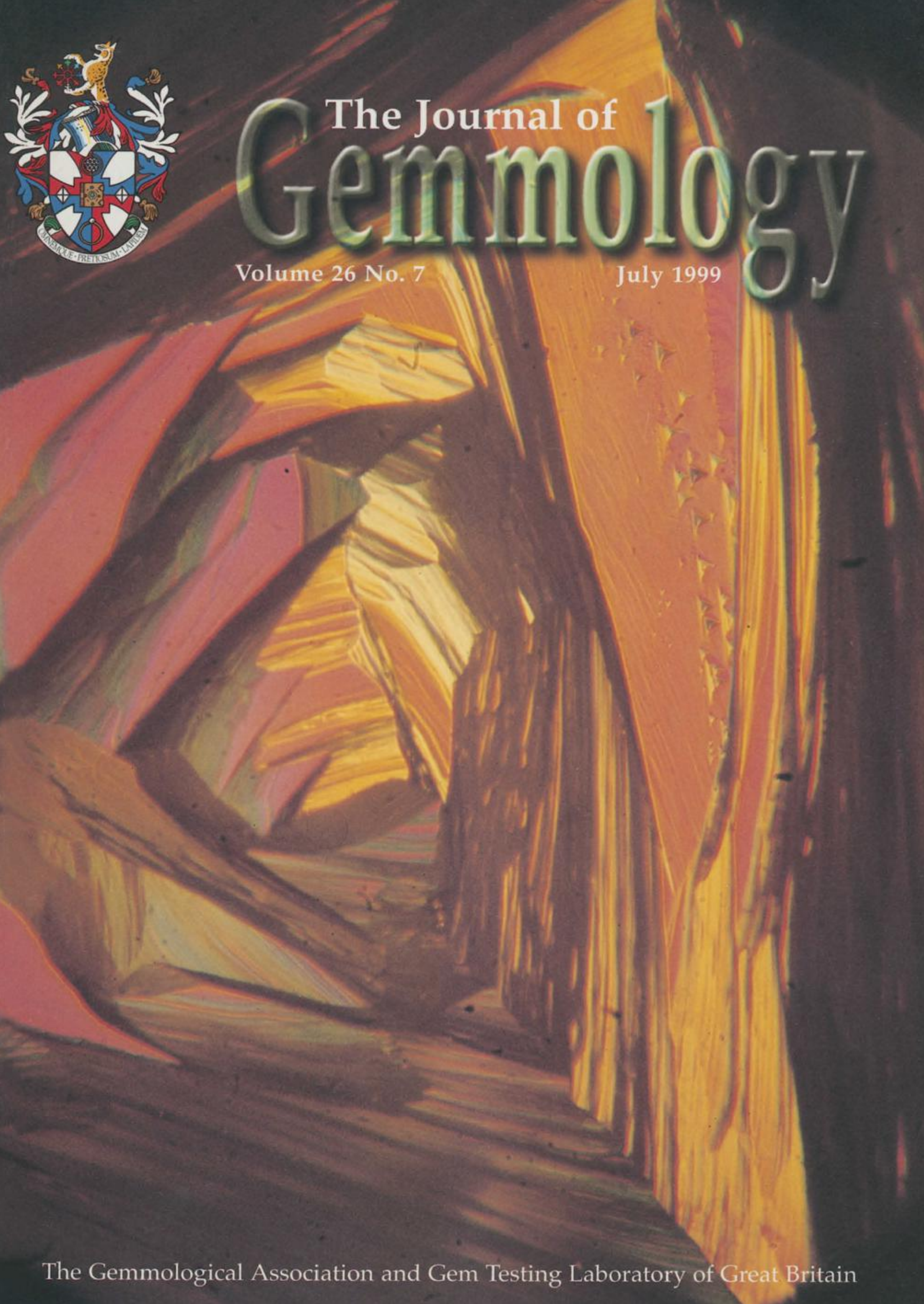

The Gemmological Association and Gem Testing Laboratory of Great Britain

Gemmological Association and Gem Testing Laboratory of Great Britain

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Review of recent studies on black jadeite jade

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ABSTRACT: Black jadeite jade, appearing on the Hong Kong market as bangles, beads and pendants, consists mainly of jadeite with small amounts of omphacitic pyroxene and accessory minerals. The colour of the jade is attributed to minute inclusions, largely of amorphous carbon with some metallic oxides and sulphides. In places the colour is patchy and the jade is colloquially known as black-skin-chicken jadeite.

Keywords: black-skin-chicken jadeite, electron microprobe analysis, inclusions, jade, petrography

Introduction

The term jade encompasses tough, compact fine-grained aggregates of minerals from two isomorphous series. Nephrite jades consist mainly of amphiboles (actinolite series) and pyroxene jades consist mainly of pyroxenes in the series jadeite-aegirine-diopside-kosmochlor. Burmese jadeite consists mainly of the sodium pyroxene jadeite with variable quantities of kosmochlor, omphacite, amphiboles (actinolite, tremolite or glaucophane) and albite feldspar (Deer *et al.*, 1978; Ou Yang, 1984, 1985, 1993a,b).

The colour of Burmese jade ranges from white (colourless) to bluish-violet, pinkish to dark purple, pale to dark and bright green, and yellow to brown and red – the latter caused by weathering and iron staining. Currently the term 'black jade' may include

Figure 1a,b: *Black jadeite jade bangles.*

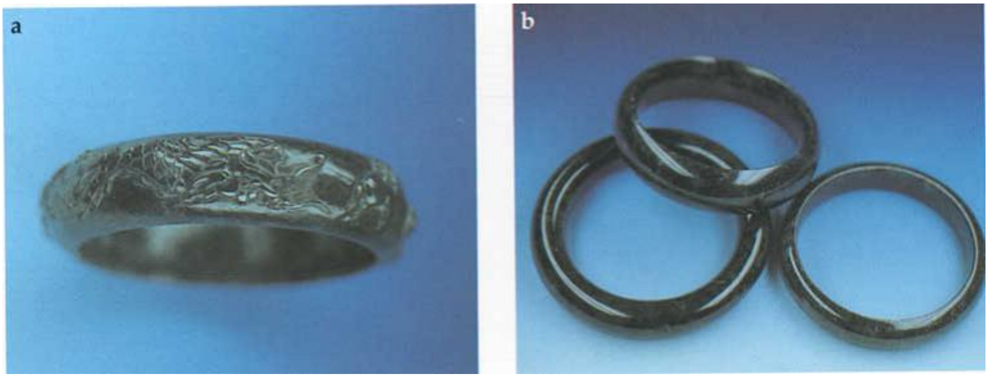

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Figure 2: Black jadeite jade pendant.

different types of pyroxene jades and is potentially confusing for the trade. This account describes a particular kind of black jade available recently on the Hong Kong market.

Black jade

The 'black jadeite' on the Hong Kong jade market is overall a greyish-black rather than pure black. It is similar in colour to that of black-skinned chickens – hence the colloquial term black-skin-chicken jadeite. Although not common on the market, it does appear in bangles, strung beads, carved pieces, and pendants (*Figures 1 and 2*). Some pieces of rough black jadeite of this type have been found in Myanmar by one author (C.M.O.Y.) and it appeared at the Myanma Jadeite Auction market in 1996 (*see Figure 3a,b*). Hitherto the black jadeite has not been popular and little is known about it, so six samples were selected for microscopic examination, X-ray diffraction studies, electron microprobe and chemical analysis, and laser Raman analysis to determine its composition and the cause of the colour.

Gemmological characteristics of black jadeite jade

Black jadeite jade is a compact fine- to coarse-grained aggregate of crystals in an interlocking granular texture. The blackness is uneven, varying between grey and jet black in patches, with the lighter parts showing a tinge of green. In general, the finer the grain size, the darker the colour. The jade is opaque (fine grained) to translucent (coarser grained) with a vitreous lustre except in a few areas where it tends towards an oily lustre; fresh and well-polished

Figure 3a,b: Rough black jadeite jade.

Figure 4: Polished surface of black jadeite jade bangle.

surfaces have a vitreous lustre. On polished surfaces, a black vein-like pattern is commonly visible (*Figure 4*), and in the more coarsely grained varieties the faces and cleavages of the constituent grains can give rise to star-like flashes in reflected light – termed 'jadeite flower' or 'fly wing flash'. Such features are not shown by black nephrite jade. On Mohs' scale the black jadeite jade is about 7, close to or slightly harder than agate. Using hydrostatic methods the SG of black jadeite ranges from 3.325–3.333, and its RI range on a Rayner refractometer is 1.653–1.665. It is inert under ultraviolet radiation, both long and short wave.

Black jadeite jade is very compact and generally free from cracks, being therefore very suitable for the manufacture of bangles. It is generally considered to be less valuable than green jadeite but is believed to bring physical protection and happiness. Black jade has been used for jewellery in Hong Kong and Taiwan.

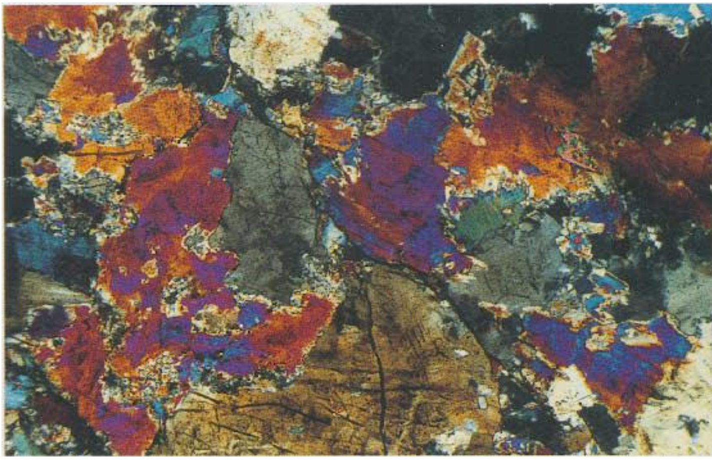
Mineral composition of black jadeite jade

Under the microscope the black jadeite jade is seen to consist of an interlocking mosaic of granular and short prismatic jadeite crystals (*Figure 5*) in a heteroblastic texture. Grain size varies greatly with some porphyroblasts reaching 1.4 x 3.5 mm in size (*Figure 6*). In general, however, the grain size lies between 0.14 x 1.28 mm and 0.70 x 1.40 mm. The pyroxene cleavages intersect at 87° and the extinction angle to the *c*-axis is 38°, although many grains show wavy extinction and some have zones of crushing or cataclasis.

Figure 5: Granular interlocking texture of jadeite crystals; crossed nicols; field of view about 6 mm across.

Microscope, X-ray diffraction, electron microprobe and laser Raman microprobe analyses indicate that black jadeite jade is essentially monomineralic, consisting of 95% jadeite and about 5% accessory minerals and black pigments. However, the jadeite is not

Figure 6: Porphyroblastic texture in black jadeite; crossed nicols; field of view about 6 mm across.



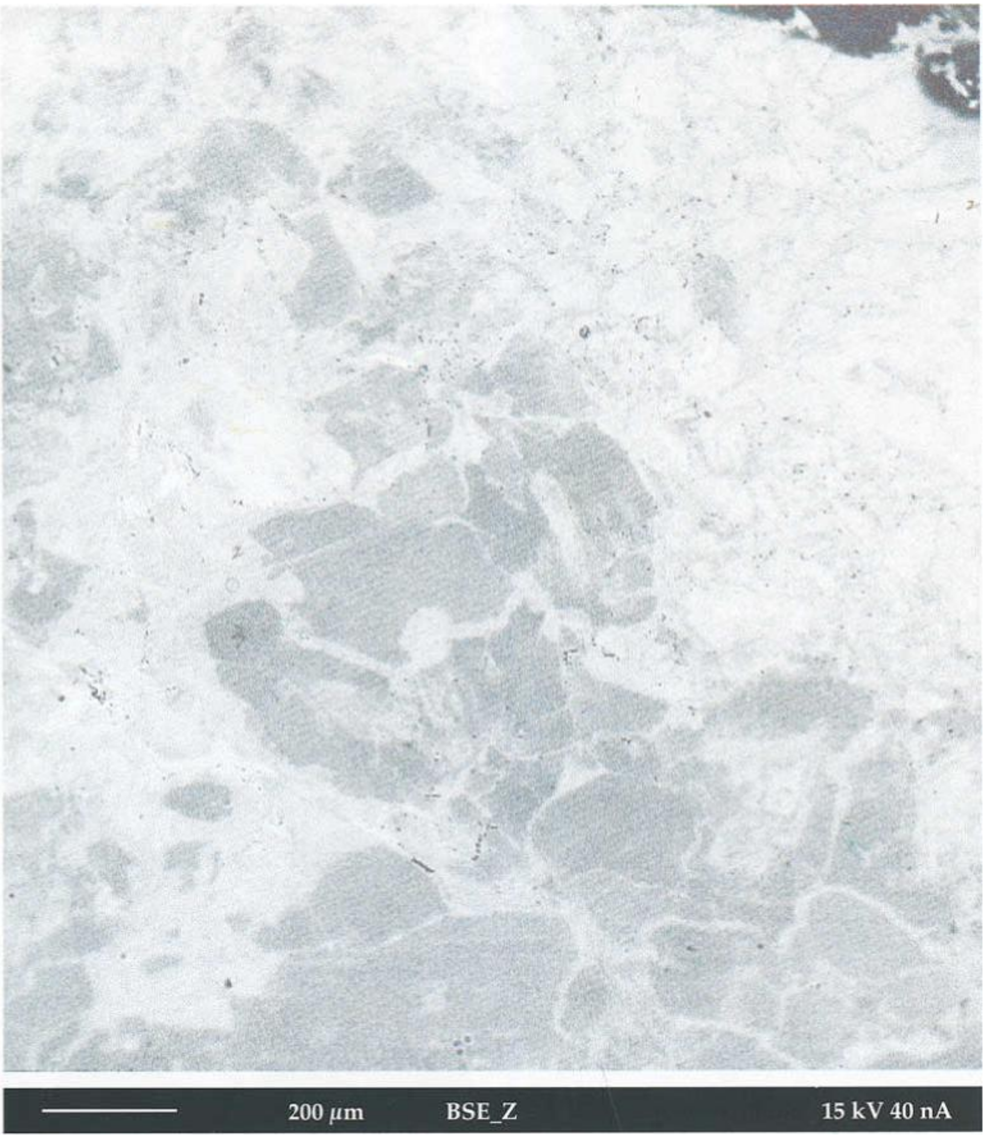


Figure 7: Black jadeite jade analysed by electron microprobe.

all pure Na Al silicate; the crystals are zoned and away from the cores the compositions grade into the jadeite-omphacite-diopside pyroxene series; the electron microprobe analyses indicate compositional zoning whereby Ca and Mg contents increase from core to margin of the grains at the expense of Na and Al (see *Table I* and *Figure 7*). In mineral terms the grains range from pure jadeite (J in Table I) to omphacitic jadeite (OJ) to jadeitic omphacite (JO). Accessory minerals in the black jadeite consist of apatite, zircon, magnetite, pyrite, titanite and opaque dust-like materials (pigments).

The major element composition of black jadeite jade

As shown in *Table I*, the whole-rock composition of black jadeite jade is close to

Table I: Composition of black jadeite.

Wt. %	Analysis of rock 1	Electron microprobe analyses of jadeite grains								
		Sample 21			Sample 28			Sample 35		
		Core 3	Zone 2	Rim 1	Core 3	Zone 2	Rim 1	Core 3	Zone 2	Rim 1
SiO_2	57.81	58.989	58.248	57.474	59.446	59.476	57.214	58.656	58.099	56.498
TiO_2	0.02	0	0.034	0.082	0	0	0.125	0	0.046	0.046
Al_2O_3	19.90	22.647	18.194	13.929	25.205	23.425	13.092	22.606	20.320	13.107
Fe_2O_3	1.10	1.678	1.598	2.464	0.033	0.579	1.912	0.550	2.128	2.830
FeO	0.35	0	0	0	0	0.381	0	0.361	0	0
MgO	2.81	1.595	4.655	7.330	0.046	0.894	8.558	1.514	2.825	8.264
CaO	4.02	2.323	6.418	10.261	0.104	1.254	11.931	2.364	4.267	11.557
MnO	0.04	0.058	0.060	0.046	0.031	0.044	0.117	0.041	0.123	0.130
NiO	n.d	0	0	0.017	0	0	0.007	0	0	0
ZnO	n.d.	0.021	0.004	0.016	0	0	0.075	0.021	0.021	0.052
Na_2O	12.39	14.043	11.503	9.274	15.281	14.554	8.364	13.803	12.803	8.415
K_2O	<0.02	0.017	0.003	0.029	0	0.003	0.018	0	0.009	0.006
Ce_2O_3	n.d	0.016	0	0	0	0.010	0	0.023	0.017	0.020
Nb_2O_3	n.d.	0.014	0	0	0	0.004	0.004	0	0.015	0
SO_3	0.01	0.003	0.006	0.019	0.009	0	0.016	0.010	0.014	0.013
CO_2	0.04									
H_2O	.0.05									
F	0.03									
Total	98.55	101.404	100.723	100.941	100.155	101.005	101.433	99.949	100.687	100.938
Classification		J	OJ	JO	J	OJ	JO	J	OJ	JO

Notes: Rock analysis (1) by the National Research Center of Geoanalyses of China, 1997.
Electron microprobe analyses by Institute of Geology, Academia Sinica, 1995, 1996.
J = jadeite; OJ = omphacitic jadeite; JO = jadeitic omphacite.
Analysis 21.2 contains 0.02% Cr_2O_3; 28.1 contains 0.03% ZrO_2. CO_2, H_2O and F were not determined for the jadeite grains.

that of relatively pure jadeite, suggesting that both the black and the greyer varieties are near monomineralic. The small differences in composition are due to the presence of accessory minerals and inhomogeneities in the jadeite. From relatively pure jadeite cores the Na and Al contents of the jadeite grains decrease towards the rims, with corresponding increases in Ca and Mg towards omphacite and diopside compositions. The chemical basis of the nomenclature is as follows: jadeite contains $Na/(Na + Ca) > 0.8$; omphacite contains $Na/(Na + Ca)$ of 0.8–0.2; and diopside has $Na/(Na + Ca) < 0.2$; also, according to Wang Pu *et al.* (1984), omphacite has $Al/(Al + Fe^3) > 0.5$. Microprobe analyses indicate that in the black jadeite jade, the jadeite grains contain 20.3 to 25.2% Al_2O_3 and 11.5 to 15.3% Na_2O, with CaO < 4.3% and Mg < 2.9%, while the

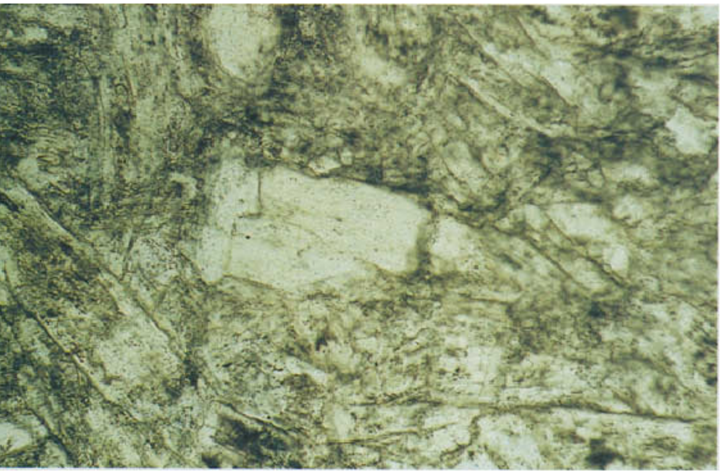


Figure 8: *Jadeite grains with black dust-like inclusions along cleavages, cracks and grain boundaries. Plane polarised light; field of view about 6 mm across.*

omphacitic jadeite and jadeitic omphacite (OJ and JO respectively in *Table I*) contain lower Na and Al and higher Ca and Mg in proportion.

The colour of black jadeite jade

On polished surfaces of the jadeite, black or dark opaque dust-like materials may be observed as dispersed grains, tiny pellets or patches, or fine networks. Under a high, resolution microscope, thin sections of the jadeite also reveal particular patterns of the microgranular or dust-like inclusions. Five such patterns can be distinguished:

1. Brown inclusions may be on particular crystal faces of the jadeite grains or dispersed at random (*Figure 8*); they consist mainly of CO_2 and organic hydrocarbons and relate to deep-seated fluid inclusions. The shapes of single inclusions are slightly irregular, while some are vermicular, but a group of associated inclusions tends to be arranged in an orderly way in the direction of a particular crystal surface.
2. Opaque or dark dust-like grains are distributed regularly along compositional zones of jadeite grains; these are primary inclusions.
3. Regular distribution of opaque or dark grains along one or more sets of cleavage planes; this may create a schiller effect and be due to segregation of the granules during formation of the jadeite crystals (*Figure 9*).
4. Opaque dust-like grains and pellets occur as discontinuous strings or as veinlets along microcracks at angles to the jadeite cleavages (*Figure 10*).
5. Dust-like grains, pellets, patches or veinlets of opaque material occur in the interstices between jadeite grains or along microcracks across mineral aggregates (*Figure 11*).

Figure 9: *Cleavage planes in jadeite with black dust-like inclusions; crossed nicols; field of view about 2 mm across.*

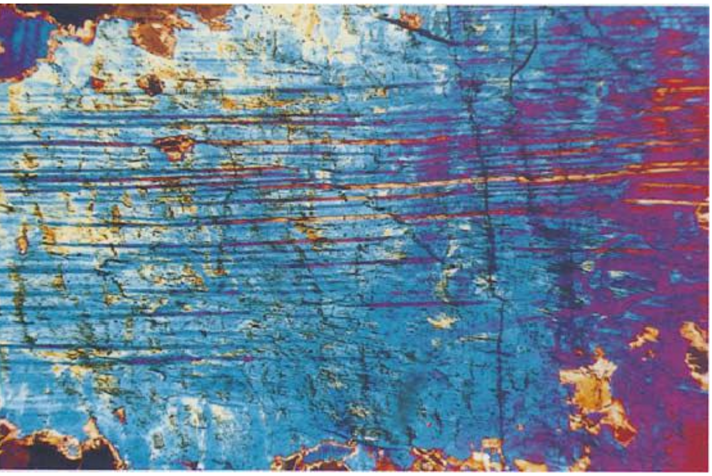


Figure 10: *Jadeite grains with black dust-like inclusions along microcracks at angles to the cleavage. Plane polarised light; field of view about 6 mm across.*

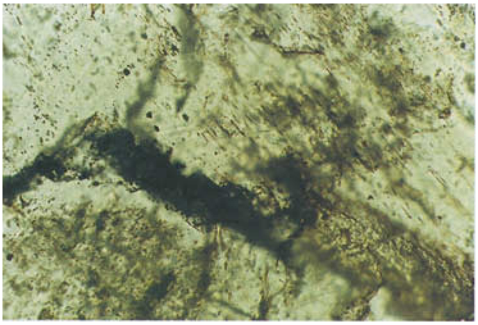


Figure 11: Black pigment concentrated along grain boundaries. Plane polarised light; field of view about 6 mm across.

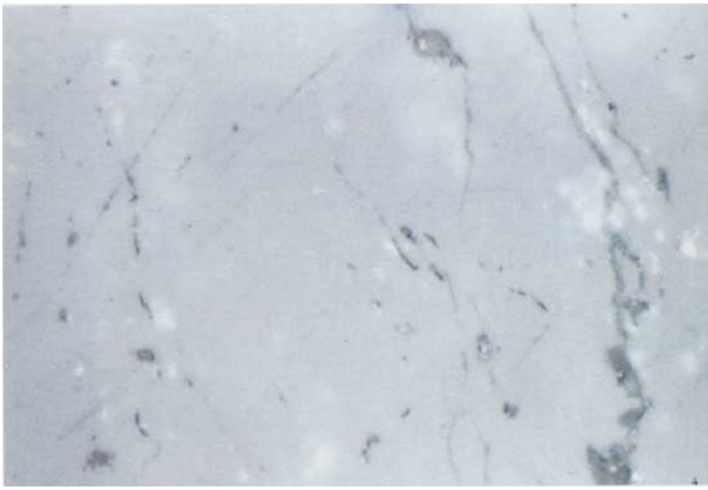


Figure 12: Metallic reflections from inclusions in jadeite, x 1600.

The dust-like and opaque microgranular material is abundant and widely dispersed, and is the reason why the jade is grey or black.

On polished surfaces of black jadeite, the intensity of blackness may vary and this is due to the amount and distribution of pigmentary material. Where the fine-grained opaque materials are thinly dispersed throughout jadeite jade of average grain size, the rock may appear greyish-black, but where perhaps the pigmentary materials have reacted to stress and fluids in the rocks and migrated to form more concentrated patches and veinlets the jade will be very black. Where the jadeite is very coarse, and perhaps originally light green, similar stress and fluids may cause the opaque grains to gather in the interstices between jadeite grains and form a greyish-green mottled rock with reticular black veinlets.

Inclusions

High-resolution microscopy indicates that there are some colourless and transparent two-phase (gas + liquid) and three-phase (gas + liquid + mineral) inclusions associated with opaque and dark-coloured solid inclusions of the first three categories outlined in the previous section. In reflected light, at high power, metallic reflections from the solid inclusions can be seen; these were probably formed syngenetically with the host jadeite (*Figure 12*). Electron microprobe analyses indicate that the solid inclusions consist of magnetite, pyrite, amorphous carbon, leucoxene and organic salts of iron. Laser Raman microprobe analyses carried out by the Xian Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences (1996), indicate that the multiphase inclusions contain a range of substances including water, CO_2, alkanes, alkenes, aromatic hydrocarbons and resins.

Some inclusions are protogenetic, originating from magma source regions, some syngenetic, forming at the time of the jadeite host crystals, and some are epigenetic, formed under hydrothermal conditions or by segregation under pressure and stress on the jadeite which in turn caused migration of inorganic and organic materials along cleavages to grain boundaries (*Figures 8, 10 and 11*).

Summary

Black jadeite jade consists of more than 95% jadeite or omphacitic jadeite, coloured black by the presence of minute inclusions evenly or unevenly dispersed throughout. The inclusions comprise metallic oxides and sulphides, amorphous carbon, organic salts, water, CO_2 and a range of hydrocarbons. Some inclusions are protogenetic or syngenetic but others are epigenetic and have concentrated in patches to give a blotchy appearance to the jade.

References

Deer, W.A., Howie, R.A., and Zussman, J., 1978. *Rock-forming minerals*, Vol. 2A, 2nd edn, Single-chain silicates, Longman, London

Harder, H., 1995. Trace elements as colouring agents in jadeites. *Journal of Gemmology*, **24**(7), 508–11

Ou Yang Chiu Mei, 1984. A terrestrial source of ureyite. *American Mineralogist*, **69**, 1180-83

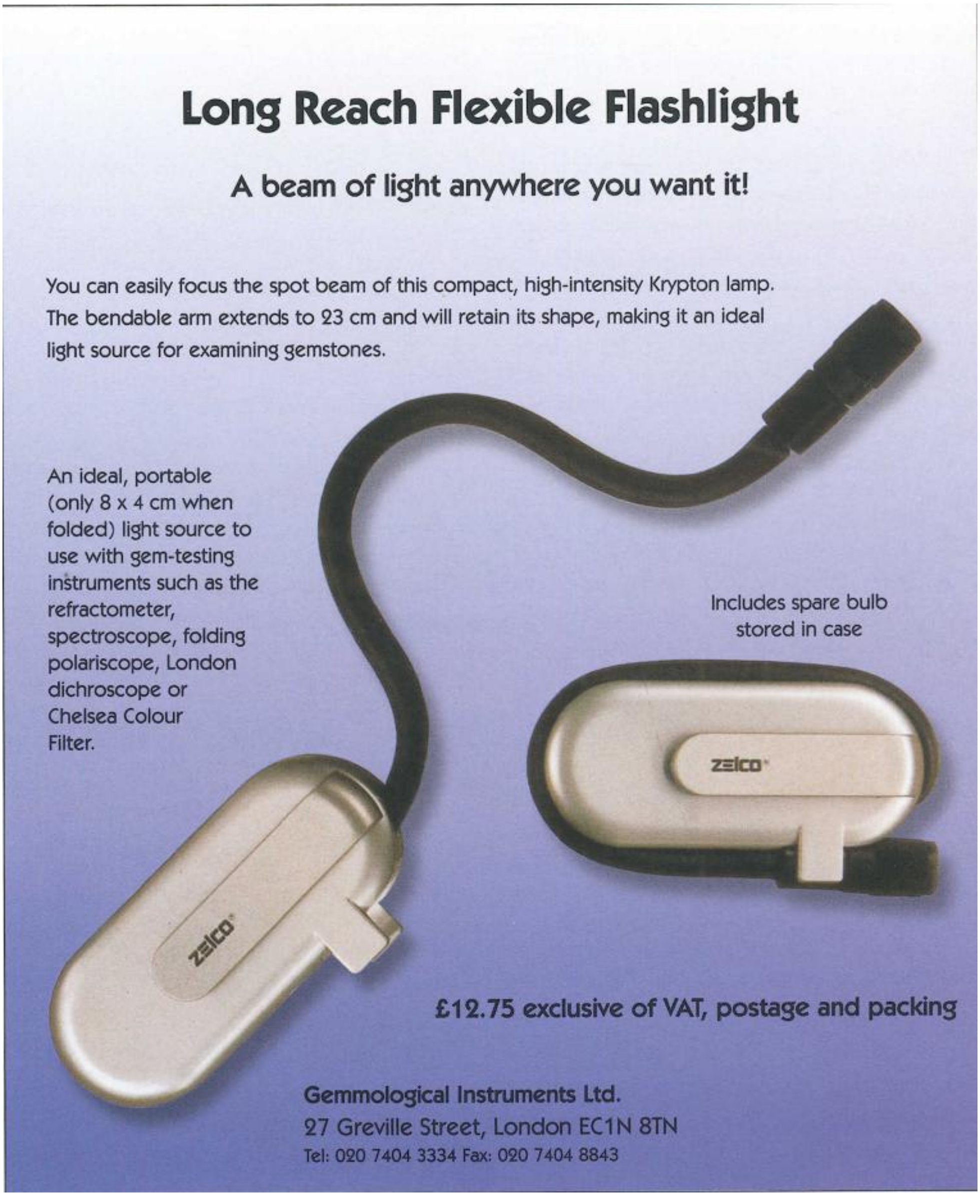
Ou Yang Chiu Mei, 1985. Mineralogical study of Burmese jadeite jade. Thesis presented for the degree of Master of Philosophy, Department of Geography and Geology, University of Hong Kong

Ou Yang Chiu Mei, 1993a. *An appreciation of jadeite*. Cosmos Books Ltd, Hong Kong

Ou Yang Chiu Mei, 1993b. Microscopic study of Burmese jadeite jade. *Journal of Gemmology*, **23**(5), 278–84

Rossman, G.R., 1974. Lavender jade. *American Mineralogist*, **5**, 868–70

Wang Pu *et al*., 1984. *Systematic mineralogy*, Vol. Middle. Geological Publishing House, Beijing, 304–10



Moissanite: a new synthetic gemstone material

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ABSTRACT: Synthetic moissanite (silicon carbide, SiC) is a new synthetic gemstone material developed and marketed by C3 Inc. of the USA. It provides a new gemstone that can also serve as a diamond substitute with properties overall closer to those of diamond than any other substitute: refractive indices 2.648 and 2.691, dispersion 0.104, birefringence 0.043, hardness 9 1/4, specific gravity 3.22. Diagnostic to the trained gemmologist are the birefringence, inclusions and surface appearance.

Keywords: diamond simulant, Moissan, synthetic moissanite, silicon carbide

Introduction

This report describes the background for, and characteristics of, synthetic moissanite (silicon carbide, SiC), a new gemstone material that can also serve as the most convincing diamond substitute to date (see *Figure 1*). A summary of gemmological data and identification techniques is given, but for more detailed spectroscopic and XRF information on moissanite see Nassau *et al.*, 1997. While moissanite does exist in nature, both terrestrially and in meteorites as discussed below, it has not been found in pieces large enough to be faceted.

As always happens with the introduction of any new synthetic, there is considerable concern in the jewellery trade. Particularly problematic are properties so close to those of diamond that synthetic moissanite passes as 'diamond' under test by thermal probe instruments, by the read-through effect and by several other tests.

Figure 1: *Twelve near-colourless synthetic moissanites; the largest is 6.37 ct, 12.5 mm, and would be classified as M, SI1 in the GIA diamond grading system. Photo by Robert Weldon.*

It is now 23 years since cubic zirconia (CZ) was first seen in the trade as a diamond

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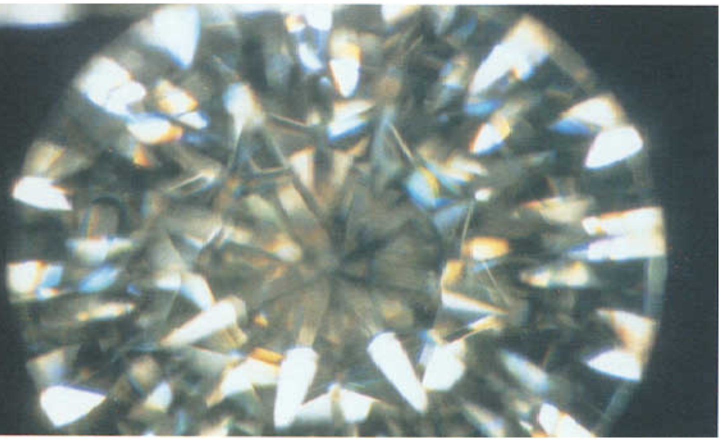


Figure 2: Viewed squarely through the table, doubling is seen in reflections of the table and crown facets, but not in the culet region (here somewhat out of focus) because the view is down the optic axis. Photo by Shane Elen, courtesy of the GIA.

imitation in 1976 (Nassau, 1980). This is probably the longest unchallenged reign of any synthetic diamond substitute and it was difficult to foresee what material might serve in an improved role – other than synthetic diamond itself.

All previous synthetic diamond imitations have significant deficiencies. As examples, synthetic spinel, colourless sapphire and yttrium aluminium garnet (YAG) are much less brilliant; synthetic rutile and strontium titanate (ST) are much too soft; gadolinium gallium garnet (GGG) and CZ have very high specific gravities, and the last of these is somewhat brittle. By contrast, the synthetic moissanite here described has (using average values):

- a refractive index higher than that of diamond (2.67 vs. 2.42);
- a significantly higher dispersion (0.104 vs. 0.044), but not as excessive as the 0.190 of ST;
- a specific gravity near that of diamond (3.22 vs. 3.52);
- a hardness of $9^{1}/_{4}$, second as a gemstone material only to the 10 of diamond; and
- it is even tougher than diamond because the pronounced octahedral {111} cleavage of diamond is absent or weak, although there may be a relatively weak {0001} cleavage.

A drawback of synthetic moissanite as an imitation of diamond is the presence of a significant birefringence of 0.043, but less than the 0.059 of zircon or the large 0.330 of synthetic rutile, both once used as diamond imitations. However, this effect is minimized because currently all stones are faceted with the optic axis perpendicular to the table facet. As a result, doubling of facets is absent when looking squarely into the top of a stone at the culet region; doubling is only seen when focusing deeper at reflections in the pavilion facets (see *Figure 2*) or when looking into a stone at an angle, say, through the girdle.

Two US patents (Hunter and Verbiest, 1998) have recently been granted to C3 Inc., giving this firm the exclusive right to market synthetic moissanite as a gemstone material in the USA. Patent applications are also under way in other countries. Their tester to identify synthetic moissanite is also patented. In mid-1998, C3 Inc. began shipping faceted stones to a limited number of retailers in the USA and to exclusive distributors internationally; 18,000 ct were shipped in 1998 and 14,000 ct in the first quarter of 1999.

The background of moissanite

The growth of single crystals of silicon carbide, SiC, mineral name moissanite, has been under investigation for more than a century for three ends:

1. as a very hard abrasive, second only to the hardness of diamond;
2. for its potential as a promising technological semiconductor material; and
3. as a possible gemstone material and diamond substitute with properties closer to those of diamond than any other known material.

The potential promise of synthetic moissanite has been described several times in the gemmological and related literatures (Gill, 1978). Enthusiastic optimism reigned, frequently with claims that colourless material was available (e.g. De Ment, 1948, 1949; Mitchell, 1962; McCawley, 1981), but Nassau (1980) outlined the situation thus:

Ferdinand Frederick Henri Moissan

Ferdinand Frederick Henri Moissan, *Figure A1* (taken from Harrow, 1920), did not normally use his first two names. He was born in Paris, France, on 28 September 1852. His father was a chemist. The young Henri was so good at science that his science teacher gave him supplementary private lessons. Because of the family's limited means, at first he had to work as a pharmacist's assistant but in time managed to return to school and received the doctorate degree in chemistry at the age of 27.

While lecturing at the Ecole Superieur de Pharmacie, he began his own research into inorganic chemistry, a subject much neglected at that time. He was the first to isolate the element fluorine from one of its compounds in 1884, a process that had been unsuccessfully attempted by many eminent chemists. There were ample rewards for this achievement, among them a full professorship, election to the French Academie des Sciences and, the ultimate recognition of all, the Nobel prize for chemistry in 1906.

Figure A1: Ferdinand Frederick Henri Moissan (Harrow, 1920), the discoverer of elemental fluorine (Nobel Prize for chemistry, 1906), the carbon-arc furnace, and moissanite in the Canyon Diablo (Arizona) meteorite.

Among the many reactions of fluorine that Moissan studied were high temperature ones with carbon. This had two consequences: he developed his famous electric-arc furnace which could reach 4000°C and he became interested in diamond, carbides and meteorites. He thought (Moissan, 1920), erroneously, that he had prepared synthetic diamond (see also Nassau, 1980).

In one of his experiments Moissan dissolved a 53 kg specimen of the Canyon Diablo (Arizona) meteorite in a succession of strong acids and identified in the residue tiny crystals of silicon carbide (Moissan, 1904). The mineral name moissanite was given to this material in Moissan's honour by Kunz:

> 'As this is the first instance in which this compound has been proved to occur in nature, and therefore, as a mineral, is entitled to a distinct mineralogical name, it would seem that the name of Professor Moissan himself should be associated with it. I would, therefore, propose for it the name of Moissanite, as a slight recognition of his many services to chemistry, and especially of his researches on the artificial carbides and his study of the constituents of meteorites, and the reproduction of similar substances by means of the electric furnace.' (Kunz, 1905)

According to Harrow, Moissan's lectures at the Sorbonne were crowded:

> 'The charm of his personality and his evident joy in exposition gave keen pleasure to his auditors. He will live long in the memories of all who were privileged to know him, as a man full of human kindness, of tact, and of true love of the subject which he adorned by his life and work.' (Harrow, 1920)

Moissan died in 1907 from appendicitis (in an era before antibiotics) at the age of 55.

Table I: Some simple polytypes of moissanite[i]

Ramsdell designation	Stacking sequence repeat unit	Space group	Optical constants[ii]			
			n_o	n_e	Birefr.	Disp.
β –SiC (β–silicon carbide) cubic[iii]						
3C	ABC	F$\bar{4}$ 3m	2.652	–	0	0.112
α –SiC (α–silicon carbide) hexagonal						
2*H*	AB	C6$_3$mc	2.633	2.707	0.074	0.106
4*H*	ABCB	C6$_3$mc	2.659	2.712	0.053	0.122
6*H*	ABCACB	C6$_3$mc	2.648	2.691	0.043	0.104
8*H*	ABCABACB	C6$_3$mc	–	–	–	–
10*H* etc.	ABCBACABCB	P$\bar{3}$ ml	–	–	–	–
α –SiC (α–silicon carbide) rhombohedral						
15*R* etc.	ABCBACABACBCACB	R$\bar{3}$ ml	2.650	2.697	0.047	0.108

i. The most common polytype of moissanite in synthetic abrasive material is 6*H*; 15*R* is the second and 4*H* the third most common polytype. The topic of this report is the synthetic moissanite 6*H*.

ii. n_o and n_e are the ordinary and extraordinary refractive indices at 589 nm; birefringence (Birefr.) is n_e–n_o; dispersion (Disp.) is n_o (431 nm) – n_o (687 nm). Values were calculated from the precision equations given by Von Muench (1982) and Harris (1995).

iii. There is only one cubic polytype; it has an inherent deep-yellow colour.

> 'Despite many decades of intense effort by scientists using a variety of different approaches, it has not yet been possible to control either the color, or even the crystal growth itself precisely enough to make single crystals suitable for either technological or gemological use.' (op. cit. p.253)

Only recently has the controlled growth of synthetic moissanite actually been achieved (Davis *et al.*, 1990; Carter *et al.*, 1998) so that material that is colourless to the naked eye is finally available for gemmological use.

Early work on silicon carbide (it has also sometimes been called carbon silicide) was summarized by Mellor (1929). Edward G. Acheson (1893) appears to have been the first to recognize its hardness and potential as an abrasive. He prepared it accidentally while trying to grow diamond by passing an electric arc between carbon electrodes through a mixture of carbon and molten clay, an aluminium silicate. He named the substance 'carborundum', later to become a trade name, because at first he thought it to be a compound of carbon and corundum (alumina, Al_2O_3) and/or because of its hardness being intermediate between those of diamond and of corundum. Subsequently, he obtained a better yield by using a mixture of carbon and sand. This came to be known as the 'Acheson process' and is still used today for the manufacture of silicon carbide for abrasive and other uses.

At about the same time, the Nobel prize-winning chemist Henri Moissan discovered natural silicon carbide in the Canyon Diablo meteorite (see Ferdinand Frederick Henri Moissan, p.427) and the mineral name 'moissanite' was given to this material in Moissan's honour by Kunz (1905).

The technological importance of silicon carbide is shown by a series of international conferences starting in 1959 (O'Connor and Smiltens, 1960), but it was not until the sixth conference in 1996 that there were:

> '... epoch-making results in the history of the subject ... For SiC these included ... a sublimation method for crystal growth ...' (Nakashima *et al.*, 1996).

The structure and preparation of moissanite

Considerable confusion resulted when early investigators found a variety of different structures for moissanite, including those having cubic (*C*), hexagonal (*H*) and rhombohedral (*R*) symmetries. This complexity is explained by the existence of *polytypes*, variations in the crystal structure that can depend on growth conditions. Such polytypes can occur in any materials which consist of the stacking of hexagonal layers as described in Polytypism and moissanite (p.430). More than 150 polytypes are known for silicon carbide, all of which are properly designated 'moissanite'.

The synthetic material here described is the moissanite-6*H* form of α-silicon carbide or SiC:6*H* (see *Table I*). The only other moissanite polytype that can be grown in large crystals is the 4*H* form (Nakashima *et al.*, 1996). The cubic 3C polytype, β-silicon carbide, might be interesting if it could be grown in bulk; however, its inherent deep-yellow colour (von Muench, 1982) would prevent its use as a diamond imitation, but not as a unique synthetic gemstone.

In the Acheson process for industrial production of moissanite (Divakar *et al.*, 1993; Verma and Krishna, 1966; Smoak *et al.*, 1978; Von Muench, 1982, 1984), carbon in the form of petroleum coke or anthracite coal is mixed with sand and a little sawdust and salt. An electric current is passed through a central graphite rod surrounded by the mixture to heat it internally to a maximum temperature of 2700°C, producing the simple reaction:

$$SiO_2 + 3C \rightarrow SiC + 2CO$$

Clusters of single crystals occasionally occur in sizes up to 1 cm across and a few millimetres in thickness, ranging from black to green to tan, as in *Figure 3*, sometimes with an iridescent coating.

For high-purity moissanite powders, volatile substances such as silicon tetrachloride, organic silicones, and gases such as methane have been reacted or decomposed by using a plasma or other heat source; moissanite fibres have been made by decomposing fibres of organosilicon polymers (Divakar *et al.*, 1993).

Single crystal growth of moissanite

Several techniques for growing crystals of synthetic moissanite have been studied for many decades (O'Connor and Smiltens, 1960; Verma and Krishna, 1966; Divakar *et al.*, 1993; Wilke, 1988; Von Muench, 1984). Of these only a seeded sublimation process, derived from the 'Lely' approach, has proved viable for the controlled growth of large single crystal boules of moissanite (Davis *et al.*, 1990; Nakashima *et al.*, 1996).

Melt processes cannot be used to grow moissanite crystals because decomposition of the starting materials begins at 2830°C, well before melting can occur. Flux processes

Figure 3: *Synthetic moissanite produced by the Acheson process for abrasives use: (a) a typical black crystal cluster; (b) faceted yellow and green stones, the largest is 0.52 ct. Photos by K. Nassau.*

Polytypism and moissanite

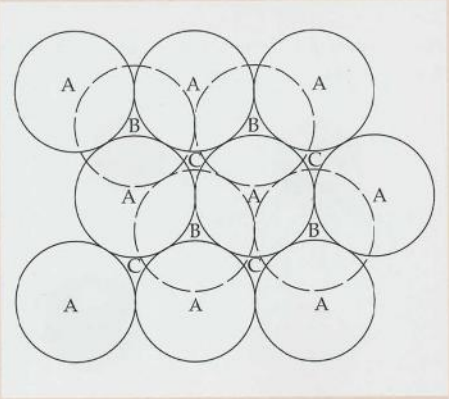
When hexagonal layers of atoms are stacked on top of each other, there are various stacking sequences that can occur. The term 'polytypism' is used for the occurrence in a substance of several crystal structures when all have the same chemical composition but have different layering sequences in the stacking direction (Verma and Krishna, 1966).

While not common, polytypes occur in several minerals. The best-known example of polytypes are the zinc sulphides: sphalerite (also blende or zinc blende, cubic) and wurtzite (several hexagonal and trigonal forms); all have the composition ZnS. The element carbon occurs in two polytypes: the cubic form diamond and the hexagonal form lonsdaleite (graphite and chaoite are not polytypes but only polymorphs).

Consider the hexagonal double layer of SiC in *Figure B1*, where each solid circle marked *A* represents a silicon atom with a carbon atom exactly below it. Let a second double layer be placed on top of the double layer *A*, occupying the positions *B* as shown with dashed circles. A third double layer can now be added in two different ways.

First consider the third double layer occupying positions exactly above the first double layer A as at (a) in *Figure B2*. This stacking, when repeated, can be described as ABABAB... Close examination of the resulting structure shows that this is hexagonal, designated *H*; since the repeat unit consists of *two* double layers, one way of designating this structure is 2*H* in the Ramsdell notation (Verma and Krishna, 1966).

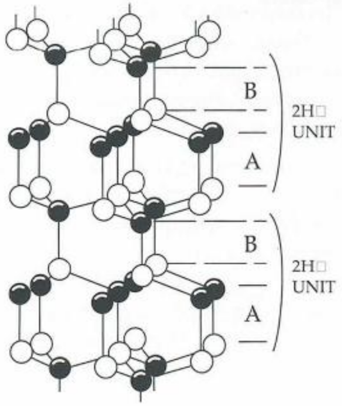
Figure B1: *The stacking of hexagonal layers.*



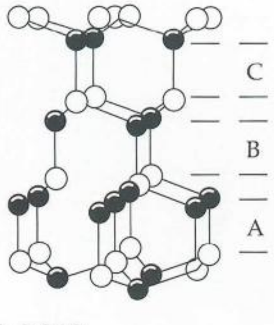
However, if the third double layer instead occupies the positions *C* in *Figure B1*, the repeated stacking can then be described as ABCABC... Although not evident from *Figure B2* at (b), examination of an actual model shows that this structure is cubic *C*; since the repeat unit consists of *three* double layers, this structure is usually designated 3*C*.

Yet two more stacking sequences are shown at (c) and (d) in *Figure B2*, corresponding to ABCB... and ABCACB... Both of these are hexagonal, with four double layer repeat units designated 4*H*, and six double layer repeat units designated 6*H*, respectively. Moissanite-6*H* is the most common form in the synthetic abrasive material and is the form that is the subject of this report. 4*H* and 6*H* are the only polytypes of moissanite that can be grown as large crystals at present. Some additional simple hexagonal polytypes are included in *Table I*. The simplest rhombohedral structure of moissanite is 15*R*, with a repeat unit as given in *Table I*.

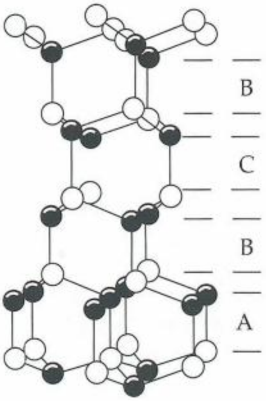
At temperatures below about 2000°C the stable form of moissanite appears to be 3C or β-silicon carbide, the only cubic form, given in *Table I*. At higher temperatures, crystals of any of the more than 150 polytypes of α-silicon carbide, either hexagonal or rhombohedral, may occur, often mixed with each other and with the cubic form (Verma and Krishna, 1966; Davis *et al.*, 1990). Interlayers of polytypes within a crystal as well as other defects can occur when crystal growth is not under good control.



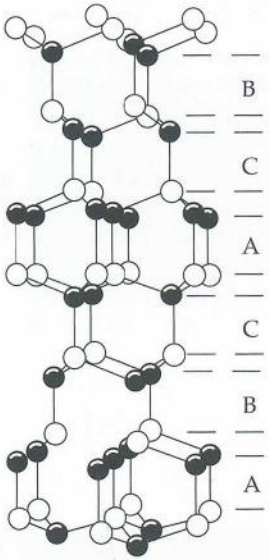
a. SiC:2H



b. SiC:3C



c. SiC:4H



d. SiC:6H

Figure B2: *The structures of the hexagonal 2H, 4H, and 6H forms of α-silicon carbide and of the cubic 3C β-silicon carbide.*

In all forms of moissanite each Si is surrounded by four C and each C by four Si atoms; all Si-C bond lengths are equal at about 1.90 Å. In all hexagonal and rhombohedral structures the stacking direction is the *c*-axis which is also the optic axis; in the cubic form the stacking direction is the body diagonal [111]. All SiC polytypes have hexagonal (or equivalent hexagonal) unit cells with dimensions very close to a = 3.08 Å and c = 2.52*n* Å, where *n* is the number of double layers in the repeat unit. Hence the specific gravities, optical and most other properties are very similar. Space groups and some optical properties of several moissanite polytypes are given in *Table I*.

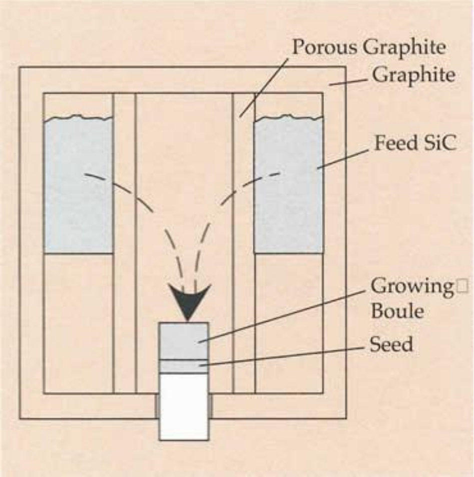
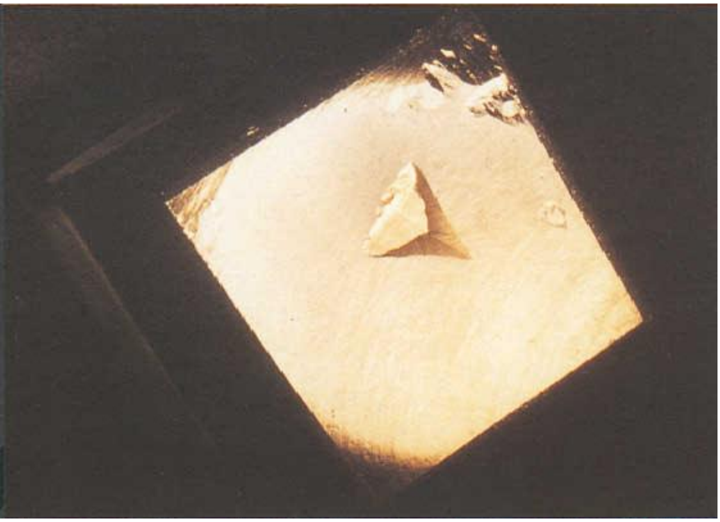


Figure 4: *The growth configuration described in the Davis, Carter and Hunter (1990) patent for the controlled growth of single crystal moissanite.*

have, however, produced results and tiny crystals of the cubic β-silicon carbide have been grown at about 1700°C from solutions of carbon in molten silicon, and from SiC solutions in molten nickel, chromium and various metal alloys. Vapour transport at 1800°C has been used to obtain thin films. In gaseous cracking, also called pyrolytic decomposition or the 'van Arkel' process, various volatile Si- and C-containing compounds are passed over a heated tungsten wire, and moissanite is deposited as small crystals.

Figure 5: *The triangular pit on the surface of this 71.4 gram part of a synthetic moissanite boule resembles the trigons commonly seen on diamond crystals. The pit has sides of 6 mm and a depth of less than 0.25 mm. Photo by K. Nassau.*



The Lely process uses sublimation, where the silicon carbide is vaporized and then condenses without ever passing through the liquid state. In his original work, Lely (1955) used a cylinder made of lumps of SiC containing a hollow cavity. This was heated in a sealed graphite crucible to 2500°C when crystals grew inside the cavity. Many modifications have been tried to control purity and polytypes, particularly the use of a thin porous graphite tube to line the cavity, as well as carefully controlled atmospheres and temperature gradients. The lining tube controls the rate of sublimation, with crystals growing on its inside. The work of Tairov and co-workers in Russia (e.g. Tairov and Tsvetkov, 1981) provided significant advances.

The final break-through to provide a greater control of the Lely process came with the patent of Davis *et al.* (1990), where growth occurs on a seed crystal. One configuration described in this patent is shown in simplified form in *Figure 4*. As indicated by the arrows, SiC vapour from the feed powder passes through the porous graphite tube to feed the growing crystal boule.

Growth factors discussed in this patent include the following typical conditions:

- feed temperature 2300°C;
- growing crystal 100°C cooler than the feed region;
- seed crystal orientation slightly off axis and prepared by a detailed cleaning process;
- seed crystal and feed powder both the same polytype;
- feed powder having controlled grain size that is constant throughout the growth;
- heat derived from a resistance-heated graphite sleeve;
- atmosphere initially vacuum, then low pressure of argon.

Other factors mentioned include seed rotation, the use of ultrasonic vibration for feeding, and the adjustment of the growing crystal position during the growth process. Because of proprietary considerations, details of the actual growth process have not been released. The Davis *et al.* (1990) patent reports the growth of a 12 mm diameter 6 mm thick moissanite–6*H* crystal during a six-hour growth period. Some boule surfaces show triangular pits resembling the trigons seen on diamonds (*Figure 5*).

Nakashima *et al.* (1996) report various aspects of moissanite growth and applications to the electronics industry and Tsvetkov *et al.* (1996) mention 50 mm diameter boules produced in 1994. To place this size in perspective, if uniformly clear this would permit the manufacture of a 50 mm diameter faceted brilliant-cut synthetic moissanite of height about 28 mm and weight about 380 ct. The equivalent weight of a diamond of equal size would be 420 ct. One can reasonably assume that even larger boules must be possible by now.

A technique for obtaining near-colourless synthetic moissanite by compensating impurities is described in a patent by Carter *et al.* (1998).

Gemmological characteristics of synthetic moissanite

Examination of 23 faceted 'near-colourless' stones, ranging from 0.09 to 1.12 ct, and several pieces of rough ranging up to 71.4 gm, were described in detail by Nassau *et al.* (1997). More than one thousand loose stones were also briefly examined, including a 4.92 ct round brilliant-cut (11.9 mm diameter) of approximate colour grade N on the GIA scale, a 17.31 ct medium green round brilliant-cut (17.5 mm), and over 100 preform cubes. Also examined were 21 pieces of jewellery containing a total of 50 stones, including the 14-carat gold ring shown in *Figure 6*, where the stones had been mounted in wax and then cast in place.

Figure 6: *A 14 ct gold ring containing two rows of faceted pale green synthetic moissanites that were mounted in wax and then cast in place. Ring courtesy of C3 Inc., photo by Maha DeMaggio, courtesy of GIA.*

An outline of gemmological characteristics, updated from Nassau *et al.*, 1997, with references, is here presented with those of diamond given in square brackets.

Visual characteristics

To the unaided eye: No visible inclusions; lustre subadamantine [diamond: adamantine]; effective brilliance similar to that of average diamond; read-through effect none [none]; pavilion flash colours orange and blue [same].

Colours on the GIA diamond colour-grading scale range from I to V, with greyish, greenish, yellowish or brownish hues; because many of these hues are not present in diamond reference stones, it is sometimes difficult to decide on a unique equivalent diamond colour grade [which is also the case for those rare diamonds having such hues].

The colours of synthetic moissanites under ordinary illumination, especially when set in jewellery, usually appear to be better than those indicated by their diamond grades. This difference has two origins: the first is particularly noted in greyish stones, which lack the expected yellow of the Cape series; the second derives from the higher dispersion of synthetic moissanite, the fire

Figure 7: The most common inclusions in synthetic moissanite are thin white needles, generally parallel to the optic axis. Photo by Gary Roskin.

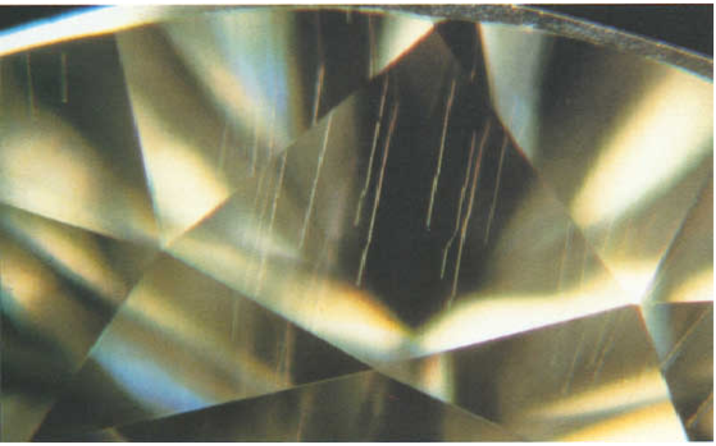


Figure 8: In a few synthetic moissanites offsetting bends occur in the needles. Photo by Gary Roskin.

Figure 9: In diamond the polishing orientation must be repeatedly changed for successive facets because of its directional hardness; synthetic moissanite can be polished in a relatively consistent direction as is shown by the polishing lines on the facets of this stone, magnified 32x. Photo by Shane F. McClure, courtesy of GIA.

from which appears to create a 'whiter' impression.

Under magnification: Facet doubling not seen when looking perpendicularly through the table at the culet, but noticeable when looking in this manner at secondary reflections in the pavilion facets as seen in *Figure 2* or when looking into the stone at an angle [absent]; white sub-parallel needles and fine reflective stringers near-perpendicular to the table facet as in *Figures 7 and 8,* pinpoint inclusions, sometimes arranged in clouds; facet junctions may be rounded; polishing lines all in one direction as in *Figure 9* [variable]; occasional small surface cavities or 'whitish' pits; girdle frosted, polished or striated, but no bearding.

Optical refractive properties

Refractive indices 2.648 and 2.691 [2.417]; reflectometers give a reading above that for diamond: doubly refractive, uniaxial positive [singly refractive, isotropic]; birefringence moderate, 0.043 [none]; dispersion strong 0.104 [moderate, 0.044]; polariscope examination negative through the table, doubly refracting in other directions [negative]; relief in SG 3.32 liquid high [high].

Examined through a hand-held spectroscope, synthetic moissanite shows no absorption lines but there is a cut-off below about 425 nm[1], which could be confused with the diamond 'Cape' line at 415 nm;

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[1] The 4*H* form of moissanite, the only other polytype that can be grown in large crystals at present, has properties very close to those of the 6*H* form here described (see also *Table I*), except that the spectrum transmission cut-off is below 400 nm

infrared, ultraviolet and Raman spectra are characteristic and different from those of diamond; fluorescence in short-wave and long-wave UV is inert (usually) to moderate orange, uniform if present [variable]; X-ray luminescence inert (usually) to moderate yellow [variable]; X-ray transparency medium opaque [transparent].

Chemical, mechanical, thermal and other characteristics

Composition SiC [C]; no other impurities detectable down to 0.001%; SG 3.22 ± 0.02 [3.52], therefore floats in methylene iodide (SG 3.32) [sinks]; precision density 3.224 g/cm^{-3}, hence a faceted stone weighs about 9% less than a diamond of equal size; hardness 9¼ [10]; Knoop hardness 2954 kg/mm^2 [8000 kg/mm^2]; toughness excellent [good to excellent]; twinning absent [twinning present]; no strong cleavage but a weak basal (0001) cleavage [prominent octahedral cleavage]; previously reported prominent cleavages in moissanite (O'Connor and Smiltens, 1960) were probably partings due to polytype mixtures, a type of twinning.

The stability of synthetic moissanite is better than diamond – in air to 1700°C, in vacuum to 2000°C, to most chemicals to well over 1000°C, except in contact with fluorine, chlorine, molten alkalis, and some molten metals (Divakar *et al.*, 1993); excellent resistance to in-situ soldering of broken prongs and all usual jewellery procedures such as setting, repairing and cleaning, including casting in place in gold jewellery as in *Figure 6*.

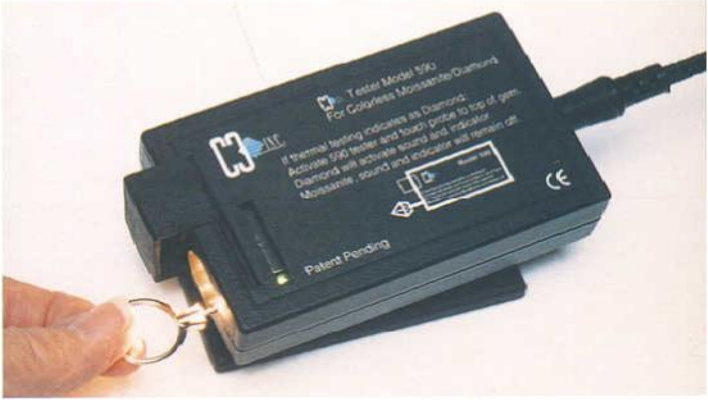
Thermal conductivity 2.3 to 4.9 W/cm.K (Harris, 1995) or 0.55 to 1.7 cal/cm.°C.sec [7 to 20 and 1.6 to 4.8, respectively], hence equally 'cold' as diamond; thermal inertia 0.3 to 0.63 cal/cm^2. °C. sec$^{1/2}$ [0.8 to 1.4], hence all thermal inertia ('thermal conductivity') testers currently in use give a 'diamond' reaction; heat capacity 28.5 J/mol.K (Verma and Krishna, 1966) or 0.170 cal/g. °C.

Moissanite is a semiconductor material just like diamond, hence only very low levels of impurities [same]; electrical conductivity variable [variable]; has been made in both highly conducting and insulating forms; conductivity (and colour) affected by the presence of very low levels (a few ppm) of donor nitrogen impurity (which also gives yellow to green to black colours when present at higher concentrations) [same], and of acceptor aluminium purity (which also gives a blue colour at higher concentrations) (Biederman, 1965; Verma and Krishna, 1966; Nakashima *et al.*, 1996) [the boron acceptor in diamond also causes it to be blue]; 'surface tension', wetting or 'diamond pen' test same as diamond (Nassau and Schonhorn, 1977).

The C3 Inc. Tester Model 590

The Colorless Moissanite/Diamond Tester Model 590 (*Figure 10*) was developed and is marketed by C3 Inc. to specifically distinguish between SiC and diamond after a thermal tester has given a positive 'diamond' indication. It determines relative transparency in the near-ultraviolet, a region where near-colourless diamond is transparent and synthetic moissanite absorbs. A polished facet of the stone being tested is placed in contact with the probe while the stone is illuminated at an angle by

Figure 10: *The Colorless Moissanite/Diamond Tester Model 590 is marketed by C3 Inc. for the purpose of rapidly distinguishing synthetic moissanite from diamond after a stone has been identified as 'diamond' on a thermal probe. Photo by Maha DeMaggio, courtesy of GIA.*



a small high-intensity halogen lamp. A light and buzzer indicate that diamond is being tested; absence of a reaction indicates moissanite. While not intended for use on other materials, many near-colourless gem materials also transmit in the near ultraviolet. Extensive testing with many moissanite specimens and with diamonds between D and X on the GIA colour scale showed a correct reaction in each instance. However, a correct indication may not be obtained from diamonds with abundant inclusions where barely any light manages to emerge from the stone. Tests with diamond/moissanite doublets made by cementing a thin diamond over synthetic moissanite also gave a 'moissanite' reaction.

Distinguishing synthetic moissanite from diamond

To a trained gemmologist, to distinguish SiC from diamond should present no problems. Under a loupe, the double refraction as seen when focusing deep within a stone (*Figure 2*) is diagnostic. It must be emphasized that visual examination looking squarely down at the table can be misleading, since all synthetic moissanites currently marketed are faceted with the optic axis perpendicular to the table.

As *Figures 7* and *8* show, the presence of sub-parallel needles and stringers near perpendicular to the table facet are strong indications of moissanite. Synthetic moissanite may also show uni-directional polishing lines (*Figure 9*) and rounded facet junctions.

Indicative but not necessarily conclusive results can be obtained from the spectroscope (but see the footnote comment on p.434 for the 4*H* form of moissanite), fluorescence and electrical conductivity, all of which can be variable. Reflectometers can give positive identification, but great care must be taken, since these may give variable responses with doublets and with dirty or poorly polished surfaces.

M. Kellam at C3 Inc. (pers. comm.) reports that during ongoing research on synthetic moissanite a process has been discovered that can lower the apparent refractive index to the point where a reflectance meter gives a 'diamond' reading. The change in refractive index is a surface effect and it is permanent. Accordingly it is not safe to rely on a reflectometer to distinguish synthetic moissanite from diamond. Removal of a thin surface layer will, of course, restore the intrinsic refractive index. The surface layer consists of silica (silicon dioxide) formed when synthetic moissanite is heated at high temperature in air or oxygen.

A thermal tester will give a positive 'diamond' response for both diamond and moissanite, distinguishing these two materials from all other gemstones; the C3 Inc. Tester Model 590 described above can then be used to further identify the diamond or moissanite. For loose stones, the measurement of specific gravity can provide a convenient method of distinction; moissanites float but diamonds sink in methylene iodide; note that care and adequate ventilation are required with this toxic material. Both the near-ultraviolet and X-ray opacities could also be used as distinguishing criteria.

Summary

Synthetic moissanite is an interesting new gemstone material. At present it can be grown in green, yellow, blue and near-colourless forms, the last of these providing a believable diamond substitute that is closer in appearance and heft to diamond than any other gemstone material.

Compared to diamond, it has more dispersion, similar brilliance, a higher RI, a slightly lower SG, is closer in hardness to diamond than any other gemstone material known to man, but does have a significant birefringence.

The structure in diamond is based on a tetrahedral network of carbon atoms in an overall cubic structure. In moissanite the network is also tetrahedral, but with every other carbon atom replaced by a silicon atom. Just as carbon can exist in two polytypes, cubic diamond and hexagonal lonsdaleite, so silicon carbide can exist in cubic, hexagonal and rhombohedral polytypes, all traditionally designated moissanite, see *Table I*.

Only two moissanite polytypes, both hexagonal, can be grown at present in large crystals, the moissanite-6*H* here described in detail, and the moissanite-4*H* mentioned above. Because the prominent octahedral (111) cleavage of diamond is not present in synthetic moissanite, this material is tougher than diamond. It is also more resistant to high temperatures and gold jewellery can be cast with stones in place (*Figure 5*).

A positive distinction from diamond is most conveniently obtained in one of three ways:

a. for the trained gemmologist, by examination under magnification primarily for birefringence (*Figure 2*) and inclusions (*Figures 7* and *8*), secondarily for girdle, facet edges and polishing marks (*Figure 9*);
b. by the use of a thermal tester followed by the C3 Inc. Tester Model 590 (*Figure 10*); or
c. for loose stones by flotation in methylene iodide.

While there have already been a number of misidentifications based on blind reliance on thermal testers, knowledge of the characteristics of this new synthetic material should readily prevent such occurrences.

References

Acheson, E.G., 1893. US Patent 492,767, February 28, 1893

Biederman, E., 1965. The optical absorption bands and their anisotropy. In: *The various modifications of SiC. Solid State communications*. Vol. 3, pp. 343–6

Carter, C.H., Tsvetkov, V.F., and Glass, R.C., 1998. US Patent 5,718,760, February 17, 1998

Davis, R.F., Carter, C.H., and Hunter, C.E., 1990. *Sublimation of silicon carbide to produce large, device quality single crystals of silicon carbide.* US Patent Re. 34, 861, February 14, 1995. (Reissue of US Patent 4,866,005, September 12, 1989; reissue application filed October 26, 1990.)

De Ment, J., 1948. New gem superior to diamond. *The Mineralogist*, **16**, 211–18

De Ment, J., 1949. Silicon carbide – rival to the diamond, in brilliancy. *The Gemmologist*, **17–18**, 53–9

Divakar, R., Chia, K.Y., Kunz, S.M., and Lau, S.K., 1993. Carbides (silicon): Silicon carbide. In: Howe-Grant, M. (Ed.), *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd edn. John Wiley and Sons, New York, Vol. 4, pp. 891–911

Gill, J.O., 1978. *Gill's index*. Gemological Institute of America, Santa Monica, CA, pp. 191–2

Harris, G.L. (Ed.), 1995. *Properties of silicon carbide. Electronic materials information service*. Vol. 13. Institute of Electrical Engineers, London (INSPEC)

Harrow, B., 1920. *Eminent chemists of our time*. D. Van Nostrand Co., New York. pp. 135–54

Hunter, C.E., and Verbiest, D., 1998. US Patent 5,723,391. March 3, 1998; US Patent 5,762,896, June 9, 1998

Kunz, G.F., 1905. 'Moissanite.' *American Journal of Science*, Series 4, **19** (113), 396–7

Lely, J.A., 1955. Darstellung von Einkristallen von Silicum-carbid und Beherrschung von Art und Menge der eingebauten Verunreinigungen. *Berichte der Deutschen Keramischen Gesellschaft*, **32**, 229–31

McCawley, E.L., 1981. Cubic moissanite – a gem mineral of the diamond family. *Lapidary Journal*, **34** (10), 2244–7

Mellor, C., 1929. *A comprehensive treatise on inorganic and theoretical chemistry*. Longmans, Green & Co., London. Vol. 5, pp 875–87

Mitchell, R.K., 1962. A rare synthetic. *Journal of Gemmology*, **8** (6), 218–20

Moissan, F.F.H., 1904. *Etude de la meteorite de Canyon Diablo*. Comptes Rendus de Academie des Sciences, Paris, **139**, 773

Moissan, H., 1920. *The electric furnace*. Translated by V. Lenher. 2nd edn. Chemical Publishing Co., Easton, PA.

Nakashima, S., Matsunami, H., Yoshida, S., and Harima, H. (Eds), 1996. Silicon carbide and related materials. *Proceedings of the Sixth International Conference, Kyoto, Japan*. September 18–21, 1995. Conference Series No. 142, Institute of Physics Publishing, Philadelphia, USA

Nassau, K., 1980. *Gems made by man*. Gemological Institute of America, Santa Monica, CA, pp. 4, 166–7, 252–3, 343

Nassau, K., McClure, S.F., Elen, S., and Shigley, J.E., 1997. Synthetic moissanite: a new diamond substitute. *Gems & Gemology*, **33** (4), 260–75

Nassau, K., and Schonhorn, H., 1977. The contact angle of water on gems. *Gems & Gemology*, **15** (12), 354–60

O'Connor, J.R., and Smiltens, J., 1960. Silicon carbide: a high temperature semiconductor. *Proceedings of the Conference on Silicon Carbide, Boston, MA*, April 2–3, 1959. Pergamon Press, New York

Smoak, R.H., Korzekwa, T.M., Kunz, S.M., and Howell, E.D., 1978. Carbides: silicon carbide. In: Eckroth, D. (Ed.), *Kirk-Othmer Encyclopedia of Chemical Technology*, 3rd edn. John Wiley & Sons, New York, Vol. 4, pp 520–35

Tairov, Y.M., and Tsvetkov, V.F., 1981. Growing large-size, single crystals of various silicon carbide polytypes. *Journal of Crystal Growth*, **52**, 146–50

Tsvetkov, V.F., Allen, S.T., Kong, H.S., and Carter, C.H. Jr., 1996. Recent progress in SiC crystal growth. In: Nakashima, *et al.*, 1996 ibid.

Verma, A.R., and Krishna, P., 1966. Polymorphism and polytypism in crystals. John Wiley & Sons, New York. pp. 81–113, 234–41, etc.

Von Muench, W., 1982. Silicon carbide. In: Madelung, O. (Ed.), *Landolt-Boernstein numerical data and functional* *relationships in science and technology*. New Series Group III. Springer Verlag, New York, Vol. 17a, pp. 132–42, 442–9

Von Muench, W., 1984. Silicon carbide. In: Schultz, M., Weiss, H. (Eds), *Landolt-Boernstein numerical data and functional relationships in science and technology*. New Series Group III. Springer Verlag, New York, Vol. 17c, pp. 403–16, 585–92

Wilke, K.-Th., 1988. *Kristallzuechtung*. Verlag Harri Deutsch, Thun, Frankfurt, pp. 492, 494–9, 999, 1011

Further reading

Balaziak, R., 1997. Manufactured abrasives in the third quarter of 1997. In: *Mineral industry surveys*. US Department of the Interior, US Geological Survey, Reston, VA

Bruton, E., 1978. *Diamonds*. 2nd edn. Chilton Book Co., Radnor, Pa. p. 402

GIA Gem Property Chart, 1992. Gemological Institute of America, Santa Monica, CA

GIA Gem Reference Guide, 1988. Gemological Institute of America, Santa Monica, CA

Hallbauer, D.K., Kable, E.J., and Robinson, D.N., 1980. The occurrence of detrital diamond and moissanite in the proterozoic Witwatersrand conglomerates and their implication for crustal evolution. *Berliner Geowissenschaftliche Abhandlungen, Series A, Geologie und Palaeontologie*, **19**, pp. 67–8

Hobbs, J., 1981. A simple approach to detecting diamond simulants. *Gems & Gemology*, **17**(1), 20–33

Mason, B., 1962. *Meteorites*. John Wiley & Sons Inc., New York, p. 61

Mathez, E.A., Fogel, R.A., Hutcheson, I.D., and Marshintsev, V.K., 1995. Carbon isotopic composition and origin of SiC from kimberlites of Yakutia, Russia. *Geochimica et Cosmochimica Acta*, **59** (4), 781–91

Moore, R.O., Otter, M.L., Rickord, R.S., Harris, J.W., and Gurney, J.J., 1986. The occurrence of moissanite and ferro-periclase as inclusions in diamonds. *Fourth International Kimberlite Conference, Geological Society of Australia, Sydney, Australia. Abstracts*, pp. 409–11

Obukhov, A.B., 1972. *Mineralogy of silicon carbide: silicon carbide in technical materials and rocks*. Akad. Nauk SSSR, Leningrad

Rodgers, K.A., Courtney, S.F., Seelye, R., McCulloch, A., and Mullholland, I., 1989. An occurrence of 'moissanite' (SiC) from Seddonville, West Coast, New Zealand. *New Zealand Natural Sciences*, **16**, 105–8

The Indian diamond-cutting industry: an assessment of the number of cutters and the size distribution of their production

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ABSTRACT: The number of diamond cutters in India during the 1990s has been estimated in published reports to be in the range of 600,000 – 800,000. Based on the number of diamonds polished annually in India, and the rate at which these stones are likely to be manufactured, we estimate that about 400,000 cutters working full time, mostly in modern factories, could produce the approximately 750 million diamonds currently polished annually in India. The high estimates for the number of cutters given in the literature include perhaps as many as 600,000 part-time workers in the cottage industry sector, some of whom only cut an average of one stone per day; there are only about 200,000 full-time diamond cutters.

Based on the amount (weight) of diamonds polished in India in the mid-1990s and their estimated average size (2.5 pt, or 0.025 ct), a hypothetical size distribution for diamonds is suggested. We calculate that approximately 80 per cent of the polished diamonds by weight, and 96 per cent by total number, are less than 10 pt (0.10 ct). Polished diamonds 3 pt (0.03 ct) and less constitute about 42 per cent by weight and 65 per cent (i.e. about 500 million) by total number of the stones polished in India.

Keywords: diamond, diamond cutting, India

Introduction

The modern diamond-cutting industry of India started very slowly in the late 1950s. In 1966 about 230,000 ct of polished diamonds, representing about 6 per cent of the world's production of polished by weight and 2 per cent by wholesale value, were exported and since then production has increased rapidly. In 1996, the most recent year for which data are available, 18.88 million carats (mct) of polished diamonds were exported from India representing about 70 per cent of the world's polished diamonds by weight and about 35 per cent by value. The Indian fiscal year, on which all statistical data are based, runs from April to March and is

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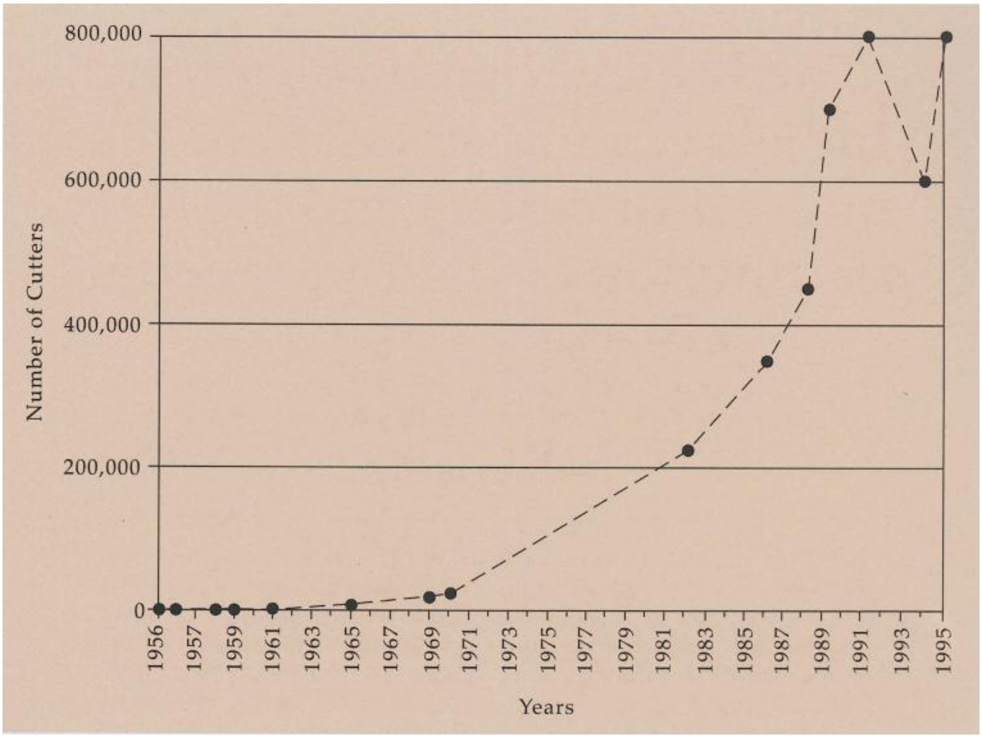

***Figure 1:** The dramatic increase in the purported number of diamond cutters in India (1955–1995) is illustrated by this graph of data from the literature.*

officially reported as, for example, 1996–97. However, for this paper we use the first year only, e.g. 1996, for simplicity and also because other data, e.g. the number of diamond cutters, are reported on a calendar-year basis. It is assumed that all diamonds polished in India are exported, as is required by law.

In general, stones polished in India are very small averaging about 0.025 ct or 2.5 pt or 40 stones per carat (spc). Thus, in 1996 we estimate that India produced about 755 million polished diamonds (18.88 mct x 40 spc) (see Sevdermish *et al.*, 1998, for a history of the development of the modern diamond-cutting industry in India and historical details of its polished production). Other estimates of the number of stones polished in India are similar. For example, Anonymous (1997) stated that worldwide about 850 million polished diamonds are set into jewellery annually, of which 11 out of 12, i.e. 779 million, are cut in India.

The vast number of small polished diamonds produced in India requires an equally vast number of diamond cutters. So, are the estimates of how many diamond cutters there are in India true? We use the term 'cutter' to include all those directly involved in the physical aspects of manufacturing polished diamonds, i.e. cleavers, bruters and polishers who we assume act as a 'team'. In the diamond market as a whole it is also of interest to know the size distribution of the diamonds polished in India.

Estimates in the literature of the number of diamond cutters in India

Table I contains a compilation from the literature of the purported number of diamond cutters in India (estimates are available for 16 years only); however, there is

Table I: Purported number of diamond cutters in India (from literature sources) and the average number of carats polished annually by each cutter (calculated)

1 Year	2 Number of cutters	3 Reference	4 Polished diamonds exported annually (mct)[1]	5 Average weight of diamonds polished annually per cutter (carats)[2]
1955	800	Leeper (1957)	not known	–
1956	1500	Moyar (1959)	not known	–
1957	1250	Moyar (1959)		
		(average of 1200–1300)	not known	–
1958	1200	Moyar (1960)	not known	–
1959	2000	Moyar (1960)	not known	–
1961	2500	Moyar and Buxant (1963)	not known	–
1965	8000	Szenberg (1973)	not known	–
1969	20,000	Stuyck (1969)	0.48	24
1970	25,000	Kinsbergen (1970)	0.53	21
1982	225,000	Rothschild (1982)	4.66	21
1986	350,000	Anonymous (1986)	7.52	21
1988	450,000	Johnson *et al.* (1989)		
		(average of 400,000–500,000)	11.03	25
1989	700,000	Liddicoat and Boyajian (1990)	10.11	14
1991	800,000	Sharma (1992)	8.72	11
1994	600,000	Jhaveri (1994)	15.98	27
1995	800,000	Pandya (1997)	19.21	24

1. See Sevdermish *et al.*, 1998
2. Average calculated by dividing Column 4 by Column 2.

no distinction between those working in modern factories (generally full time) and those working in the cottage industry sector (generally part time). The data are plotted in *Figure 1* and graphically show the amazing 1000-fold increase in the number of cutters in 36 years from 800 in 1955 to a peak of 800,000 in 1991. Since then there has been a decrease to 600,000 cutters in 1994 but then another rise to an estimated 800,000 in 1995; these changes approximately reflect market conditions, specifically, the quantities of diamonds polished in India that were sold in world markets annually (Sevdermish *et al.*, 1998). Thus, if we accept the data in *Table I*, in 1995 about one out of every 1125 people in India cut diamonds as a source of income (assuming a population of 900 million). It is unlikely, however, that all – or even most – of these people were cutting full-time.

Calculations necessary to determine the number of cutters in India

Purported productivity of Indian cutters

By dividing the annual polished diamond exports (by weight) from India (*Table I*, column 4) by the reported number of cutters (*Table I*, column 2), the average number of carats polished annually per cutter is

Table II: Reported productivity of Indian diamond cutters in the mid-1990s compared with expected productivity based on the authors' assumptions (see text for details).

	Reported	Expected	Ratio (Expected/ reported)
Number of carats polished annually per cutter	23	48	2.1
Number of stones polished annually per cutter	920	1920	2.1
Number of stones polished per day per cutter	4	8	2.0
Number of points polished per day per cutter	10	20	2.0

obtained (*Table I*, column 5). Eliminating the two extremely low values of 11 and 14 (again see *Table I*, column 5), all remaining values from 1969–1995 are within the relatively narrow range of 21–27, with an average of approximately 23 ct per year per cutter. (Even if the two low values are included, the average is 21 ct per year, a value that does not significantly affect the following discussion.)

If we accept that each cutter in India produces 23 ct of polished diamonds each year, and we accept that India's polished diamond exports average 40 stones per carat (i.e. they are 2.5 pt stones; see above), then the average cutter in India produces 920 stones (23 ct x 40 stones) per year. Further, assuming that an Indian cutter works 240 days per year, then the average diamond cutter in India cuts a mere four (actually 3.8) stones per day (920 stones ÷ 240 days) which is equal to 10 pt (4 stones x 2.5 pt) of polished diamonds per day. (Full-time workers in India typically work 5.5 to 6 days a week, 44–48 hours per week and take 10 weeks of leave annually; about 6 weeks for Diwali and about a month in May/June. Part-timers also take about two additional months at harvest time.)

Estimated productivity of Indian cutters

When the above information is considered in the light of the production of cutters in other parts of the world, especially those in modern factories, we encounter an enigma. For example, in Israel when diamond cutters polished 5 pt stones they produced an average of 10 stones (50 pt of polished) per day (although stones of this small size are rarely cut in Israel today). Based on the senior author's experience, a full-time, experienced worker in a modern factory in India could cut an average of eight 2.5 pt stones (20 pt of polished) a day (the lower number, i.e. 20 pt vs 50 pt polished per day for cutting stones of different but comparable sizes, i.e. 2.5 pt and 5 pt, reflects a lesser degree of automation in India compared to Israel). From this it follows that: (a) an experienced, full-time diamond cutter in India could cut, on average, 1920 2.5 pt stones per year (240 days x 8 stones per day), equivalent to 48 ct (1920 stones ÷ 40 stones per ct) of polished diamonds per year.

Our estimate of the number of diamond cutters in India

Table II contains a summary of the reported vs. expected productivity of Indian diamond cutters in the mid-1990s based on the assumptions we have made, e.g. cut stones average 2.5 pt. Most importantly, if the Indian diamond-cutting industry did employ 800,000 experienced and full-time workers, expected productivity should be about 2.1 times (ratio: expected/reported) greater than it actually is.

Further, it follows that if each of the purported 800,000 workers in India in 1995 (*Table I*) were experienced and full time, then India should have produced 1536 million 2.5 pt stones (800,000 cutters x 1920 stones per year). Again assuming 40 stones per carat, this would be the equivalent to 38.4 mct annually – about two times greater than the maximum ever produced in any one

Table III: Hypothetical distribution of diamond cutters in India in 1996 by employment category designation and the contribution of each category to the total number of diamonds polished.

Employment category designation	1 Number of diamond cutters	2 Number of diamonds cut per day per cutter (estimated; this paper)	3 Number of diamonds cut per year per cutter (col. 2 x 240)[1]	4 Number of diamonds cut annually by all workers (col. 1 x col. 3)
A. Full time (in modern factories)	200,000	8	1920	384,000,000
B. Cottage industry predominantly	200,000	5	1200	240,000,000
C. Part-time workers in cottage industry and factories	200,000	2	480	96,000,000
D. Auxiliary workers	200,000	1	240	48,000,000
Total	800,000			768,000,000

1. Assuming 240 working days per year

year (19.21 mct in 1995; *Table I*, column 4). Working from another direction, we would also say that if all the cutters in India worked full time (240 days per year), each producing 8 stones per day (or 48 ct per year), then 'only' 400,000 cutters in India would have been needed to cut all the polished stones produced in 1995 (19.21 million ct/yr divided by 48 ct/yr/cutter).

Clearly, the purported number of diamond cutters must include a vast number of people who work only part time if the total number of workers in 1995 is assumed to be 800,000. They range from farmers, who do not cut diamonds during the growing seasons, to children who only cut diamonds when not in school. Older studies reported that children made up 10–15 per cent of the workforce (Anonymous, 1989), but a 1995 survey showed that child labour (below the age of 14 years) constituted only 0.4 per cent in the 'organized sector' (i.e. factories) of the workforce and 3.4 per cent in the 'unorganized sector' (i.e. cottage industry) (Pandya, 1997); further improvements toward the total eradication of child labour is a goal of the Government of India.

Employment for occasional workers also depends on market conditions. For example, in 1991 when polished-diamond production in India was very low (only 8.72 mct; see *Table I*), occasional workers were probably not employed to any significant extent even if they were available for work. (The low production of polished diamonds in 1991, coupled with the apparent employment of 800,000 cutters when there was undoubtedly significant unemployment, is the reason for the average of only 11 ct/yr/cutter that year.)

Supportive of our concept that there are fewer cutters than stated in the literature is the fact that in mid-1990, when there were a purported 800,000 cutters, there were only about 135,000 scaifes in use in India (Curtis, 1991) which are too few to enable 800,000 cutters to work full time. More likely, at that time about half these scaifes were in modern lapidaries where two cutters typically use the same scaife (a total of 135,000 cutters) and the other half were engaged in the cottage-industry sector where typically three (rarely four) cutters use the same scaife (a total of 202,500 cutters).

A hypothetical scenario illustrating the number of full-time and various categories of part-time workers in India, and their productivity, is given in *Table III*. The categories are based on the average number of polished diamonds, i.e. 1, 2, 5 and 8, that we suggest Indian diamond cutters produce daily over the year. Based on data from 1996 in which about 755 million diamonds averaging 2.5 pt were cut in India, and which data we believe are representative of the

Table IV: Hypothetical distribution by size (weight) of 18.88 million carats of diamonds polished in India in 1996.

1 Size categories (weight)	2 Weight range	3 Number of carats of polished	4 Percentage of polished stones by weight (from col. 3)	5 Average number of polished stones per carat; 1 ÷ by col. 2)	6 Number of polished stones (col. 3 x col. 5)	7 Percentage of polished stones produced (from col. 6)
A	> 0.5	500,000	2.6	2	1,000,000	0.1
B	0.2–0.5	1,000,000	5.3	5	5,000,000	0.7
C	0.1–0.2	2,500,000	13.2	10	25,000,000	3.3
D	0.03–0.1	7,000,000	37.0	33	231,000,000	30.6
E	< 0.03	7,900,000	41.8	62.5	493,750,000	65.3
Total:		18,900,000			755,750,000	

Indian diamond industry at least since 1995, there are probably about 200,000 full-time cutters in well organized lapidaries, some using modern equipment, who produce about half of India's polished diamonds (*Table III*, column 4). The vast majority of the remaining 600,000 or so workers do not work full time, and certainly not in modern factories; some probably average no more than one stone per day working at home with relatively simple equipment in the cottage-industry environment. Thus, we conclude that there might be 800,000 people in India involved to some extent in cutting diamonds; however, only about 25 per cent of them are involved full time.

Size distribution of diamonds polished in India

To this point we have emphasized for purposes of calculation that the average size of diamonds polished in India is 2.5 pt (40 spc) and now it is appropriate to consider the size distribution of Indian polished diamonds in greater detail. Although most of India's production is very small in size, in recent years perhaps 20 per cent by weight of the stones have been over 10 pt. Further, in the period 1991–1996 about 1 mct of polished diamonds from India weighing over 0.50 ct were imported into the United States (see Sevdermish *et al.*, 1998, for further details).

Taking these facts into account it is possible to estimate the size distribution of the stones (range of sizes) of the Indian production. We use data for 1996 in which 18.88 mct of polished diamonds were produced which represents about 755 million stones averaging 2.5 pt (18.88 mct x 40 spc = 755.2 million). The hypothetical size distribution is presented in *Table IV* where the polished diamonds are placed in five size categories.

The data in *Table IV* show that the vast majority of the stones polished in India are under 10 pt (categories D and E); these total 78.8 per cent by weight, and 95.9 per cent by number, of all polished diamonds. Further inspection of the tabulation above shows that: (a) although the largest stones above 0.50 ct (category A) constitute 2.6 per cent of the total production by weight, they make up only 0.1 per cent of the total number of polished stones; and, similarly, (b) although the largest three categories (A, B, C; 0.1 ct and above) constitute 21.1 per cent of the total production by weight, they make up only 4.1 per cent of the total number of polished stones.

Discussion and conclusions

There can be few industries in the world for which reliable statistics are as elusive as the diamond business. Because the diamond market is secretive and there is a reluctance on the part of all segments to disclose detailed information on their activities, researchers are forced to make do with what is available in the open literature that originates from such sources as Government bodies and trade journals. In addition, this study has been hampered by the difficulty in obtaining accurate data from the cottage industry sector which is characterized by poor record keeping. Thus, the use of estimates and extrapolations is normal to discern concepts, trends and other objectives. We have found it necessary to resort to such techniques, including developing certain hypothetical models. Nevertheless, we feel that the hypotheses upon which we base our discussions and manipulations are realistic, particularly since they permit us to arrive at logical conclusions that are internally consistent and also are in agreement with conventional wisdom in the industry.

The diamond-cutting industry in India currently produces about 750 million polished diamonds annually. Calculations based on a hypothetical size distribution show that about 96 per cent of these diamonds weigh less than 10 pt; about 65 per cent of these diamonds, consisting of about 500 million stones, are about 3 pt or less. To cut and polish this huge number of stones, there are about 200,000 full-time workers, mostly in modern factories who polish half the stones. Another 600,000 workers are part time, some of them produce no more than one stone per day.

In recent years, and especially starting in 1998, India has seen a considerable change in the nature and the size of polished diamonds produced there. Until 1997 one could safely assume that the average cut stone was about 2.5 pt, or 40 spc, and of poor quality. However, today the average size of the diamonds cut in India is certainly larger, and the quality is improving. This is not due to the fact that India has stopped cutting low quality gems of 1–3 pt, rather it is because in recent years many more larger, better quality stones are cut in India than ever before. Many stones, larger than 50 pt and up to 2 ct, cut in India now are available on the world market. This trend becomes clear when we compare the official cut-diamond import data for the U.S.A. in 1996 and 1997. In 1996, 259,000 ct over 50 pt were imported into the U.S.A. from India which represented 3.5 per cent of the total U.S.A. imports from India. In 1997 this increased to 375,000 ct which represented a 45 per cent increase in this size category and 4.6 per cent of the total Indian polished-diamond imports to the U.S.A. (United States Geological Survey, 1998, table 7). Although figures are not yet available for 1998, we are confident that the statistics will show that the amount of larger (> 50 pt) Indian cut diamonds, and the ratio of larger gems to smaller gems cut in India, imported into the U.S.A. will have increased even more. The effect of these changes on the local Indian cutting industry will be significant in two main areas: first, the cutting of larger stones will require more highly trained personnel and, secondly, there will be an increase in the number of well-equipped modern facilities required for expensive stones and not available in the cottage-industry sector.

References

Anonymous, 1986. B. Arunkumar's 25th anniversary. *In-Sight*, Spring, 12

Anonymous, 1989. India expands on all fronts. *Diamond International*, 1, 29–31, 33–6

Anonymous, 1997. 1998: the year of the ripple effect. *Mazal U'Bracha*, 14 (97), 19

Curtis, A.C., 1991. Scaife technology: polishing powders and binders. In: Cooke, P., and Caspi, A. (Eds), *Proceedings of the International Diamond Technical Symposium, Tel Aviv*, 1991, Chapter 19, CSO Valuations AG [London], 19.1–19.15

Jhaveri, K.C., 1994. India needs more, better rough for successful diversification. *Diamond World*, **21** (4), 48–9

Johnson, C.J., Marriott, M., and von Saldern, M., 1989. World diamond industry: 1970-2000. *Natural Resources Forum*, **13** (2), 90–106

Kinsbergen, A., 1970. Difficult times for the diamond industry. *Diamant*, **13** (131), 7

Leeper, R., 1957. The development of the diamond industry. *Optima*, 7(3), 125–9

Liddicoat, R.T., and Boyajian, W.E., 1990. The 1980s in review: new realities of the gem and jewelry industry. *Gems & Gemology*, **26** (1), 1–2

Moyar, A., 1959. *The diamond industry in 1957–1958*. Vlaams Economisch Verbond, Antwerp

Moyar, A., 1960. *The diamond industry in 1958–1959*. Vlaams Economisch Verbond, Antwerp

Moyar, A., and Buxant, E., 1963. *The diamond industry in 1960–1961*. Vlaams Economisch Verbond, Antwerp

Pandya, P.S., 1997. Child labour allegations strongly refuted by India. *Diamond World*, **25** (1), 23–5

Rothschild, G.L.S., 1982. Diamond: today and tomorrow. In: Eash, D.M. (Ed.), *Proceedings of the International Gemological Symposium 1982*, Gemological Institute of America, Santa Monica, CA, xxv-xxxvi

Sevdermish, M., Miciak, A.R., and Levinson, A.A., 1998. The rise to prominence of the modern diamond cutting industry in India. *Gems & Gemology*, **34** (1), 4–23

Sevdermish, M., and Mashiah, A., 1997. *The dealer's book of gems and diamonds*. Gemology AM, Israel, 584–7

Sharma, S.N., 1992. The diamond industry of India. In: Keller, A.S. (Ed.), *Proceedings of the International Gemological Symposium 1991*, Gemological Institute of America, Santa Monica, CA, 49

Stuyck, R., 1969. Rise of the Indian diamond cutting industry. *Diamant*, **12** (113), 20–1

Szenberg, M., 1973. *The economics of the Israeli diamond industry*. Basic Books, New York, 183 pp

United States Geological Survey, 1998. Gemstones. 1997 Annual Review. In *Mineral Industry Surveys*, United States Dept. of the Interior, Washington

Druses of synthetic alexandrite and synthetic phenakite from Russia

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ABSTRACT: Two druses of synthetic alexandrite and phenakite crystals were reportedly grown in Novosibirsk, Russia. Both minerals contain inclusions typical of flux growth, and their origin in a silicate melt rich in Be, Al and Cr is discussed.

Keywords: synthetic alexandrite, synthetic phenakite

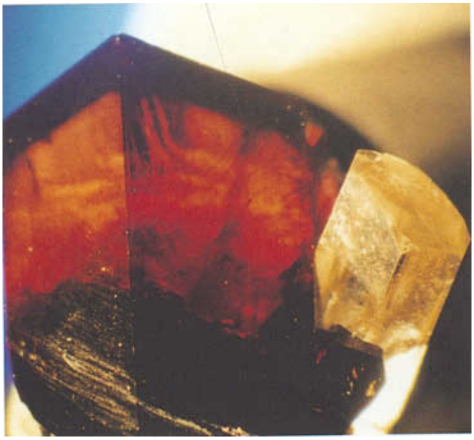
Introduction

Growing synthetic stones from a flux is a common practice nowadays and the method is used particularly to produce rubies, sapphires, emeralds, alexandrites and spinels. Normally, crystals are grown singly or in monomineralic druses. Exceptions to these conditions are very rare and when a different mineral starts growing on the seed it indicates that some unpredicted changes have taken place in the growing process.

Some years ago, the senior author first saw an example of this phenomenon, a specimen consisting of two olive-green YAG crystals (each about 1 cm long), with a flat dark-red ruby crystal about 3 cm long which was covered by younger pink ruby pseudo-octahedrons. Apparently, this unique specimen had been grown accidentally in the Bell Laboratories (Art Grant, pers. comm.).

Figure 1: *Synthetic alexandrite and phenakite, 15 x 13 mm (photo: J. Hyrsl).*

Figure 2: *Synthetic alexandrite and phenakite, 11 x 9 mm, transmitted light (photo: I. Quintens).*



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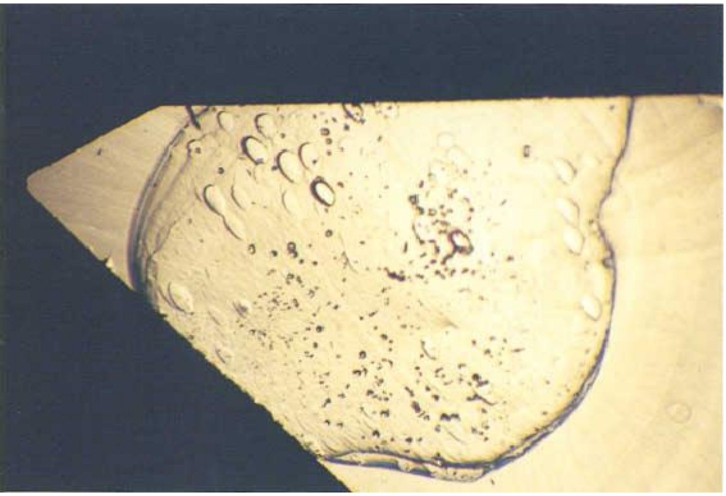


Figure 3: *Rounded growth patterns on synthetic alexandrite, x35, oblique light (photo: I. Quintens).*

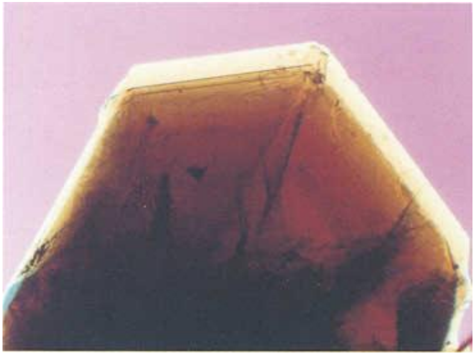


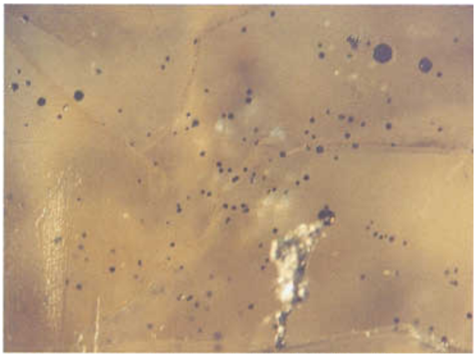
Figure 5: *Near colourless outer zone and flux veils in synthetic alexandrite, x15, transmitted light (photo: I. Quintens).*

Alexandrite and phenakite

Two interesting specimens were obtained recently from a Russian dealer and reportedly come from Novosibirsk. These consist of almost black crystals of alexandrite up to 12 x 9 x 9 mm supporting yellowish phenakite crystals up to about 5 x 2 x 2 mm (*Figures 1 and 2*). Crystal faces of the alexandrite show rounded growth patterns, indicating a synthetic origin (*Figure 3*) and are irregularly developed trillings. The typical colour-change of the alexandrite can be seen only at the edges of the crystals and under strong illumination. The saturated colour also makes it very difficult to observe inclusions. Nevertheless, with strong transmitted light, some typical internal characteristics can be detected. Trigonal or distorted blackish inclusions with submetallic lustre (?hematite) reach the surfaces of some crystals (*Figure 4*), and flux veils are abundant; growth features and colour zoning are less common (*Figure 5*) and mostly confined to the outer rim. Refractive indices were measured on flat crystal faces

Figure 4: *Black triangular crystal of ?hematite in synthetic alexandrite, x63, oblique light (photo: I. Quintens).*

Figure 6: *Hexagonal ?platinum crystals in a synthetic phenakite crystal, x30, transmitted light (photo: J. Hyrsl).*



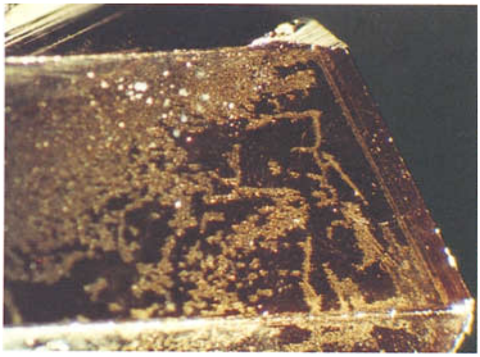


Figure 7: *Flux particles near the surface of a synthetic phenakite crystal, x16, oblique light (photo: I. Quintens).*

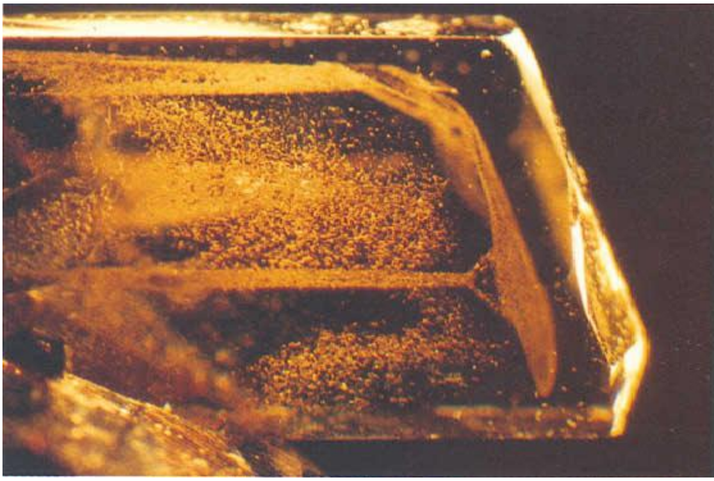


Figure 8: *Flux in a form resembling a phantom crystal in synthetic phenakite, x25, darkfield (photo: I. Quintens).*

and yielded values between 1.750 and 1.758, with a birefringence of 0.008. No fluorescence in UV was observed, possibly indicating the presence of iron.

Phenakite forms simple hexagonal prisms terminated by several irregular low rhombohedron faces. It is yellowish and transparent. Three similar single synthetic phenakite crystals from Novosibirsk were also available for study; they are only slightly yellowish and are up to 13 mm long. Their refractive indices are o = 1.659 and e = 1.673 with a birefringence of 0.014, and their specific gravity was found to be 2.97–2.99. No fluorescence was seen under an ultraviolet lamp. Under a microscope they show fine curved veils of brown and yellow flux, much coarser black remnants of a ?flux with a strong metallic lustre in reflected light and flat, almost round crystals of ?platinum in groups near the surface (*Figure 6*). Dust-like flux following crystal faces can in rare instances form phantom-like patterns (*Figures 7 and 8*). Blue-green crystals of flux-grown synthetic phenakite from Russia were described by Koivula *et al.* (1994).

Conclusion

The association of these two synthetic species is somewhat surprising. Phenakite (Be_2SiO_4), as a by-product of synthesis of beryl in a silica-rich medium, is a very common inclusion in synthetic beryl ($Be_3Al_2Si_3O_8$). On the other hand, chrysoberyl variety alexandrite ($BeAl_2O_4$ + Cr), being an oxide, is generally grown in silica-poor conditions. Nevertheless, the described specimens must have grown in a mixture where elements Be, Al, Cr and Si were all present in sufficient amounts to develop both alexandrite and phenakite.

Reference

Koivula, J.I., Kammerling, R.C., and Fritsch, E. (Eds.), 1994. Gem news. *Gems & Gemology*, 30, 199–200

Abstracts

Diamonds

Instruments and Techniques

Gems and Minerals

Synthetics and Simulants

Diamonds

Rb–Sr ages on kimberlites from the Lac de Gras area, Northwest Territories, Canada.

R.A. ARMSTRONG AND R.O. MOORE. *South African Journal of Geology*, **101**(2), 1998, 155–8.

Rb-Sr dating of two kimberlites, from the Lac de Gras area within the Slave craton in the Northwest Territories, shows they are of Eocene age. Leached phlogopite and whole-rock isochrons give Rb–Sr ages of 47.5 ± 1.6 and 52.1 ± 1.0 m.y., confirming palaeontological evidence from fossils in mudstones preserved as xenoliths within the kimberlites. J.F.

Has science overthrown the King of Gems?

A. BERNARD. *Australian Gemmologist*, **20**(4), 1998, 138–40, 1 illus. in black-and-white.

A brief review of the history of diamond synthesis which contrasts the attributes and appeal of natural diamond with its synthetic counterpart and, in terms of hardness, with the new superhard material carbon nitride. P.G.R.

Subduction-related diamonds? – The evidence for a mantle-derived origin from coupled $\delta^{13}C$–$\delta^{15}N$ determinations.

P. CARTIGNY, J.W. HARRIS, D. PHILLIPS, M. GIRARD AND M. JAVOY. *Chemical Geology*, **147**(1–2), 1998, 147–59.

Coupled determinations of $\delta^{13}C$–$\delta^{15}N$, for more than 150 diamonds of known paragenesis, originating from different localities, argue against a direct formation from subducted biogenic carbon, and confirm the isotopic disequilibrium of nitrogen between the internal (mantle) and external (atmosphere + crust) reservoirs of the Earth, thus supporting the heterogeneous accretion model of the Earth inferred from earlier fibrous diamond studies. Non fibrous diamonds have recorded the evolution of the nitrogen isotopic mantle composition, from a $\delta^{15}N$ value <-25‰ to the present value of ~ -5‰, caused by recycling of nitrogen on a large scale during the early history of the Earth. J.F.

Diamond in jewellery manufacture.

D. HAYES. *Industrial Diamond Review*, **58**, 1998, 26–7, 6 photographs.

The article describes an operation in which precision, single-crystal diamond tooling is used as standard in the manufacture of gold, silver and copper jewellery in Korea. E.S.

Gemmologische Kurzinformationen. Ein neuer Typ farbbehandelter Diamanten. (A new type of colour treated diamonds.) [German with English abstract.]

U. HENN AND C.C. MILISENDA. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(1), 1999, 43–5, 2 illus. in colour, 1 graph, bibl.

The yellow-greenish stones were enhanced to brown 'fancy' coloured diamonds using the Russian 'BARS' system at high temperatures and high pressure. The absorption spectrum is different from that produced by natural as well as irradiated stones. They fluoresce green, partly along growth lines. Under the microscope one can see strong graining, fine cracks and cleavages under the table and around the girdle, as well as visible burn marks. E.S.

Mineral inclusions in diamonds from the River Ranch kimberlite, Zimbabwe.

M.G. KOPYLOVA, J.J. GURNEY AND L.R.M. DANIELS. *Contributions to Mineralogy & Petrology*, **129**(4), 1997, 366–84.

More than 99% of the small diamonds from the River Ranch kimberlite contain minerals of harzburgitic paragenesis: olivine, orthopyroxene, chromite and garnet,

Abstractors

A.A. Finch	A.A.F.	R.A. Howie	R.A.H.	W.E. Sharp	W.E.S.
J. Flinders	J.F.	M. O'Donoghue	M.O'D.	E. Stern	E.S.
R.K. Harrison	R.K.H.	P.G. Read	P.G.R.	I. Sunagawa	I.S.
C.L. Hayward	C.L.H.	G.W. Robinson	G.W.R.	I. Vesselinov	I.V.

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

ISSN: 1355-4565

with rare ferropericlase, amphibolite, pyrrhotite, pentlandite, strontian K–Cr loparite, rhönite, Cr-chevkinite and perovskite. Their compositions have been determined by EPMA. Most inclusions were equilibrated at 1080–1320°C and 47–62 bar with fo_2 between IW and WM buffers; the P–T profile beneath the Limpopo mobile belt is consistent with an ancient heat flow of 42 mW/m^2.
R.A.H.

Emplacement and reworking of Cretaceous, diamond-bearing, crater facies kimberlite of central Saskatchewan, Canada.

D.A. Leckie, B.A. Kjarsgaard, J. Block, D. McIntyre, D. McNeil, L. Stasiuk and L. Heaman. *Geological Society of America Bulletin*, **109**(8), 1997, 1000–20.

Detailed stratigraphical descriptions are given of a core through four facies of subaerial kimberlitic volcanism. The deposit is noted for the preservation of a pyroclastic kimberlitic facies with 5–25 μm diamonds. Detailed petrographical descriptions, XRD and chemical analyses are given for 18 samples. U-Pb dates on perovskites in a kimberlite lapillistone give an age of 101.1 m.y. which is consistent with the sedimentary setting. W.E.S.

Graphite pseudomorphs after diamond? A carbon isotope and spectroscopic study of graphite cuboids from the Maksyutov Complex, south Ural Mountains, Russia.

M.L. Leech and W.G. Ernst. *Geochimica et Cosmochimica Acta*, **62**(12), 1998, 2143–54.

Cuboid graphite aggregates (< 5 mm long mainly, but up to 13 x 10 mm) composed of flakes (4–100 μm) occur in mica schist near Karayanova. Carbon isotope analyses indicate that it is biogenic C. Spectroscopy, including TEM imaging, XRD and laser Raman microspectroscopy, shows that the graphite is well crystallized with only minor dislocation defects. IR spectroscopy shows no relict organic compounds. Comparison of thin sections through the cuboid aggregates and SEM imagery of Maksyutov graphite aggregates with diamond pseudomorphs from the Beni Bousera peridotite (N Morocco) shows many similarities. Although the results are inconclusive, the evidence suggests that the present graphite pseudomorphs are after diamond. R.K.H.

Simple identification and quantification of microdiamonds in rock thin-sections.

H.-J. Massonne, H.-J. Bernhardt, D. Dettmar, E. Kessler, O. Medenbach and T. Westphal. *European Journal of Mineralogy*, **10**(3), 1998, 497–504.

A method is described for the preparation of polished thin-sections which allows the rapid and quantitative detection of microdiamonds in high-P metamorphic rocks by distinctive pattern of striations on the polished surface of the thin-section. Diamonds as small as 1 μm are revealed by a striation pattern as soon as they emerge on the surface during the polishing procedure, but this pattern disappears almost immediately after extraction of the microdiamond that caused it. Results are presented for samples from diamondiferous gneiss and marble from the Lake Kumdy-Kol region of the Kokchetav Massif, N Kazakhstan. The examination of > 600 polished thin-sections of igneous and metamorphic rocks without a high-P origin showed striation patterns in < 1% of them;. here, the striations could conceivably be due to outside contamination. M.O'D.

Evaluation of diamond potential from the composition of peridotitic chromian diopside.

P. Nimis. *European Journal of Mineralogy*, **10**(3), 1998, 505–19.

Chemical variations known in synthetic and natural, high-P chromian diopsides have been used to evaluate the potential use of mantle-derived clinopyroxene as a diamond-indicator mineral in kimberlite and lamproite exploration. A two-step model is proposed that involves 1) identification of clinopyroxenes from garnet peridotite and 2) discrimination of those equilibrated within the diamond stability field. The first step is achieved via a Cr_2O_3 *vs* Al_2O_3 classification diagram together with a consideration of Al_2O_3 *vs* MgO relations. The exclusion of all other clinopyroxenes allows simple chemical parameters to be used as P–T indicators. The Ca in clinopyroxene is negatively correlated with T and the Al content is negatively correlated with P. A Ca *vs* Al plot can be used to identify clinopyroxenes that last equilibrated within the stability field of diamond with an 'accuracy' of 89%. R.A.H.

Of diamonds, dinosaurs and diastrophism: 150 million years of landscape evolution in southern Africa.

T.C. Partridge. *South African Journal of Geology*, **101**(3), 1998, 167–84.

In this Alex du Toit Memorial Lecture, the tectonic and geomorphological evolution of southern Africa during the post-Gondwana period is reviewed. Basic to an understanding of post-rifting events are: 1) the high elevation which much of Africa possessed prior to rifting, 2) the erosion of 1–3 km from its surface during the Cretaceous and 3) the role of Neogene uplift in re-establishing high elevations, particularly within the E half of the subcontinent. The configuration of the Upper Cretaceous river system is fundamental to an understanding of the present distribution of alluvial diamonds and of gems transported to the sea via these rivers. R.A.H.

Diamond precipitation and mantle metasomatism – evidence from the trace element chemistry of silicate inclusions in diamonds from Akwatia, Ghana.

T. Stachel and J.W. Harris. *Contributions to Mineralogy & Petrology*, **129**(2–3), 1997, 143–54.

Trace element concentrations in garnet, olivine, orthopyroxene and clinopyroxene included in diamonds from Akwatia were determined by SIMS. Incompatible trace elements are hosted in garnet and clinopyroxene, except for Sr which is equally distributed between orthopyroxene and garnet in harzburgitic diamonds. The separation between lherzolitic and harzburgitic paragenesis is also seen in the Ti and Sr contents in both olivine and garnet. Chondrite-normalized *REE* patterns of lherzolitic garnets are enriched (10–20 times chondritic) in *HREE* (La_N/Yb_N 0.02–0.06) while harzburgitic garnets have sinusoidal REE_N patterns with the highest values for Ce and Nd (2–8 times chondritic). The *REE* patterns for calculated melt compositions fall into the compositional fields for kimberlitic-lamproitic and carbonatitic melts. The much more strongly fractionated *REE* patterns calculated from harzburgitic garnets, and low Ti, Y, Zr and Hf, differ significantly from known alkaline and carbonatitic melts and require a different agent. Equilibration *T* for harzburgitic inclusions are generally below the C–H–O solidus of their paragenesis, those of lherzolitic inclusions are above; crystallization of harzburgitic diamonds from CO_2-bearing melts or fluids may thus be excluded. Diamond precipitation by oxidation of CH_4-rich fluids with highly fractionated trace element patterns is therefore favoured. R.A.H.

Rare and unusual mineral inclusions in diamonds from Mwadui, Tanzania.

T. Stachel, J.W. Harris and G.P. Brey. *Contributions to Mineralogy & Petrology*, **132**(1), 1998, 34–47.

Syngenetic diamond inclusions of diamond from the Mwadui kimberlite indicate sampling of an unusually fertile section of lithospheric mantle beneath the central African craton, as shown by a very high ratio (1:2) of lherzolitic to harzburgitic inclusions and low Mg/Fe ratios in olivine and orthopyroxene. Disequilibrium between garnet-olivine and garnet-orthopyroxene pairs suggests successive iron enrichment during diamond formation, e.g. giving harzburgitic garnet and lherzolitic olivine in the same diamond. Two diamonds, one with eclogitic garnets with moderate pyroxene solid solution, and the other with a single ferro-periclase inclusion, suggest the contribution of a small sub-lithospheric component. The discovery of the association Fe-FeO-Fe_3O_4 in one single diamond indicates diamond formation over a range of fo_2 conditions, possibly along redox fronts. Steep compositional gradients may also be reflected by the joint occurrence of harzburgitic garnet and a SiO_2-phase in the same diamond; alternatively, the SiO_2-phase may be due to extreme carbonation of the peridotitic source. Other unusual occurrences are the exsolution of a silicate phase from magnetite inclusions (i.e. primary solution of γ-olivine) and an ilmenite inclusion with an eskolaite (Cr_2O_3) component of 14.5 mol.%, the latter together with harzburgitic paragenesis silicate inclusions. R.A.H.

Gems and Minerals

(Gem corundums and zircons from the Primorye placers.) [Russian with English abstract.]

S.A. Ananyev, T.A. Ananyeva, V.K. Garanin and G.P. Kudryavtseva. *Proc. Russian Mineralogical Society*, **127**(4), 1998, 120–4.

Descriptions are given of sapphire and hyacinth, and their associated chromespinel, magnetite and enstatite, in heavy mineral concentrates ultimately derived from alkali basalts. Transparent blue, blue-green, green and occasional multicoloured sapphires are represented by rolled crystals 2–5 to 30 mm in size; silky and star-shaped stones may also be found. Chemical analyses and optical absorption spectra show that the colouring is related to the presence of Fe (FeO 0.72–1.75 wt. %) and Ti (TiO_2 0.02–0.20 wt. %). Inclusions of hercynite and ferrocolumbite have been noted in some of these corundums. Hyacinths are represented by strongly rolled crystals from 1–3 to 25 mm in size; they are transparent orange, orange-yellow or brown-red in colour; on heating, they become completely colourless. The chemical compositions of these zircons correspond with the rare variety naegite, with Ta_2O_5 4.59–6.14, Nb_2O_5 3.22–3.59 and ThO_2 3.98–4.09 wt. %. R.A.H.

The Idar-Oberstein gemstone industry's 500th anniversary – a brief history.

H. Bank. *Australian Gemmologist*, **20**(4), 1998, 141–4, 5 illus. in colour, 1 map, 1 table.

This brief history traces the five-hundred year evolution of Idar-Oberstein's gem cutting industry which, although developed around the agate occurrences of the Nahe-Saar region of Germany, now polishes gem material from all the major occurrences around the world. P.G.R.

Gemmologie Aktuell (Gemmological news).

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie, Z. Dt. Gemmol. Ges.*, **47**(4), 1998, 179–82, 4 photographs.

Tourmalines showing a wide range of colours, particularly green, red, pink and bi-coloured now come from Nigeria, although the exact location is not known. The crystals are prismatic, RI 1.622–1.640, DR 0.018, SG 3.06, often trigonal growth zones are visible, and there are round birefringent mineral inclusions. A brownish-black rutile cat's-eye, 0.51 ct, SG 4.30, was found in Sri Lanka. The name 'erenite' found in the trade is a term for a pale green synthetic spinel, usually found in cheap jewellery. A new opal occurrence has been reported in Lambina Station in South Australia, about 260 km north of Coober Pedy. More than 4000 requests for claims have been submitted after a 100 kg piece with beautiful opal veins was found in June 1998, value said to be about £18,000. E.S.

Gemmologie Aktuell (Gemmological news).

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie, Z. Dt. Gemmol. Ges.*, **48**(1), 1999, 1–8, 10 photographs in colour.

New gem occurrences have been discovered in Madagascar; these include corundums of various colours, chrysoberyls and garnets; some pink corundums were examined: they are coloured by chromium and their inclusions are very similar to those corundums found in the Tunduru-Songea area of Tanzania; it seems likely that both areas belonged to a single sedimentation field before the break-up of Gondwana. Beautiful bluish-green tourmalines have been found on a farm called 'Neu-Schwaben' in Namibia. Stones from this locality have been known in Idar-Oberstein since 1925, but only in the last two years have larger quantities reached the market; RI 1.621–1.640, DR 0.019, SG 3.07. There are also short notes on some green-yellow opal cat's-eyes from Sri Lanka; also from Sri Lanka some minerals thought to be rutile, but identified as monazite, a cerium-lanthanum-thorium-phosphate. A rose-quartz cat's-eye from Brazil is described, as is also a parcel of faceted green iridescent sapphires from Australia. Other items described include a tourmaline with artificial fracture filling and a tourmaline-plastic doublet. E.S.

'Lombardische Diamanten' aus Selvino bei Bergamo/Italien.

M. BENZ. *Lapis*, **24**(3), 1999, 23–5.

Doubly-terminated rock crystal specimens are described from Selvino, near Bergamo, Italy. The resemblance to the American Herkimer diamonds is noted. M.O'D.

Chinas Nordosten: Saphirgruben und eine der besten Diamantminen der Welt.

P. BOSSE. *Mineralien Welt*, 9(6), 1998, 68–72, illus. in colour.

Brief survey of sapphire and diamond production in the north-east of China, with special reference to the provinces of Liaoning and Shandong. M O'D

A miscellany of organics – Part 2.

G. BROWN. *Australian Gemmologist*, **20**(5), 1999, 193–7, 1 illus. in black-and-white, 16 colour illus., 1 graph.

A further compilation of unusual biological materials which describes and illustrates a composite blister pearl, a 'jet' necklace, a shell cameo whose colour had been degraded by the use of a cleaning agent containing bleach, tiger's claw jewellery and a carved tagua nut. The author concludes with a warning against the use of ultrasonic cleaners for pearls, and news of a new imitation amber being manufactured in southeast Asia in which (non-struggling) insects are embedded in yellowish brown polystyrene. P.G.R.

Rare gem minerals from Brazil – Part 1: Euclase and phenakite.

M.L.S.C. CHAVES, J. KAARFUNKEL AND D.B. HOOVER. *Australian Gemmologist*, **20**(2), 1998, 80–6, 5 illus. in colour, 1 map.

The authors give a brief historical review of the discovery in Brazil of the rare beryllium-bearing gem minerals euclase and phenakite. Euclase was first discovered over 200 years ago near Ouro Preto in the State of Minas Gerais, and phenakite was discovered 80 years ago at Rio Piracicaba in the same State. The eight principal occurrences of euclase and the three principal occurrences of phenakite are described, and the minerals' optical and physical properties summarised. Their locations are indicated on a map showing the States of Minas Gerais, Espirito Santo, Bahia and Rio Grande do Norte. Due to their scarcity cut examples of these minerals are much sought after by gemmologists and gemstone collectors. P.G.R.

Die Amethyste aus dem Bieligertal, Wallis.

D. CHESEAUX. *Schweizer Strahler*, 11, 1999, 384–7.

Amethyst, sometimes of gem quality, is described from the Bieligertal area of Canton Valais, Switzerland. Well-formed single crystals and crystal groups are found, some specimens reaching up to 30 cm in length. The faceted stone illustrated shows some signs of colour zoning. M.O'D.

New opal carving factory at Khao Yai, Thailand.

R.R. COENRAADS AND P.E. ELMER. *Australian Gemmologist*, **20**(5), 1999, 198–201, 8 black-and-white illus., 7 illus. in colour.

Opened in 1997, the Pacific East Trading Company's boulder opal cutting factory and showroom is located some two hours drive northeast of Bangkok at a popular tourist destination near Khao Yai. Local carving expertise and the large Asian market for carved material are the reasons for setting up the factory which is capable of handling the large quantities of Australian boulder opal shipped in from numerous mines in Queensland. P.G.R.

Axinite vom Piz Vallatscha (GR).

U. EGGENBERGER. *Schweizer Strahler*, **11**, 1998, 229–32, illus. in colour.

Axinite of gem quality is reported from Piz Vallatscha in the Lukmanier region of Canot Graubünden, Switzerland. The crystals were found at around 2900 m and are the characteristic brown-violet colour for this mineral. The axinite-containing fissure also produced adularia, violet apatite, pericline, epidote and some smoky quartz. Though axinite is found at many locations in the Val Cristallina granodiorite to the east of the Gotthard massif, the present find has produced exceptional specimens. M.O'D.

Comparative study of Indian rubies vis-a-vis other rubies.

S. FERNANDES, V. JOSHI AND S. SARMA. *Indian Gemmologist*, 7(3/4), 1998, 29–32.

Mean SG of Indian rubies was 3.93, the lowest value of 3.75 being shown by some specimens from Orissa while some material from Karnataka gave 4.13. Tables of inclusions are given in which Indian rubies are compared with those from the Morogoro area of Tanzania, from Mogok, Vietnam and Kenya. Properties of rubies from the various Indian deposits are also given. M.O'D.

Pink topaz from the Thomas range, Juab County, Utah.

E.E. FOORD, W. CHIRNSIDE, F.E. LICHTE AND P.H. BRIGGS. *Mineralogical Record*, **26**(1), 1995, 57–60.

The colour of pink topaz crystals from lithophysal cavities in rhyolite from the Thomas Range, Utah, is thought to be due to $Mn^{3+} \pm Fe^{3+}$ substitution for Al^{3+}. LA–ICP–MS analysis shows Mn is concentrated in the pink-red colour zones (MnO 0.65, Fe_2O_3 0.35 wt.%). Cr, V, Co or other possible chromophores were not detected. G.W.R.

La détection du jade B.

E. Fritsch. *Revue de gemmologie*, **136**, 1999, 14–18.

Summarizes methods of detecting B-jade by IR absorption spectroscopy which proves the presence of impregnating material which is not found in untreated A-jade. IR spectroscopy is advocated for use in laboratories in which jade samples may need to be tested. M.O'D.

Sur la piste de la ligne verte: un voyage vers les mines de jade du Myanmar.

O. Galibert and R.W. Hughes. *Revue de gemmologie*, **136**, 1999, 19–25.

Description of a visit by the authors to the jade mining areas of Myanmar with an account of the recovery and selling of the rough material. M.O'D.

XRD and IR spectroscopic investigations of some chrysoprases.

A. Gawel, S. Olkiewicz and W. Zabinski. *Mineralogia Polonica*, **28**(1), 1997, 43–51.

The crystallinity of chalcedonic quartz in several samples of chrysoprase from various localities was determined. Samples with a low crystallinity index have, in general, higher Ni contents and intense green colour. In the XRD patterns of some chrysoprases with low crystallinity, diffraction lines due to the microcrystalline silica phase, moganite, were noted, as well as a broad reflection at $d \sim 10$ Å. No reflections due to bunsenite (NiO) were seen, even in samples with NiO ≥ 1.71 wt. %. R.A.H.

Le jade-jadeite du Guatemala: archéologique d'une rédécouverte.

F. Gendron. *Revue de gemmologie*, **136**, 1999, 36–42.

History of the use of jadeite in Guatemala in which seven types are identified and distinguished. Present-day recovery and use are described. M.O'D.

Ambra in Provincia di Ragusa.

G. Giardina. *Rivista Mineralogica Italiana*, **22**(2), 1998, 50.

Amber specimens from Ragusa province, Italy, are shown to contain insect inclusions. The main occurrence is on the coast of Pozzallo where amber is thrown up by the sea. Most pieces contain some red and when fashioned show a characteristic amber colour with red overtones. Some specimens have reached 2–3 cm in diameter. M.O'D.

Hildegard von Bingen De Lapidibus. Welsche Steine beschrieb Hildegard tatsächlich?

M. Glas. *Lapis*, **23**(6), 1998, 46–52, illus. in colour.

An attempt is made to identify stones described in Hildegard von Bingen's *De Lapidibus* (1098) with their modern equivalents. M.O'D.

Réflexion sur l'esthétique des objects de jade traditionnels chinois avant le XVIIIéme siécle.

E. Gonthier. *Revue de Gemmologie*, **136**, 1999, 31–5.

Thoughts on the use of jade by the Chinese for ornamental purposes before the 18th century. M.O'D.

Manganese minerals from the southern New England district.

M.P. Goodwin. *Australian Journal of Mineralogy*, **4**, 1998, 101–7.

Rhodonite of ornamental quality is described from the southern part of the New England district of New South Wales, Australia. Fine quality specimens have been found at the Black and White mine at Danglemah. M.O'D.

Alexandrite, emerald, ruby, sapphire and topaz in a biotite-phlogopite fels from Poona, Cue District, Western Australia.

G. Grundmann and G. Morteani. *Australian Gemmologist*, **20**(4), 159–67, 6 illus. in colour, 5 black-and-white illus., 1 map.

During 1994, corundum (ruby and colourless to blue sapphire), chrysoberyl (green alexandrite – the first discovery of alexandrite-bearing rocks in Australia), colourless topaz, beryl (light green emerald), pink fluorite, margarite, muscovite and quartz were discovered at Poona in Murchison Province, Western Australia. The report includes the history of mining in the area and details of the mineralization of the deposits. Although very little material suitable for faceting has been found to date, it is hoped that ongoing exploration will result in more and better quality gem material being discovered. P.G.R

Cloudiness in zircons – a chemical and morphological study.

L.N. Gupta, G. Meier and W. Johannes. *Journal of the Geological Society of India*, **51**(4), 1998, 475–84.

A study of zircons from migmatites in the Turku area, Finland, using EPMA and IR techniques, showed that cloudy areas in these zircons contain additional Fe_2O_3, CaO, MgO, Al_2O_3 and water over values for the clear areas. IR spectroscopic analysis showed that the clouded parts have both molecular H_2O and OH molecule in similar proportions; the total H_2O in these clouded parts is ~ 8 wt. %. A direct relationship exists between water + secondary components and the cloudiness of the zircons. It is suggested that the Fe_2O_3, CaO, MgO and Al_2O_3 dissolved in water got incorporated into the crystal structure of the zircon, replacing ZrO_2 and SiO_2 simultaneously. R.A.H.

Tiefgrüner Lazulith.

V.M.F. Hammer. *Lapis*, **24**(5), 33–4, 1999, 1 map in colour.

Transparent crystals of dark-green lazulite are reported from the Skardu district, Northern Areas of Pakistan. The specimens are sharply pyramidal and range up to 5 cm in length. M.O'D.

'Transvaal-jade' aus Südafrika.

R. Hochleitner and M. Vogt. *Lapis*, **23**(10), 1998, 36–8, illus. in colour.

Various colours of hydrogrossular garnet to which the undesirable name 'Transvaal jade' has long been in use for the green variety are described from the Rustenberg area of South Africa where they occur near the Buffelfontein and Turffontein farms, the area forming part of the Bushveld complex. Chromium is held to be responsible for most of the green coloration and manganese for the pink. M.O'D.

Scottish gem lab news.

A. Hodgkinson. *Australian Gemmologist*, **20**(4), 1998, 154–8, 15 illus. in colour, 1 table.

The author reports on three new gem materials seen during the 1998 Tucson Show and gives recommendations on methods of identification. With synthetic moissanite, a table indicates the main identification features of large DR, high RI and some electrical conductivity. The author's visual optics method can also be used to distinguish synthetic moissanite from diamond, and is particularly useful for identifying the second new material, bluish-green cobalt-diffused topaz which produces a negative reading on a refractometer and a CZ type reading on a reflectance meter. The third new material described is a red synthetic diamond which can be identified by floating it on a raft and checking its attraction to a small rare earth magnet. P.G.R.

Achate aus Sachsen und Thüringen – Ein Überblick zu ihren Vorkommen in Gängen und Vulkaniten.

G. Holzhey. *Gemmologie, Z. Dt. Gemmol. Ges.*, **47**(4), 1998, 199–224, 25 photographs, 4 diagrams, 3 maps, extensive bibl. 1 table.

The author describes in detail what types of agates are found in Saxony and Thuringia in their geological and geographical contexts. The agate-bearing spherulites from Wiederau are mentioned – these are shown in the green Vaults in Dresden. Beautiful colours and cracks are characteristic features of both vein agates and agates in rhyolitic spherulites found at the foot of the Ore Mountains. Amygdaloidal agates occur in the andesitic volcanic rocks both in Saxony and in the Harz mountains in Thuringia. Other occurrences with agate which contain spherulites from the Thuringian Forest are located within marginal facies of volcanic domes and lava flows. Because of the fine cracks in many of these agates, usually only small cabochons can be cut from them. E.S.

Alaskan jade.

P. Howard. *Australian Gemmologist*, **20**(4), 1998, 149–53, 8 illus., in colour, 1 map.

First discovered by Eskimos who used it for ornamentation as well as for tipping weapons and tools, gem-quality nephrite, known commercially as Alaskan jade, is mined from several deposits in north-west Alaska's Baird or Jade mountains. Although early explorers of the region such as Captain James Cook were aware of its use by the Eskimos, the precise location of the Alaskan 'greenstone' source remained a mystery to Europeans for many years until it was finally discovered in the Kobuk area of Alaska in 1885. Today gem-quality nephrite jade is mined and stockpiled during the three months of Alaskan summer from June to September before being hauled out on sledges during the first freeze of the on-coming winter. P.G.R.

Foreign affairs – fracture healing/filling of Mong Hsu ruby.

R.W. Hughes and O. Galibert. *Australian Gemmologist*, **20**(2), 1998, 70–4, 12 illus. in colour, 1 map.

Although not of the same quality as Mogok rubies, the stones from the Mong Hsu deposit in Myanmar's Shan State have recently dominated the world's ruby trade in sizes below 3 carats. 99% of rubies traded today in Chanthaburi, Thailand, are from Mong Hsu. The stones have a strong purplish colour and contain dense clouds of silk, both of these features being improved by heat treatment to produce stones having a rich clear red colour. However the stones are also heavily fractured and these flaws are filled and 'healed' in Thailand by heating the stones in a flux containing borax and other chemicals. This latter treatment has created problems as it is generally accepted by Bangkok dealers/gemmologists, but rejected by those outside the country. P.G.R.

Eine neue gemmologische Untersuchung der Sankt Wenzelskrone in Prag. (A new gemmological study of the St. Wenceslas crown in Prague.) [German with English abstract.]

J. Hyrsl and P. Neumanova. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(1), 1999, 29–36, 12 illus. in colour, bibl.

The crown was ordered by Charles IV and made between 1346 and 1387. In the front there is one sapphire, one rubellite, five spinels and one pearl. On the right one spinel, six sapphires, one aquamarine and one pearl; the back has two sapphires, 14 spinels and one pearl, the left one spinel, seven sapphires and one pearl. Four spinels are on the metal closure. The two bows on top have 25 emeralds, 15 rubies, four spinels and 16 pearls; the cross on top contains a cross-shaped sapphire cameo, two sapphires and one spinel. Many stones, especially the sapphires, are of exceptional quality, seven of them weighing more than 100 ct. They are probably from Sri Lanka as are the spinels; some stones come from Afghanistan. The rubies are either from Sri Lanka or Burma. The origin of the emeralds is unknown. Most stones are irregularly shaped, just polished, and some have primitive facets. E.S.

A theoretical study of the absorption spectra of Pb^+ and Pb^{3+} in the K^+ site of microcline: applications to the colour of amazonite.

A. Julg. *Physics & Chemistry of Minerals*, **25**(3), 1998, 229–33.

The blue-green colour of amazonite has been assigned by various authors to Pb^+ ($6s^26p$) and/or Pb^{3+} (6s) in the K^+ site of microcline. Owing to the complex which forms between the Pb^{3+} ion and the lone pairs of the O atoms surrounding it, the peripheral electron of Pb^{3+} passes onto the 6p level, which results in great similarity between the spectra of Pb^+ and Pb^{3+} in amazonite (the transition energies are increased). In the isolated state, however, the spectra are completely different. A model for the crystal field around the K^+ is developed. Under the effect of the crystal field, the transition $^{2}P^{1}/_{2} \rightarrow 2P^{3}/_{2}$ (6p) is split into two double transitions. Only the lower transition falls in the visible domain (1.6–1.8 eV for Pb^+) – the second in the UV. The green colour arises from the Pb^+ ion, whereas the blue is attributed to Pb^{3+}. A.A.F.

Bernstein an den Küsten und im Binnenland der norddeutschen Tiefebene.

K. KRAUSE. *Aufschluss*, **49**, 1998, 205–12, illus. in colour.

Amber of near-ornamental quality is described from the north German Baltic coast and adjoining lowlands. Details of transportation and formation are given with notes on the history of amber recovery in the area. M.O'D.

Neue Amazonitfunde aus Colorado.

B.K. LEES. *Mineralien Welt*, 9(4), 1998, 33–48, illus. in colour, 5 maps.

Fine gem-quality crystals of amazonite have been found at the classic Lake George location in Pike National Forest, Colorado, U.S.A., the area forming part of the Pikes Peak batholith. Well-crystallized amazonite specimens reach up to 12 cm in length. Details of the location, recovery methods and specimen descriptions are given. Large clear crystals of smoky quartz occur in association with the amazonite. M.O'D.

(Comparative study on the colour of natural emerald, synthetic emerald and green beryl.) [Chinese with English abstract.]

LI YALI. *Journal of Gems and Gemmology*, 1(1), 1999, 50–3.

EPMA results and transmission spectra in the visible range are presented for five specimens, and their colour indices are calculated. The concentrations of the trace elements Cr and V are diagnostic, each giving a characteristic colour index. R.A.H.

New occurrence of demantoid in Namibia.

TH.LIND, U. HENN AND H. BANK. *Australian Gemmologist*, **20**(2), 1998, 75–9, 6 illus. in colour 2 graphs, 3 tables.

The new demantoid occurrence in Namibia is located in a large steppe-like plain in the central part of the Damara Orogen. These andradite garnets display similar compositions and spectroscopic features as low-chromium demantoids from the Ural mountains of Russia. The differences in patterns of internal inclusions in stones from both sources reflect the differing genesis of both occurrences. Chrysotile (asbestos) fibres, typical of demantoids from the Ural mountains, have not been found in the Namibian material. P.G.R.

Origin of sapphires from the Jizerska Louka alluvial deposit in north Bohemia, Czech Republic, Europe.

P. MALIKOVA. *Australian Gemmologist*, **20**(5), 1999, 202–6, 1 black-and-white illus., 6 illus. in colour, 1 map.

A study of the optical features, inclusions and surface patterns of Jizerska Louka sapphires reveal that these characteristics are very similar to those found in and on sapphires from Thai and Australian alluvial deposits, and suggest an origin in a basaltic vent breccia. P.G.R.

The mineralogy, geology and occurrence of topaz.

M.A. MENZIES. *Mineralogical Record*, **26**(1), 1995, 5–53.

Various tectonic settings and geological environments hosting topaz are reviewed. Worldwide occurrences of topaz in rhyolites, granitic pegmatites and hydrothermal deposits including greisens, skarns and veins, are discussed in detail, and their parageneses summarized. (OH) substitution for F is related to decreasing *T*, and results in a progression from orthorhombic volcanic topaz to predominantly triclinic hydrothermal topaz. G.W.R.

Demantoid aus Eritrea. [German with English abstract.]

C.C. MILISENDA AND J. HUNZIKER. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(1), 1999, 37–42, 4 illus. in colour, 1 graph, 1 table, 2 maps, bibl.

The demantoid garnets from Eritrea have been known for about 50 years, but were unknown to the public. They are found in sandy gravel near Asmera. Of eight faceted stones and a parcel of rough (altogether nearly 240 ct) one faceted stone and a few pieces of rough were found to be peridot. The remainder were found to be demantoid garnet of SG 3.80 to 3.88 and above the RI limit of a standard refractometer. The absorption spectra show typical bands of trivalent iron, and chromium. Horse-tail chrysolite inclusions, similar to those found in Russian demantoids, were observed. The occurrence of demantoid garnets together with peridots suggests that they had primarily been formed in serpentinized peridotites. E.S.

Edelsteine aus Sambia – Teil 1: Smaragd. (Gemstones from Zambia – part 1: emerald.) [German with English abstract.]

C.C. MILISENDA, V. MALANGO AND K.C. TAUPITZ. *Gemmologie – Z. Dt. Gemmol. Ges.*, 48(1), 1999, 9–28, 8 illus. in colour, 3 graphs, 2 tables, 6 maps, bibl.

The article describes the geological and geographic location of the Kagem Kafubu gemstone mines and the examination of their production. The Kagem is at present the largest mine within the Kafubu emerald field in the Ndola Rural District. The licensed mining area is about 40 square km and includes many open pit mines, such a FwayaFwaya, Chama, etc. The emeralds occur as porphyroblasts in biotite-phlogopite rocks and were formed during the late stages of the Pan-African event (approx. 500–450 million years ago). Kagem was privatized in 1998 and it is hoped that it will produce very fine emeralds. The stones are sorted into five categories, according to colour and clarity. RI 1.581–1.597, DR 0.008, SG 2.69–2.77. Mica platelets form the most characteristic inclusions; rod-like inclusions were shown to be amphiboles. Fluid inclusions are oriented square to rectangular negative crystals filled with a liquid and there were also some gaseous inclusions. E.S.

Contemporary identification to [sic] green jadeite. [In French and English.]

D. MOK. *Revue de gemmologie*, **136**, 1999, 11–13.

Present-day methods of treating green jadeite are summarized. Particular care needs to be taken with B and B + C jade. M.O'D.

What's new in minerals.

T. MOORE ET AL. *Mineralogical Record*, **29**, 1998, 209–21, illus. in colour.

An overview of the Tucson show of 1998 describes a number of interesting gem specimens, in particular a 43 cm plate of benitoite crystals on matrix: smaller benitoite specimens were also on sale. Among other gem materials were azurite from the Hanover #42 mine, Fierro, New Mexico, yellow baryte from the Barrick Meikle mine, Carlin, Elko County, Nevada, pale yellow amblygonite from a number of different locations, pale to deep green Mali garnet and demantoid (lacking crocidolite inclusions) from the Namgar mine, Usakos, Namibia. More transparent green zoisite was on show as well as red spessartine from the Gilgit area of Pakistan. M.O'D.

What's new in minerals.

T. MOORE. *Mineralogical Record*, **30**, 1999, 211–40.

Gem-quality green andradite has been found at the Yellow Cat mine, New Idria District, San Benito County, California, and shown at the 1999 Tucson Show. Other gem-quality materials at this show were: green diopside crystals up to 8 cm long from Chamachu, Baltistan, Pakistan, and rhodochrosite (some found with silver) from Uchucchacua, Peru: crystals and faceted tourmaline from Keffi, Nigeria (crystals predominantly red but showing some other colours): gemmy yellow rhodizite from Antsogombato, Madagascar: red spinel from Pain Pyit, East Mogok, Myanmar: gem-quality forsterite from Sappat, Pakistan: spessartine of fine quality from an as-yet unnamed location in Yunnan Province, China. Finally a deep turquoise-blue euclase crystal measuring 12 cm from Colombia. M.O'D.

Emerald chemistry from different deposits – an electron micropobe study.

I.I. MOROZ AND I.Z. ELIEZRI. *Australian Gemmologist*, **20**(2), 1998, 64–9, 3 illus. in colour, 1 table.

Twenty-nine emerald samples were analysed chemically using a JEOL JXA-8600 electron microprobe at the Institute of Earth Sciences of the Hebrew University of Jerusalem. The samples consisted of a selection of rough and faceted emeralds from occurrences in Australia, Brazil, Colombia, Mozambique, Nigeria, Russia Tanzania and Zambia, and included three hydrothermally grown synthetic emeralds. Emeralds from schist-type deposits (Australia, Brazil, Mozambique, Russia, Tanzania and Zambia) were characterized by high concentrations of MgO, FeO and Na_2O, while Colombian and Nigerian emeralds had low concentrations of MgO and Na_2O. The synthetic emeralds had the smallest amount of Na_2O. P.G.R.

The IMA Commission on New Minerals and Mineral Names: procedures and guidelines on mineral nomenclature.

E.H. NICKEL AND J.D. GRICE. *Mineralogical Record*, **30**, 1999, 163–76.

Describes the work of the Commission and how minerals are finally named and published. A list of nomenclature changes from 1987 to 1998 is appended. M.O'D.

How to make an appraisal of jadeite.

C.M. OU YANG. *Australian Gemmologist*, **20**(5), 1999, 188–92, 10 illus. in colour, 2 tables.

Because of the difficulties in appraising jadeite, the author (one of Hong Kong's acknowledged experts in this field) proposes the use of the four Cs (colour, clarity, cutting, cracks), the two Ts (transparency, texture) and one V (volume) in the valuation of this material. Guidelines and colour illustrations are included for the assessment of colour, clarity, cutting, cracks, transparency and texture. P.G.R.

(Mineral component of jadeite jade.) [Chinese with English abstract.]

C.M. OU YANG. *Journal of Gems and Gemmology*, **1**, 1999, 18–25, illus in colour.

Three types of minerals can be determined as jadeite jade: they are metamorphic crystalloblastic minerals, primary and secondary minerals. These were studied with the polarizing and electron microscopes and details are given. M.O'D.

Quarz und Fluorit von Selvino und Zogno, Lombardiche Kalkalpen/Oberitalien.

F. PEZZOTTA. *Lapis*, **24**(3), 1999, 13–22, 1 map.

Gem-quality crystals of quartz and fluorite are described from Selvino and Zogno respectively in the Lombardy Alps of Italy. The quartz crystals are compared with those from Herkimer, New York, U.S.A., and the fluorite occurs in a number of different colours, reaching large sizes. M.O'D.

Grosse Sphenkristalle aus dem Kötschachtal bei Badgestein (A).

W. PFEFFER. *Lapis*, **24**(5), 11–14, 1999.

Fine well-formed crystals of sphene up to several cm in length are reported from Kötschachtal near Badgestein, Austria. Some crystals display a characteristic roundness. Rock crystal with black inclusions of chlorite and short prismatic crystals of phenakite have also been found in the area. M.O'D.

Chrysoberyl from Azklary – a new occurrence in Poland.

A. PIECZKA AND B. GOLEBIOWSKA. *Mineralogia Polonica*, **28**(1), 1997, 31–3.

Chrysoberyl occurs in a granitic pegmatite in contact with serpentinites of the Szklary massif, Lower Silesia, as fine, 6–8 mm long, idiomorphic, single or twinned individuals, translucent to transparent in hand specimen, with a greenish or yellow-green colour. The XRD and IR spectra are reported; the chrysoberyl has *a* 5.4800, *b* 9.4147, *c* 4.4289 Å, space group *Pbnm*. R.A.H.

Purple-red colour of quartz caused by piemontite inclusions.

A.N. Platonov, M. Sachanbinski, A. Szuszkiewicz and V.S. Sedenko. *Gemmologie, Z. Dt. Gemmol. Ges.*, 47(4), 1998, 193–8, 3 photographs, 4 diagrams, 2 tables, bibl.

The article describes a new variety of purple-red quartz from the North Caucasus. Lens-shaped pieces of quartz with piemontite from distinctive veins up to 15 cm thick; where they become thin, the quartz is of purple to cherry-red colour. The material was investigated by microprobe and optical absorption spectra were obtained. E.S.

(Mechanism for kosmochlor symplectite and compositional variation zoning in jadeite jade.) [Chinese with English abstract.]

Qi Lijian, Zheng Shu and Pei Jingcheng. *Journal of Gems and Gemmology*, **1**, 1999, 13–17, illus in colour.

A study on the petrography and geochemistry of kosmochlor in jadeite is reported, together with the EPMA results. The kosmochlor mainly occurs as a symplectite substituting or surrounding chromite; part of the kosmochlor next to jadeite has been metasomatized by chromite, resulting in a three-layer symplectitic zoning of kosmochlor + calcic kosmochlor + uvarovite. The chemical zoning reveals the multiple stages and complexity of the unbalanced metasomatic reaction. The coupling of diffusive bimetasomatism with flow-percolating metasomatism between the mineral grains is the main reason for the formation of kosmochlor symplectite and the compositional zoning. R.A.H.

(Testing of copal resin and amber.) [Chinese with English abstract.]

Qiu Zhili, Chen Binghui and Zhang Yuguang. *Journal of Gems and Gemmology*, 1, 1999, 35–9, illus in colour.

New Zealand Kauri copal and amber are compared. Alcohol and infrared spectroscopy are used in identification but care needs to be taken when fluorescence, SG, RI and inclusions are tested. M.O'D.

Zwei Wege zur Bildung von Augenachaten.

R. Rykart. *Schweizer Strahler*, **11**, 1999, 476–80.

'Eye' agate may have been formed either from a silica gel or from different pre-existing minerals. Examples of agate from a number of world localities are considered in the light of both theories. M.O'D.

Smaragde, das 'Grüner Feuer' aus Kolombien.

F. Schindler. *Lapis*, **23**(10), 1998, 13–18, illus. in colour.

Up-to-date review of emerald production in Colombia with emphasis on the Muzo group of mines and their specimens. Crystal aggregates, a rare form of emerald occurrence, have been found with calcite at the Coscuez mine, Muzo. M.O'D.

Rote, rosafarbene und zweifarbige Turmaline aus einem neuen Vorkommen in Nigeria.

K. Schmetzer. *Lapis*, 23(11), 1998, 25–6.

Crystals of gem-quality tourmaline from Nigeria are described. Diagrams of the crystals are given. Red and multi-coloured crystals of characteristic form are found near the town of Ogbomosho in the Benin area of the country. M.O'D.

Aus farblos wird Blau: synthetische Saphire und ihre Diffusions-behandlung.

K. Schmetzer. *Lapis*, **24**(5), 1999, 39–40.

Short account of the methods by which pale sapphires may be turned blue by diffusion of colouring agents into the surface. US patent 3, 897,529 (1975) is cited and examples quoted were Verneuil-grown sapphires. M.O'D.

Les jades de la Chine ancienne.

S. Soubra. *Revue de gemmologie*, **136**, 1999, 27–30.

Description of the use of nephrite in China during the Neolithic period (around 6000–1700BC) and the Han Dynasty (206BC–AD220). M.O'D

Lavra da Sapo-derzeit fündigate Turmalin-Mine in Minas Gerais, Brasilien.

G. Steger. *Lapis*, **24**(3), 1999, 26–8.

Fine gem-quality tourmaline is described from Sapo, near Goiabera in the Brazilian state of Minas Gerais where crystals up to 14 cm long have been found in pegmatites. Zoned and water-melon varieties are reported though the majority are a fine bluish or green colour. M.O'D.

A new phase of natural feldspar, An_xOr_{100-x}, $x \approx 50$.

T. Takagi and T. Hoshi. *Proceedings of the Japan Academy*, **71B**, 1995, 72–4.

A new phase, An_xOr_{100-x} was found as inclusions in labradorite from Ylämaa, Finland, during the course of study by TEM. The chemical composition of this labradorite was determined by X-ray microprobe analysis as $Ab_{40}An_{56}Or_4$. A thin-section parallel to the b^*–c^* plane of this labradorite was subjected to observations under the TEM equipped with an analytical system. A TEM micrograph obtained showed two kinds of exsolution lamellae, A and B and an inclusion, where the compositions of A and B were determined as $Ab_{43}An_{57}$ and $Ab_{53}An_{47}$, respectively, by TEM analysis. K was confirmed to be localized in the inclusion, and it was also discovered that the inclusion contains Ca but is free from Na. The composition of the inclusion derived by TEM analysis can be expressed as An_xOr_{100-x}, a phase of natural feldspar not having been reported up to the present. The value of x in the above formula is tentatively estimated to be close to 50. [Authors' abstract] I.S.

Les épidotes du Mont-Chemin (VS).

B. Veigel. *Schweizer Strahler*, **11**, 1999, 446–8.

Epidote crystals of gem quality are reported from Mont-Chemin, Valais, Switzerland, where they occur in a quartz matrix. The colour of the crystals depicted is a yellowish- to brownish-green and some crystals up to 3.2 cm in length have been found. M.O'D.

Gemstones of New England.

G.B. Webb and F.L. Sutherland. *Australian Journal of Mineralogy*, **4**, 1998, 115–22.

Notes on the occurrence of diamond, sapphire, peridot, topaz, zircon, garnet, rhodonite, nephrite, fluorite and feldspar group minerals are given for the New England area of New South Wales, Australia. The New England area includes the sapphire mines at Inverell: diamonds are found at Copeton and emerald in the Emmaville and Torrington areas. Some geology and mining history is given. M.O'D.

Faszination Vesuvian.

P. Welti. *Schweizer Strahler*, **11**, 1999, 437–46.

Vesuvianite crystals from areas of Switzerland are described. The area of Saas-Fee in the Swiss Valais, which is 1800 m above sea level, provides particularly attractive specimens. Clinochlore, diopside and hessonite have been found as accessory minerals, and crystals up to 3 cm in length are illustrated. Some are of facetable quality. M.O'D.

(Research on texture and structure type of Hetian jade in Xingjiang.) [Chinese with English abstract.]

Wu Ruihua, Li Wenwen and Ao Yan. *Journal of Gems and Gemmology*, **1**, 1999, 7–2, illus in colour.

Discusses the structure of Hetian jade, a material found in Xingjiang. Specimens illustrated show blastic textures, some being felt-like cryptocrystalline, some radiated and others microflaking or wispy. M.O'D.

(Study on clinopyroxene minerals of jadeite jade.) [Chinese with English abstract.]

Zou Tianren, Yu Xiaojin, Xia Fengrong and Chen Weishi. *Journal of Gems and Gemmology*, **1**, 1999, 24–32.

While jadeite jade is mainly $NaAlSi_2O_6$ (occurring as mineral aggregates) other clinopyroxene minerals in jadeite include chromian jadeite, diopsidic jadeite, ureyitic jadeite, omphacite, ureyitic omphacite, diopsidic ureyite, jadeitic ureyite, ureyite, diopside, jadeitic clinoenstatite, diopsidic clinoenstatite, aegirine-augite and aegirine. A jade specimen composed mainly of other clinopyroxene minerals should carry the name of the mineral as a qualifying noun before the noun jade, thus aegirine-jade and so on. M.O'D.

Instruments and Techniques

History of the development of the crystallographic goniometer.

U. Burchard. *Mineralogical Record*, **29**, 1998, 517–83.

The goniometer was devised to measure the interfacial angles on crystals. Beginning with a simple instrument which could be laid directly on to the specimen, the goniometer developed into a complicated piece of apparatus which has sometimes been used by gemmologists. By the beginning of the twentieth century large (and beautifully-constructed) three-circle goniometers were being made, especially by the Berlin firm of Fuess: English and French firms were prominent in the first half of the preceding century. M.O'D.

The cutting edge.

Goldsmiths' Review 1997/98, 1998, 40–3, illus in colour.

Short account of the history of lapidary work in Hatton Garden where, now as in past years, a small number of firms deal with the high-quality cutting of fine gemstone rough. Lapidaries are concerned to find suitable trainees to take up apprenticeships. Details of the stages of polishing coloured gemstones are given. M.O'D.

Raman spectra of silicate garnets.

B.A. Kolesov and C.A. Geiger. *Physics & Chemistry of Minerals*, **25**(2), 1998, 142–51.

The single-crystal polarized Raman spectra of four natural silicate garnets with compositions close to end-members almandine, grossular, andradite and uvarovite, along with synthetic spessartine and pyrope, were measured along with powder spectra of synthetic pyrope-grossular and almandine-spessartine solid solutions. Mode assignments were made based on a comparison of the different end-member garnet spectra and, in the case of pyrope, based on measurements made on additional crystals synthesized with ^{26}Mg. A general order of mode frequencies, i.e. $R(SiO_4) > T$ (metal cation) $> T (SiO_4)$, is observed which should also hold for most orthosilicates. The main factors controlling the changes in mode frequencies as a function of composition are intracrystalline P (i.e. O–O repulsion) for the internal SiO_4-vibrational modes and kinematic coupling of vibrations for the external modes. Low frequency vibrations of the X-site cations reflect their weak bonding and dynamic disorder in the large dodecahedral site, especially in the case of pyrope. Two mode behaviour is observed for X-site cation vibrations along the pyrope-spessartine binary, but not along the almandine-spessartine join. A.A.F.

GemScan II.

T. Linton, R. Pemberton, A. Cumming, B. Sweeney and N. Masson. GAA Instrument Evaluation Committee report. *Australian Gemmologist*, **20**(5), 1999, 182–5, illus in black-and-white.

Marketed by GemScan International, the GemScan II is a reflectance meter fitted with both an instrument mounted test pad and a remote test probe. Readout is on a three and a half digit LCD panel. Test results indicate good repeatability of readings from a range of natural and synthetic sapphires (*abstractor's comment:* although the majority of synthetic sapphires tested on the instrument gave a lower reading than natural sapphires, this is due to the poorer polish of machine cut synthetics). While warning of the pitfalls associated with the inexperienced use of reflectance meters, the Evaluation Committee considers that the GemScan II will work efficiently once the operating principles and test constraints are understood. P.G.R.

Expanded scale Eickhorst refractometer.

T. Linton, S. Sultman and J. Peters. *Australian Gemmologist*, 20(4), 1998, 145–8, 3 illus., in black and-white, 1 table.

Tested by the GAA's Instrument Evaluation Committee, the Eickhorst SR/XS refractometer was reported to be of robust construction and was therefore particularly suitable as a replacement for the Division's teaching instruments. Its expanded scale compared favourably to those of other refractometers, including the Topcon, and this particular feature enabled easy estimation of RIs to the third decimal place. Compared to the price of other refractometers, the Eickhorst SR/XS was also considered to be good value for money. P.G.R.

Tieftemperaturspektroskopie von farbigen Diamanten mit neuartiger Kühlzelle.

M. Luhn and L. Ackermann. *Gemmologie, Z. Dt. Gemmol. Ges.*, 47(4), 1998, 225–30, 2 photographs, 5 diagrams, bibl.

The authors have developed a new cryostat for spectroscopic measurements of coloured diamonds at low temperatures. Because of the simple geometric arrangement of the light path, maximum intensity of light through diamond is obtained. The result is a very accurate spectrum where the absorption lines relevant for the separation of naturally coloured diamonds from irradiated diamonds are clearly visible. E.S.

Neue Entwicklungen der CVD-Diamantsynthese für den Schmucksektor.

E.M. Winter and J. Gäbler. *Gemmologie, Z. Dt. Gemmol. Ges.*, **47**(4), 1998, 183–92. 6 photographs, 2 diagrams, bibl.

The article deals with two new developments of Winter in conjunction with the Fraunhofer Institute for Thin Films and Surface Engineering. The first is the CVD diamond generated with microprisms at the rear, allowing larger brilliant dimensions than the conventional brilliant cut natural diamond. The surfaces of the microprisms appear as sparkling reflections. The large number of total reflections generates the splitting-up of the light beam. The second development is a motif diamond, in which individual images are created on the gem diamond by means of lithography and are aimed at producing personalised jewellery.

The motif appears as a bright picture on the darker diamond background. This technique can be applied on natural diamonds which are not suitable to be cut as brilliants but are cut into slices, or the technique can be used with CVD diamond layers. The CVD can be applied as a silky black layer to give a good contrast background for the bright motif. The CVD method can extend diamond faces to several centimetres, which could be applied to rings, medals and amulets. Suggested applications include commemorative coins, brooches or medals, and special anniversary and birthstone jewellery. E.S.

Synthetics and Simulants

Melting of corundum using conventional and two-phase molecular dynamic simulation method.

A.B. Belonoshko. *Physics & Chemistry of Minerals*, **25**(2), 1998, 138–41.

The melting curve of corundum is calculated using two approaches: the first is conventional and the second by two-phase molecular dynamics (MD) both utilizing the same pairwise interatomic potential previously developed. The melting curve obtained by the 2-phase simulation is in agreement with experimental data up to 25 GPa. A comparison of melting curves obtained by a 2-phase simulation and a conventional MD in NPT ensemble conventional MD. The inaccuracy of the conventional method increases with increasing *P*, and in the case of corundum, changes from about 300 K at 1 bar to 1000 K at 1 Mbar. A.A.F.

'Faux et usage de faux': les falsifications de minéraux. Part 1.

M. Borzykowski. *Schweizer Strahler*, **11**, 1998, 242–55. illus in colour.

Introduces natural minerals with their synthetic counterparts, outlining the ornamental, research and industrial uses of artificial mineral products. A number of gemstone simulants are described and illustrated. M.O'D.

'Faux et usage de faux': les falsifications de minéraux. Part 2.

M. Borzykowski. *Schweizer Strahler*, 11, 1998, 294–301. illus in colour.

Second and concluding part of a short review of mineral fakes, synthetic and imitation gemstones. Extensive bibliography. M.O'D.

'Pseudosinhalite', a new hydrous MgAl borate: synthesis, phase characterization, crystal structure, and *PT*-stability.

P. Daniels, S. Krosse, G. Werding and W. Schreyer. *Contributions to Mineralogy & Petrology*, **128**(3), 1997, 261–71.

'Pseudosinhalite' is a new, provisionally-named phase produced during hydrothermal experiments at 4–40 kbar, and ~650–900°C. Stability at higher T increases with increasing P. 'Pseudosinhalite' forms monoclinic crystals, elongated along b, with a 7.455, b 4.330, c 9.825 Å, β 110.68(1)°, V 296.7(1)A^3; space group $P2_1/c$. The structure is based on hexagonal close packing of oxygens with tetrahedral B and octahedral Mg and Al. Boron fully occupies all tetrahedral sites. $M1$ sites are occupied only by Al, while $M2$ and $M3$ contain both Al and Mg in the proportion 0.17:0.83 and 0.95:0.05 respectively. The ideal formula is $Mg_4Al_6B_4O_{18}(OH)_2$. No OH-stretching bands are observed in IR spectra, possibly because of the strong hydrogen-bonding which results from H location at a split position between two O atoms which are only 2.55 Å apart. The experimental P–T conditions of 'pseudosinhalite' formation and the mineral's chemistry indicate that this mineral may in theory form naturally. If so, the properties of 'pseudosinhalite' are sufficiently similar to those of sinhalite that the two minerals might be mistaken. [It has since been recognized in rocks from the Tayozhnoye deposit, Siberia.] C.L.H.

Gemmologische Kurzinformationen. Synthetische Feueropale mit Farbenspiel von Kyocera, Japan. (Synthetic fire opals with play-of-colour from Kyocera, Japan.) [German with English abstract.]

U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(1), 45–8, 1999, 2 illus. in colour, 1 graph, bibl.

These synthetic opals have the usual characteristics, like lizard-skin effect and columnar structure. RI 1.459–1.460, SG 1.87–1.91. Sharp absorption peak of an artificial resin was seen in the infrared spectrum. The colours are mainly yellow-orange with some stones having a yellow-green colour flash, some showing a definite red play-of-colour. E.S.

Hydrothermal growth of man-made corundum crystals.

M. Maleev. *Review of the Bulgarian Geological Society*, **57**(2), 1996, 57–60.

Growth runs were carried out in 150 ml unlined steel autoclaves at crystallization T of ~500°C and P 140–170 MPa. The systems consisted of 1 M and 1.5 M $NaHCO_3$ and $KHCO_3$ aqueous solutions as solvents, melt-grown corundum, electrocorundum, corundum ceramics and metal Al as nutrients, and platelets of melt-grown corundum cut parallel to $(10\bar{1}1)$ as seeds. The solubilities of the nutrients in the different solvents have been studied to optimize the growth conditions. The crystals grew at rates of 5–10 g per week and always produced well defined morphologies. The rates of growth forms have been found to decrease in the order $\{10\bar{1}1\} > \{22\bar{4}3\} > \{11\bar{2}0\} > \{0001\}$, and in 30 days all crystals reached a final growth morphology of $\{0001\}$ and $\{11\bar{2}0\}$ only. The study also reports data on the surface morphologies of growth forms and on colour effects due to iron and copper impurities. I.V.

(FTIR features of Guilin hydrothermally-grown synthetic emerald and its significance.) [Chinese with English abstract.]

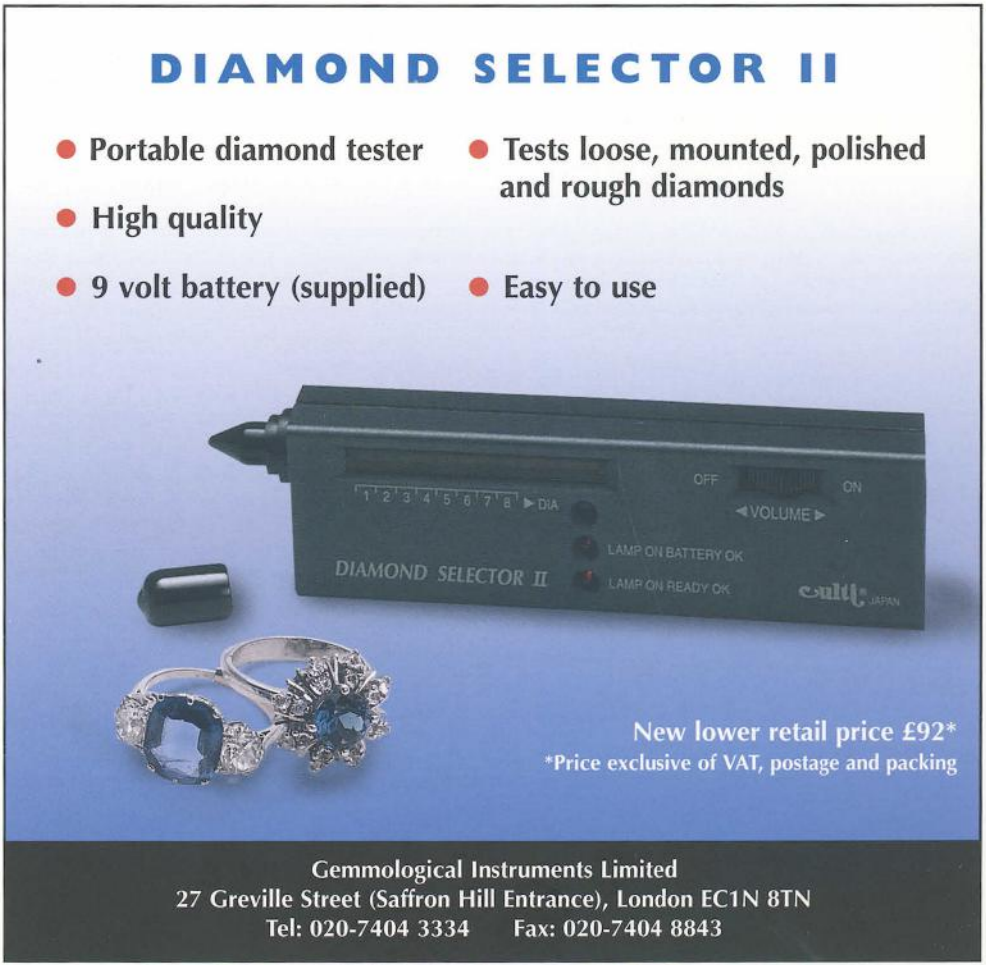
Shi Guohua. *Journal of Gems and Gemmology*, **1**, 1999, 40–4, illus in colour.

The nature of the colour and the form of water molecules in Guilin synthetic emerald were investigated by electron microprobe and IR spectra. The results show that the Guilin synthetic emerald is characterized by low contents of alkalis and Fe (and Cl); both I-type and II-type water is present. The colour should be attributed to the separation of the ^4F spectrum term and the spectrum resulting from electrons jumping between the different energy levels. Nail-like inclusions are typical. FTIR spectra can be applied to the identification of all types of emerald. R.A.H.

(Identified characteristics of Guilin hydrothermally-grown synthetic ruby.) [Chinese with English abstract.]

Yuan Xingqiang, Kuang Yonghong and Di Jingru. *Journal of Gems and Gemmology*, 1, 1999, 47–9, illus in colour.

Guilin hydrothermally-grown ruby shows an orange-red colour, no absorption in the blue-green part of the spectrum, a colourless seed and crumb-like inclusions. The extraordinary ray has the stronger (yellow) colour, the ordinary ray being a weaker orange-red. M.O'D.



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BOOK REVIEWS

Understanding jewellery (revised edition)

D. Bennett and D. Mascetti, 1994. Antiques Collectors' Club, Woodbridge. pp 425, illus. in colour, hardcover. ISBN 1 85149 205 4. £39.95.

Though the reproduction of some of the photographs (in my copy, at least) leaves something to be desired, this easy-to-read survey of the history of jewellery has been updated to take into account developments in techniques and styles over the period 1960–1980 which has a 40-page chapter to itself. Simple gem testing is described over the first 40 pages: thenceforward the text is arranged chronologically, beginning with the late eighteenth century to 1820. Many readers will find particular interest and information in the tables of approximate auction values (of many of the items depicted in the main text), occupying six pages, and there is a short but useful bibliography. For so comprehensive a survey this book accomplishes its task well and is very good value for the price. M.O'D.

Science and technology of diamond

G. S. Bhatnagar (Ed.), 1999. Mineral Club of India, New Delhi, and Cambridge International Science Publishing, Cambridge. pp 181, illus. in colour, hardcover. ISBN 1 898326487. £55.00.

A multi-author book with chapters on: The diamond connection (D. Lal), discussing age and depth of formation: Biogene indicators of kimberlities and lamproites (P. O. Alexander): Relevance of stream sediment sampling in kimberlite exploration (T.R.K. Chetti *et al*): Gemmology of diamond (M. O'Donoghue): Synthetic gem diamonds and their gemmological identification (J.R Shigley and E. Fritsch): Diamond synthesis (the late B.K. Agarwala): The ultrahard abrasives industry (M.P. Jennings): Science of diamond in protohistoric India (G.S. Bhatnagar and S.R.N. Murthy). There is an excellent bibliography with 253 entries all of papers of significance and including some which would be quite hard to track down otherwise, and eight pages of colour photographs, several indicating distinguishing features of synthetic gem diamond. The book is a useful and pleasingly-written mixture of current topics with some history. It has taken some time to appear: I remember writing my chapter while at the National Physical Laboratory of India in New Delhi quite early in this decade.

Compared with some recent multi-author diamond books, this is on a smaller scale but the contents are easily assimilated and relevant to many branches of gemmological and geological study. M.O'D.

The complete handbook for gemstone weight estimation

C. I. Carmona, 1998. Gemania Publishing, Los Angeles. pp xiv, 434, softcover. ISBN 0 9666370 0 3. US$ 59.95.

In suggesting a reliable method for finding out the weight of mounted gemstones the book places the major gemstones into eight groups on the basis of their specific gravity. Having identified the stone, its SG is noted and its measurements are taken. Style of cutting affects the final result which is calculated by multiplying length by width by depth by SG by a weight correction factor which is designed to take into account various non-standard features of cutting such as a very large table. Without a considerable number of tests the reader takes a certain amount on trust but the idea seems sound and the presentation is very clear, with diagrams illustrating sizes and cutting styles. For a book whose text consists mainly of columns of figures the chosen type-face has succeeded in allowing the user to work at speed with minimum eyestrain and wide readership can be predicted. M.O'D.

(Emerald.) [In Chinese]

Chang Wang Shi Ying and Chang Si Fen, 1996. Kenny Jewellery, Taipei, Taiwan. pp 95, illus. in colour, hardcover. ISBN 957 97172 4 9. Price on application.

A survey of emerald from different localities is illustrated by excellent photographs of emerald-set jewellery. Some characteristic inclusions are also shown. A very attractive book undoubtedly intended for the firm's customers but well worth buying in any case if you are collecting books on emerald. M.O'D.

Shells

C. Claasen, 1998. Cambridge Manuals in archaeology. Cambridge University Press, Cambridge. pp xiv, 266 Illus. in black-and-white, softcover, ISBN 0 521 57582 3. Price on application.

Though tangential to gemmological studies however widely interpreted, learning something of the nature of shells is important, especially when as in this case they are treated from the point of view of the archaeologist. In fact there is quite a lot here about the biology of freshwater and marine molluscs (and about the people who collected them) and also about pearls. There is a first-class bibliography as one would expect from this publisher. M.O'D.

A journey with colour: a history of Queensland opal 1869–1979

L. Cram, 1998. The Author, PO Box 2, Lightning Ridge, New South Wales 2834, Australia. pp 368, illus. in colour, hardcover. ISBN 0 9585414 O X. A$ 178 (including postage and packing to the UK: about £115.00).

Australian opal books are always very pleasing to the eye but this one is up to now the most magnificent of all. In conversation with the author it was established that the

ISSN: 1355-4565

book is in fact intended to form the first volume of a complete history and review of Australian opal in general (and also of opal from other places in the world) – this is why the otherwise mysterious 'volume one' appears on the spine but nowhere else. I make this point on behalf of Len Cram so that readers will not imagine that the final work will deal only with Queensland opal. It is expected that the succeeding volumes will be quite a lot larger than the present one, so that there is a good deal to look forward to!

Queensland opal has taken a leading role over the last few years: the state, once associated only with boulder opal (sometimes superb, sometimes found only as streaks in a dark ironstone), now produces what is probably the finest material in the world. The text (with magnificent photographs on every opening) deals with the history of the earliest discoveries of Australian opal (in South Australia) and then proceeds to examine all the major Queensland deposits. Miners, methods of working, local geological conditions, celebrated stones and opal commerce are all described. A map and a useful glossary can be found at the end of the main text. This is one of the most beautiful books on any gemstone that I have yet seen: while opal is almost always spectacular in some way, it is hard to imagine how the quality of the photographs here could be improved. The book is by no means expensive for the riches it contains: the print run is only 1600 so try to buy it if you can. M.O'D.

L'émeraude

[Monographic issue of] *Revue de gemmologie*, 134/135, 1998. (pp 192), illus. in colour. ISSN (for the series) 0398 9011. This issue comes under the annual subscription of FF250 (Europe, 1 year).

This multi-author issue is devoted entirely to emerald in both its natural and synthetic forms, giving the physical and optical properties of specimens from all major sources and for the different man-made varieties. Inclusions are well-photographed and reproduced, the illustrations showing the differences between emeralds from the different places of origin. Both students and experienced gemmologists will find this a useful book to keep on the bench or counter. Monographs on emerald in so convenient a size are not plentiful and the customer could well be interested in the photographs, especially if they can be related to actual items in stock. There is room for similar works on the other major gem species. M.O'D.

Die Staatliche Bernstein-Manufacktur Königsberg, 1926–1945

U. Erichson and L. Tomczyk, 1998. Ribnitz-Damgarten: Deutschen Bernsteinmuseum (Im Kloster 1 - 2, D-18311). pp 153, illus. in colour, landscape format. ISBN 3 00 002986 9. DM49.00.

Not-to-be-missed, beautifully-illustrated history of the Königsberg amber factory during its most productive years. Many of the pieces shown are items of jewellery or other ornaments and the methods used to fashion the amber are clearly described with contemporary black-and-white photographs. There is a useful bibliography and reproductions of some price lists and advertisements. M.O'D.

Falize; a dynasty of jewellers

1999. Wartski, London (14 Grafton Street, London W1X 4DE) pp 36, illus. in colour, softcover. £5.00.

Attractively produced catalogue of a loan exhibition held at and by Wartski for the benefit of Befrienders International, this short study of a number of items by Falize describes and illustrates some of the work of one of the major jewellery designers and makers of the late nineteenth/early twentieth century. Many of the items have been featured in a major study of Falize by Katherine Purcell (Thames & Hudson, London, 1999). M.O'D.

Das Ei. Kostbare Ostereier aus Edelstein

S. Frazier, A. Frazier, D. Jerusalem, B. R. Starke, and M. Wild, 1999. Stiftung Deutsches Edelsteinmuseum Idar-Oberstein. pp 71, illus. in colour, hardcover. ISBN 3 932515 13 7. Price on application.

A small book, as beautifully produced as the hardstone Easter eggs described and illustrated between its covers. The exhibition of which the depicted examples form a part celebrates 25 years of the Deutsche Edelsteinmuseum, catalogues of whose contents have appeared in the journal *Aufschluss* and separately. Not only are the eggs described but methods of making them, with some history, form the first part of the book. Views of the Museum itself encourage visitors. M.O'D.

Gem Testing Laboratory Silver Jubilee 1972–1997

The Gem Testing Laboratory, Jaipur, India. 1997. pp 80, illus. in colour, softcover. Price on application.

Gem testing history is not often found in the literature so this is a very useful survey of how work has been carried out at the centre of the Indian gemstone trade. Short biographies are especially welcome and there are some notes on topics of the moment, particular gemstone enhancement. M.O'D.

Gold in Bayern: Vorkommen am Westrand der Bˆhmischen Masse

Forms 102 of *Geologica Bavarica*, 1997. pp 424, Illustrated in colour, softcover, ISSN for the series 0016-755X.

For the gemmologist who also collects gold specimens this study of the gold-bearing areas of the Western end of the Bohemian massif will be indispensable. Chapters cover all types of occurrences as well as the history of gold mining in the region. M.O'D.

Guide to affordable gemology

W. W. Hanneman, 1998. Poulsbo (PO Box 942, Poulsbo, WA 98372). pp xii, 172, softcover ISBN 0 9669063 0 6. US$25.00.

Eminently readable and amusing too in many places: this reviewer suspects that 'combative' would be another aim of this polymath and fascinating author who enjoys setting up imaginary scenarios travelling through which he can quixotically defeat or, better, irritate a series of cardboard enemies who, if they existed, would almost certainly be on his side!

This is not a book for the beginner but most certainly one for the teacher whose methods and ideas need constant refreshment. I found it a genuinely excellent conspectus of a number of simple and trusted techniques lucidly described with a leavening of gentle malice with which, if I am honest, echoes many thoughts which have at some time passed through my mind. The book begins with a survey of instruments and long accepted testing methods (with extensive comment on Alan Hodgkinson's rediscovery and careful development of the once-abandoned visual optics technique) and follows with an evaluation of various textbooks, specimens and tests: maybe he errs in not realizing that there are some quite good books around and in dismissing (or appearing to dismiss) some of the work done by the perhaps dull organisations whose staff look wonderingly up from their old textbooks and the instruments of academic determinative mineralogy as Comet Hanneman-Hodgkinson traverses the skies above!

Whatever your experience of gem testing, the book can add to it so buy it and see where you can take issue with the author. Perhaps not too often? But a note to the beginner – 'affordable' does not mean 'elementary' so students, take care while you read! M.O'D.

Mineralogical studies of archaic jades

HSIEN HO TSIEN (Ed.), 1996. **Special issue** (no 32 of 1996) of *Acta Geologica Taiwanica*. pp 199 Illustrated in colour, softcover. Series ISSN 0065-1265. Price on application.

Presented as a set of essays in honour of Professor Li-Ping Tan, this important study should be required reading for all with an interest in the jade minerals and the artefacts fashioned from them. Essays include discussions of Raman spectroscopy as applied to the jades, sources of jade materials, methods of working with crystal growth and whitening of archaic tremolite *yu*. Each chapter has its own list of references and there is a short glossary. M.O'D.

Chaumet, Paris: two centuries of fine jewellery

R. HUREL AND D. SCARISBRICK, 1998. Musées de la Ville de Paris, Paris. (pp 173), illus. in colour, hardcover. ISBN 2 87900 390 3. £28.00.

The history and artefacts of the Parisian jeweller Chaumet are described in this catalogue of an exhibition held at the Musée Carnavalet, Paris, from 25 March–28 June 1998. Items are well illustrated and described, the catalogue entries giving details of personages, materials, dimensions and provenance. A short history of the firm opens the text and there is a useful bibliography. M.O'D.

(Natural bleach jadeite identification.) [In Chinese]

J.W. HWANG, 1995. GGL, Taipei, Taiwan. pp 216, illus. in colour, hardcover, ISBN 957 99831 19. (Obtainable through World Trade and Technical Publications Co. Ltd, Room 1423, Star House, 3 Salisbury Road TST, Kowloon, Hong Kong.) Hong Kong $2760.00.

Yes, this is an expensive book but there is nothing else in monograph form on the bleaching of jadeite and even though the text is in Chinese, as always the photographs and their captions are so good that the reader can tell what is being discussed. This time the photographs are magnificent rather than good and despite the price, libraries in the West at least ought to make an effort to buy so important a treatment of this vital subject. I assume that gem collectors and laboratories in China already have it.

The text opens with several pages of photographs showing jade pebbles and boulders, including a number of shots of material on sale at the 1990 Myanmar gem auctions. This is interesting for a number of reasons, not least because you can see the different colours revealed by the saw cutting of the boulders and also the price paid for particular lots. I have never met this feature before. Details and illustrations of the treatments follow and the remainder of the book covers testing for the various materials used in colour alteration – again, this section is profusely illustrated. There are at least four and usually 10 photographs to be seen on each opening, making an average of five pictures on each separate page. At least try to get a look at this and at other China-produced books. M.O'D.

Kristallmuseum Riedenburg im Altmühltal, München

Lapis [Christian Weise Verlag], 1998. pp. 96, illus. in colour, softcover. DM 16.00.

This guide to one of Germany's most interesting mineral museums forms the first issue of a new series from this excellent publisher. The aim is to supplement the journal *Lapis* (founded in 1976 and which also has the monographic series *extraLapis*) by adding guides to notable museums. Riedenburg is north-east of Munich and south-east of Nuremburg and the museum contains many items of gemmological and ornamental interest. Notes on gemstones in general, including notable diamonds, accompany the guide. M.O'D.

(Gemstone inclusions identification.) [In Chinese]

LAI TAI-AN, 1995. Gemological institute of Lai Tai-An (PO Box 53-1142), Taipei, Taiwan. pp ix, 342, illus. in colour, hardcover in slip case. ISBN 957 99439 0 7. US$115.00.

Yes, there is enough English in the captions to be able to work out what is being shown in the magnificent series of inclusion photographs in this large and beautiful book, in which no opening has less than 4 pictures and sometimes up to ten. Beginning with instructions on how best to look for significant inclusions, the text goes on to review the major gem species, both natural and synthetic: treated and enhanced specimens are also discussed. The standard is at least as high as in other books on inclusions and in many instances excels them. M.O'D.

(Gem jade identification and buying guide.) [In Chinese]

LIAO ZONG TING AND BIAN QING, 1997. Shanghai Illustrated Magazine Publishing House, Shanghai, P.R. China. pp 123, illus. in colour, softcover. ISBN 7 80530 286 3. Price approximately £10.00.

With all the colour at the front, this is a very neat and concise guide to the jade family of minerals in their fashioned form, so it is especially useful for gemmology students who are in fact using them during their courses. A few text diagrams complete the survey. M.O'D.

Fleischer's glossary of mineral species (8th edn)

J. A. Mandarino, 1999. The Mineralogical Record, Tucson. (pp vi, 226), softcover, ring-bound. Approx. £13.50 in UK.

The small but significant change in title of this very popular book comes through the recent death of Michael Fleischer, its begetter, at the age of 90. The *Glossary* has long been the bible of mineral species collectors and is worth serious consideration by gemmologists for its up-to-date information on species, their composition, group membership, crystal system and most topical reference in English. In this edition, now in the charge of the former junior author, colour has been omitted (since it may vary significantly with location) as have non-validated species: the 'compositions in words' are also omitted this time for the sake of saving space.

For the rest we have the now familiar alphabetical arrangement, retaining the squares preceding each entry and intended to be marked off by the fortunate collector who secures an example. The main text is followed by the section describing mineral groups and their constituent species (whose compositions are repeated): since there have been major revisions of the amphiboles and zeolites the opportunity has been taken to incorporate the new information gained. The *Glossary*, first published in 1971, appears once more as a welcome survey of mineral species with emphasis on relationships. For today the price is amazingly reasonable and the production as good as ever. M.O' D.

Jewellery making in Birmingham, 1750–1995

S. Mason, 1998. Phillimore, Chichester. pp xi, 211, illus. in colour, hardcover. ISBN 0 86077 079 7. £25.00.

The visitor to Birmingham today will find a rail (and tramway) station named 'Jewellery Quarter'. Alighting, the surrounding scene, though clearly one of contraction, is still devoted almost entirely to the jewellery trade which at last has a worthy history of its own. While Birmingham is correctly regarded as the centre of what in any other form of manufacture would be called mass-production, there has been no lack of innovative techniques or designs since jewellery-making began in the eighteenth century. By 1773 Birmingham had its own Assay Office and the trade employed a high proportion of the city's workforce. In 1887 the jewellers had their own trade association and a training school, established in 1890 and well in evidence today.

In this fairly short book the origins of the Birmingham jewellery manufacturing trade are discussed with considerable comment on how designs, machinery and skills developed. The author has been able to draw quite a lot of material from local records and this shows in the excellent bibliography and text references, both sections placed together at the end of the book. The text is well illustrated with both black-and-white and colour photographs, of a good standard: I can recommend it highly and also a visit to the jewellery quarter, where a really first-rate museum is open daily. The museum is in fact a jewellery-making factory, preserved in its original state after the owners decided, virtually overnight, to retire, leaving the workers, correspondence, gold stocks and work in progress just as they were. M.O'D.

Jewelry from the Pearl Museum, Vol. 1

K. Matsuzuki, 1998. Mikimoto Pearl Island Co. Ltd, Mie, Japan. pp 47, illus. in colour, hardcover. £13.00.

The first in a series of volumes describing and illustrating artefacts in the Pearl Museum is concerned with sash clips from the Meiji, Taisho and Saisho periods as well as with sash clips and hilt ornaments in general. All exhibits in the Pearl Museum are set with pearls: each of the 50 or so items is described with dimensions and notes on the metals and stones used. In many cases small insets show designer's drawings. Though a small book it is beautifully produced and other volumes in the series are eagerly awaited. M.O'D.

El maravilloso mundo del la esmeralda Colombiana (The remarkable world of the Colombian emerald.) [In Spanish and English]

R. Moncada and T. Quinn, 1995. Photo World Press-Editores, Santafé de Bogota. pp 131, illus. in colour, hardcover. ISBN 958 95780 0 4. Price on application.

A vocabulary of words and phrases concludes this excellent and well-illustrated book on the Colombian emerald, its nature, mining and marketing. 'Voladora' is working a mine 'on the sneak' while 'cuerda' is a collection of fighting cocks belonging to an individual. While this might seem rather distant from gemstones it shows that the authors have found and reproduced the spirit and life of everyday Colombian emerald working which of course is well described throughout the remainder of the book. Words for emerald qualities and for miners' agreements are also given while tables identify the different working shafts of the Chivor, Muzo, Quipama and Coscuez mines. Many mining scenes are graphically and dramatically shown by a series of fascinating pictures and the gemmologist will need this book as an addition to any serious library. M.O'D.

Museés royaux d'Art et d'Histoire [Belgium]. Quand la pierre se fait précieuse...

The Museum, Brussels, 1995. pp 134, illus. in colour, softcover. £15.00.

Catalogue of an exhibition at the Brussels and Tervuren museums of art, the book acts as a quite useful and well-illustrated introduction to gemstones and jewellery and shows a large number of rough and fashioned stones (in rather small dimensions), later turning to the history of jewellery which is also pleasingly illustrated. M.O'D.

Kristalle aus den Schweizer Alpen

E. Offermann, 1999. Christian Weise Verlag, München. pp 66, illus. in colour, softcover. ISBN 3 921656 47 8. Price on application.

A pocket-sized book worth noting for the number of gemmologists who are also crystal-specimen collectors and also for the unique combining of high-quality photographs with computer-produced diagrams, generated with the software Shape 4.2 with Canvas 3.5.4 for the graphics. A most attractive production which shows developments and translation of forms in a very simple way, the book should be of interest as much for its production as for the fine specimens presented. M.O'D.

(Jadeite observation.) [In Chinese]

C. M. Ou Yang, 1995. World Library Ltd, Hong Kong. pp 191, colour, hardcover. ISBN 962 257 584 6. HK $198.00.

A survey of jadeite from the geological and mineralogical standpoints as well as from that of the gemmologist and connoisseur, this book is a good starting point for the Chinese reader who wishes to learn, fairly quickly, about jadeite. The text begins with jadeite occurrences (shown on maps) and continues with notes on structure before proceeding to the series of pictures depicting finished jewellery set with the finest qualities of the material. Production is excellent, as seems to be the case with many Far Eastern books on jade. M.O'D.

(Jadeite ABC.) [In Chinese]

C.M. Ou Yang, 1997. Cosmos Books, Hong Kong. pp 192, illus. in colour, hardcover, ISBN 062 950 214 3. HK $238.00.

Exhaustive study of jadeite from recovery and fashioning to testing, enhancement, imitation and sale. The illustrations are first-class, especially of jadeite in the rough, not often seen in much larger books. The excellence of the illustrations greatly diminishes the inevitable textual difficulties which could be experienced by non-Chinese readers. M.O'D.

(Jadeite selection and buying.) [In Chinese]

C. M. Ou Yang, 1998. World Library Ltd, Hong Kong. pp 185, illus. in colour, hardcover. ISBN 962 950 379 4. HK $190.00.

Beautiful pictures of set jadeite enliven this most useful buyer's guide which seeks to point out the beauty of the material rather than to give notes on treatment and testing. As such the book succeeds admirably and will be welcome to all readers, whether or not they can read Chinese. M.O'D.

Rough diamonds. Internal and external features

N. Peters, 1997. American Institute of Diamond Cutting, Inc., Deerfield Beach, Florida (PO Box 4067) 33442-4067, USA. pp 46. Illus. in colour. Hardcover. Price on application.

A series of 86 excellent colour photographs illustrates diamond crystals, indicating external and internal features which may affect initial sorting and subsequent fashioning. The polishing process and some finished stones are also illustrated and the whole book is a first-rate introduction to the subject, whether the reader is a polishing beginner or a student of gemmology. A larger treatment of the subject is promised by the author and publishers and if the same standard is maintained it will be worth waiting for. M.O'D.

Rough diamonds. A practical guide

N. Peters, 1998. American Institute of Diamond Cutting, Inc., Fort Lauderdale. pp 172. Illus. in colour. Hardcover ISBN 0 9665854 1 0. £55.00.

The author has previously produced *Rough diamonds: internal and external features* and this larger text also considers diamond crystals and how their nature influences their final polished state. The first chapter gives an overview of the rough diamond market: this is followed by a discussion of the structure of rough diamonds and how to obtain optimum weight from a finished specimen. Surface and internal features, colour in the rough state and details of manufacturing each has its own chapter and the final section details the valuation of rough diamonds.

A great deal of the material in the book would be difficult to find elsewhere and the majority of the photographs give good views of the specimens they illustrate. Although a few of the black-and-white pictures are slightly out of focus, the student of diamond should have this book available for reference. M.O'D.

Handbook of industrial diamonds and diamond films

M.A. Prelas, G. Popovici and L.K. Bigelow, 1998. Marcel Dekker Inc., New York. pp xii, 1214. Illus. in black-and-white. Hardcover ISBN 08247 9994 1. £140.00.

While aimed in the first instance at readers interested in the use of diamond as an engineering and research material, this large book brings together all extant and on-going research into the physical and optical properties of natural and synthetic diamond. A team of 45 writers has compiled a guide to all the properties of diamond (including a section by Collins giving up-to-date ideas on band theory): pages 232–343 attribute defect-induced vibrational bands, one- and two-phonon Raman bands and optical bands to their causes. For gem diamond specialists this section allows finding the particular band (e.g. 415.2 nm [as cited]) and finding out the exact cause (this band has a 25-line paragraph devoted to it) and treatment of similar length, with diagrams where appropriate, is given to other well-known optical absorption bands (together with bands in the ultraviolet and infrared regions). Altogether more than 100 vibrational and over 400 electronic optically active centres have been identified in diamond in the spectral range from 20 to 0.17 µm (i.e. from the middle IR to the vacuum UV region).

While this section will certainly interest the scientific gemmologist most, much of the information elsewhere in the book will also be useful. Pages 481 to 526 deal with natural diamond, its locations, formation (in kimberlites and lamproites), distribution, exploration, mining and processing, mineralogy and geochemistry, classifications, fashioning and marketing. In the absence of a similar in-depth study in English this summary chapter gives one of the best sets of current references.

The book also contains individual chapters on thermal properties and characterization methods and includes a very large section on the chemical vapour deposition of diamond thin-films. This opens with the theory of CVD and follows with sections on the modelling and diagnostics of plasma reactors and on methods of CVD growth. Similar exhaustive treatment is given to the structural modification of diamond (nucleation and epitaxy, ion implantation of diamonds and diamond films, and processing). This section deserves careful study since any kind of alteration of diamond has considerable significance for many areas of materials science.

The last sections describe many of the applications of industrial diamonds (as abrasives, in computers and in other fields) and conclude with a discussion on diamond economics and commercialization. This is a large and expensive book but potential readers should ensure that their university library obtains a copy. M.O'D.

Catalogue of Mineralientage München 1998

Rot and Lebendig, 1998. Mineralientage München, Oberhaching. pp 288, illus, in colour, softcover, DM50.00.

This year's theme of the Munich Mineral Show was red minerals and gemstones and this beautifully-illustrated catalogue includes a number of short papers certain to be interesting to gemmologists. My eye was particularly caught by a description of trapiche ruby as well as a survey of the role played by chromium in the coloration of minerals and gemstones. A short photographic essay showing interference figures, a return to Mogok and a review of rhodochrosite from the Sweet Home mine, Colorado, U.S.A., are among other articles accompanying the show guide, the main purpose of the catalogue. M.O'D.

Geology of East Africa

T. Schlüter, 1997. Gebrüder Borntrager, Berlin. pp xii, 484. ISBN 3 443 11027 4. [*Beiträge zur regionalen Geologie der Erde.* Bd 27] DM 196.00.

The series has already included studies of the gem-producing areas of Myanmar and Pakistan, each with considerable mention of gem minerals and their occurrence, so that a similar comprehensive coverage of the geology of East Africa is particularly welcome since there are fewer detailed studies outside the Survey reports (where they exist) of the original colonies. The book sets out to give an account of the regional geology and stratigraphic history of East Africa: the countries included are Kenya, Tanzania and Uganda, but surrounding regions with similar geology are frequently mentioned.

The text is arranged in geochronological order by country, stratigraphy, petrology and mineralization, and students with an interest in the gemstones of the region will find the best account in the section (2.84) dealing with the neoproterozoic of the Mozambique belt in Kenya, Tanzania and Uganda. Here we have treatments of gemstone mineralization which include the desilication of granite pegmatites or gneisses by ultramafic rocks leading to the formation of ruby, sapphire, spinel, emerald, alexandrite and tourmaline: medium- to high-grade metamorphism of closely associated crystalline limestones and graphic gneisses giving tsavolite, tanzanite and rarer collectors' species: classic emplacement of Li- and Be-rich pegmatites providing the well-known granite pegmatite gem minerals tourmaline, beryl, quartz, phenakite and euclase: hydrothermal alteration of serpentinite and other ultramafic bodies giving peridot, and the lower-temperature establishment of chrysoprase, rhodonite and prase-opal.

There is an excellent bibliography and subject, fossil and locality indexes. The book is a worthy companion to others in this distinguished series and the price is not unreasonable for a work of this quality. M.O'D.

Gemstones of the world (revised and expanded edition)

W. Schumann, 1997. NAG Press, London. pp 271, illus. in colour. Hardcover ISBN 0 7198 0271 7, £18.50.

This well-known text is popular with students and has now been edited to get rid of some really awful mistakes which were included in some at least of the earlier editions. The pictures are as good as ever: for students the main drawback is what C.S. Lewis, one of my professors long ago, calls 'the boundless assurance of the pure textbook' so that what you are told has to be compared with serious textbooks, which, in fairness, this has never claimed to be. It is very pleasant to look at and most of the information is more or less correct. Read with care. M.O'D.

Pearls and pearl oysters of the world. [In English and Japanese]

S. Shirai, 1994. Marine Planning Co., Nagano, Japan. pp 108 Illustrated in colour, hardcover, ISBN 4 9900287 1 6. Price on application.

Illustrations with dimensions and descriptions of 275 species of mollusc of which 24 marine examples are pearl-bearing, 238 freshwater pearl-bearing and 13 other pearl-bearing species. While the majority of examples are arranged by continent the major marine pearl molluscs are arranged under the Pacific, Atlantic and Indian oceans. Both Latin and English names are given with commonly-used synonyms where applicable. Endangered species are flagged and museum specimens indicated. The standard of photography is state-of-the art and the book is a very welcome addition to the still rather sparse pearl literature. M.O'D.

Mineralienlexikon der Schweiz

H.A. Stalder, A. Wagner, S. Graeser and P. Stuker, 1998. Verlag Wepf & Co., Basel, Switzerland. pp 579, illus. in colour, hardcover. ISBN 3 85977 200 7. SFr 178.00.

As a highly mineralized country Switzerland is naturally of great interest to the mineral collector and gemmologist. The present book is a worthy successor to the earlier surveys of Parker in 1954 and Parker (with some of the present writers) in 1973. A further general study by Weibel *et al.* was published in 1990.

The book opens with mineral descriptions in alphabetical order, the entries giving chemical composition, details of crystallization and other properties, together with notes on major Swiss occurrences. This large section is followed by descriptions of the major types of mineral occurrence, details of meteoritic and organic materials and a 21-page bibliography. The book concludes with an index and with coloured maps illustrating geology and some of the major mineral occurrences. This is essential reading for all interested in Swiss minerals and is well-produced and reasonably priced. Gem mineral collectors will be especially eager to read about Swiss occurrences of fluorite, sphene and the various types of quartz. M.O'D.

Standards and applications for diamond report, gemstone report, test report. [English language edition]

SSEF Swiss Gemmological Institute, 1998. Basel, Switzerland. pp 118, Illustrated in colour, Softcover, US $65.00.

Very well-illustrated guide to standards employed in testing gemstones by the Swiss Gemmological Institute and a model of its kind. A large number of coloured photographs accompany specimen certificates and explanations of the grading systems used. The book will be especially valuable for the study of inclusions and of colour-enhanced specimens. M.O'D.

Limpiar la tierra: guerra y poder entre esmeraldos

Uribe Alarcón, M.V., 1992. CINEP, Bogotá. pp 150, illus. in black-and-white, softcover. ISBN 958 644 016 8. Price on application.

Official and unofficial emerald miners, the Colombian government, political parties and the Roman Catholic Church have traditionally striven for power in the east of Boyaca state since the discovery of emerald there. The book describes many elements of social conflict arising from the power struggle and also gives a good deal of detail, including maps, of the emerald-producing districts of Colombia and how the stones are recovered. Violence has been especially severe from the 1960s and the area is still unsafe. A useful bibliography includes a good deal of unpublished material. M.O'D.

(Pearl Science.) [In Chinese]

Xie Yukan, 1995. South China Sea Institute of Oceanology, Guangzhou, P.R. China. pp 313, 11 colour plates, hardcover, Price on application. ISBN 7 5027 4090 2.

A serious and comprehensive study of pearl and pearl fishing with the emphasis on the biology of the various pearl-bearing molluscs, this book will be required reading for Chinese students of the pearl and for marine biologists working in this particular field. The structure of the molluscs is drawn in great detail and here, as elsewhere, the reader longs for a translation into a Western language. Even so, there are useful points to be found and the index is in English – sadly the extensive bibliography remains in Chinese and no doubt conceals many treasures of information! Reproduction is somewhat faint in places but on the whole the book is well produced. M.O'D.

(Jadeite identification pictorial book.) [In Chinese]

Zheng Yong Zhen, 1984. Bao Hong Jewellery Company, Taipei, Taiwan. pp 392, illus. in colour, hardcover. ISBN 957 97114 2 9. Price approximately £115.00.

Compared to the earlier work by the same author, this one, though as magnificently illustrated, deals more with the day-to-day identification of all types of jadeite, going as far as to provide the spectra of some of the materials used as fillings. All that the reader could want appears to be here and it is hard not to believe that this author's production will not set the standard for many studies to come. M.O'D.

(Gem jade.) [In Chinese]

Zheng Yong Zhen, 1986. Bao Hong Jewellery Co., Taipei, Taiwan. pp 325, illus. in colour, hardcover. ISBN 957 97074 4 8. Price approximately £115.00.

Beautifully illustrated survey of gem-quality jade with an emphasis on jadeite as most current Chinese studies for publication show. The first section describes and illustrates the recovery of jadeite and gives the reader an excellent view of the material in its rough pebble and boulder forms. The following sections describe qualities, testing and treatment, with a sudden appearance right at the end of the book of a number of other gem species in faceted form. For readers who are connoisseurs of jade this is yet another unmissable item for their personal libraries. M.O'D.

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

PHOTOGRAPHIC COMPETITION

The 1999 Photographic Competition on the theme 'Gems of the Century' produced a fascinating selection of photographs illustrating gems that were considered of special significance in the twentieth century.

First Prize

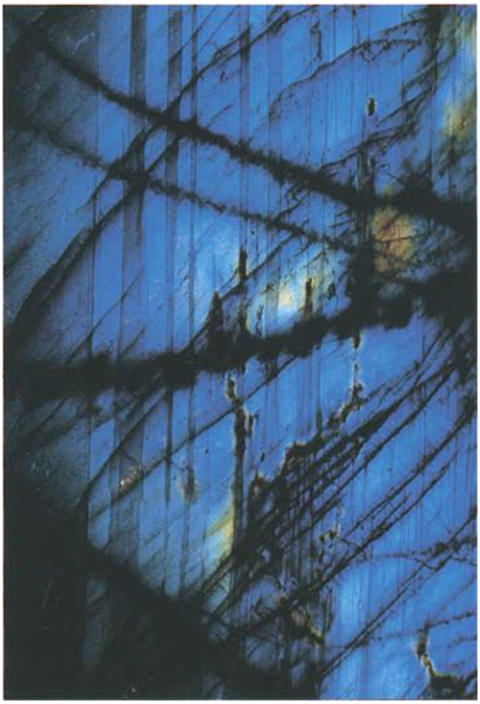
Roy Huddlestone, London

Etched cave diamondscape (see front cover)

Second prize

Bob Maurer, FGA, DGA, London

Detail from a large specimen of labradorite



Third Prize

Spencer J.A. Currie, FGA, Auckland, NZ

Leaf opal

We are pleased to announce that the prizes were sponsored by Quadrant Offset Ltd, and the GAGTL is most grateful to them for their generosity. The prizes were presented and the winning entries exhibited at the Reunion of Members held on 28 June.

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AWARDS

The Council of Management has recently made the following awards:

Professor Dr. H. Bank of Idar-Oberstein, Germany, has been awarded Honorary Life Membership of the Association in recognition of his services to gemmology on the international scene, and particularly for his support for education both at the GAGTL and in Europe.

Professor Chen Zhonghui of Wuhan, P.R. China, has been awarded an Honorary Fellowship of the Association for his extensive and devoted services to the establishment and development of modern gemmology in China.

NEWS OF FELLOWS

Congratulations to David J. Callaghan, Kenton, on his recent election as President of the National Association of Goldsmiths.

MEMBERS' MEETINGS

London

On 6 May 1999 at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8TN, Dr W. W. Hanneman gave a lecture entitled *A guide to affordable gemmology.*

On 14 May at the Gem Tutorial Centre, Cecilia Pople gave an illustrated talk entitled *Shining examples – the teaching potential of a gemmologist's jewel box.*

The Annual General Meeting was held on Monday 28 June, followed by the Reunion of Members and a Bring-and-Buy Sale. A full report will appear in the October issue of the *Journal.*

Midlands Branch

On 30 April 1999 at the Earth Sciences Building, University of Birmingham, Edgbaston, the Annual General Meeting was held at which David Larcher, Gwyn Green, Elizabeth Gosling and Stephen Alabaster were re-elected as President, Chairman, Hon. Secretary and Hon. Treasurer respectively. The AGM was followed by an ID Challenge.

On 23 May at Barnt Green, Peggy Hayden led a Gem Club session on jet.

On 26 June a Summer Supper was held at Barnt Green.

North West Branch

On 19 May 1999 at Church House, Hanover Street, Liverpool 1, Rosamond Clayton gave a talk on *Pearls – romance and fact.*

Scottish Branch

The Annual General Meeting and Conference of the Scottish Branch was held at Perth from 30 April to 2 May. At the AGM, Alan Hodgkinson, Brian Jackson, Catriona McInnes and Gillian O'Brien were re-elected as President, Chairman, Secretary and Treasurer respectively. A report of the Conference was published in the June issue of *Gem and Jewellery News.*

ANNUAL REPORT

The following is the report of the Council of Management of the Gemmological Association and Gem Testing Laboratory of Great Britain for 1998.

The Gemmological Association and Gem Testing Laboratory of Great Britain (GAGTL) is a company limited by guarantee and is governed by the Council of Management. The President, Professor R.A. Howie, was re-elected at the Annual General Meeting in June, and the Vice-Presidents, E. Bruton, A.E. Farn, D.G. Kent and R.K. Mitchell, continued in office. M.J. O'Donoghue joined the Council of Management in September. The company also benefits from the contributions of the Trade Liaison Committee, the Board of Examiners and the Members' Council. Dr G. Harrison Jones continued as Chairman of the Board of Examiners, and J. Greatwood was appointed to strengthen the gemmology examination team.

At the AGM in June, S.A. Everitt, A.G. Good and P.J. Wates were elected to the Members' Council, which continued to be chaired by C. Winter. The Chairman and Vice-Chairman of the Trade Liaison Committee were T.M.J. Davidson and J. Monnickendam respectively.

We were greatly saddened by the death of Howard Vaughan of De Beers, who had been a major contributor to the Trade Liaison Committee and was a very sincere friend to the GAGTL in so many ways. The committee welcomed the continued attendance of D.J. Callaghan in his role as a Jewellery Consultant.

At the Gem Tutorial Centre in Greville Street, the Gemmology and Diamond courses have been well subscribed with a good mix of students

GIFTS TO THE ASSOCIATION

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

Gerhard Becker, Idar-Oberstein, Germany, for rough specimens of benitoite, rhodolite, axinite, scapolite, amblygonite, phenakite, demantoid garnet, sphene and red tourmaline from Nigeria.

Daniel Dower, London, for a selection of specimens including natural and artificial lapis lazuli, elephant ivory, marble, rough and fashioned chalcedony, and a large bag of amber pieces.

Sonja I. Glaser N.V.K., Galle, Sri Lanka, for packets of various materials including hessonite and colour-change garnet, opal, cultured pearl, coral and turquoise.

Beverly Mitchell of the Signet Group plc, London, for 40 bags of fashioned gem materials including chalcedony, quartz, opal, garnet, moonstone, sapphire, emerald, ruby and zircon.

Susanna van Rose, B.Sc., Northwood, Middlesex, for olivine nodules from Raumer Kulm.

Dr N. P. Wijayananda of the Geological Survey and Mines Bureau, Colombo, Sri Lanka, for a Geological Map of Central and Western Sri Lanka together with *Geology in South Asia II.*

coming from both inside and outside the gem trade. The number of Allied Teaching Centres (ATCs) continues to grow with new additions in Montreal, Canada, and the Caribbean, and the commencement of the Gem Diamond course at Tongji University, Shanghai.

There has been continued investment in developing aspects of the Preliminary and Diploma Gemmology courses and plans are well in hand to update the Gem Diamond Diploma course. The new stone library service launched in September for UK-based home study students working towards their Gemmology Diploma has proved very popular. Enhanced visual aids for tutors and students are also being developed with a new system for scanning and archiving photographs and illustrations for CDs. More visual aids are also being produced for the GAGTL website, which is now receiving an average of 20,000 visits per week.

A wide range of short courses and tutorials were offered in 1998 and in addition to the regular programmes in Greville Street, tutorials were presented in Norway, Finland and in Washington DC, USA. We extend our very sincere thanks to the many people who have kindly made donations to the stone and mineral library; these items are crucial to providing a comprehensive service to our students.

In 1998 the Tully Medal and the Anderson-Bank Prize were awarded to Laurent Kellerson of London. The Diploma Trade Prize was awarded to Tina Notaro of Madison, Wisconsin, USA. The Anderson Medal for the best candidate of the year in the Preliminary Examination went to Long Chu of Guilin, P R of China, and the Preliminary Trade Prize was awarded to Linda Rythen of Stockholm, Sweden. As no student excelled in the year's Diamond Examination the Bruton Medal was not awarded.

Once again the Presentation of Awards was held in Goldsmiths' Hall. The guest of honour was Mr R. Buchanan-Dunlop, CBE, Clerk of the Worshipful Company of Goldsmiths, who presented the diplomas and prizes to the successful students.

In January 1998 the Gemmological Association hosted the second General Assembly of the Federation of European Education in Gemmology (FEEG), attended by representatives of gemmological schools from six European countries. The FEEG examinations were again held in London.

The annual Spring tour to Idar Oberstein, Germany, was very successful and later in the year there were field visits to Whitby and Edinburgh in search of jet and agates. In addition a trip was arranged to visit the diamond workshops in Antwerp.

The Laboratory continued to issue both London and CIBJO diamond reports, origin of colour reports for coloured diamonds, identification and treatment reports for coloured stones and pearl reports. One interesting 14.02 ct pale-yellow stone proved to be a new gem variety; after a joint investigation with the Natural History Museum, it was identified as the rare borate mineral, johachidolite.

FORTHCOMING EVENTS

5 August	**Scottish Branch.** An apatite for faceting. Art Grant
15 September	**North West Branch.** Photographing gems and their inclusions. John Harris
26 September	**Midlands Branch.** Play group – a practical gemmology session
20 October	**North West Branch.** Window to beauty. Piero Di Bela

Annual Conference

New Developments in the Gem World

Sunday 31 October 1999 – Barbican Centre, London

Keynote speaker: James Shigley
Director of Research at the GIA, Carlsbad
The challenges of gem identification at the close of the twentieth century

Campbell Bridges, Nairobi, Kenya
New African gemstones and their acceptance in the market place

Jack Ogden – Secretary General of CIBJO and
Chief Executive of the National Association of Goldsmiths
Colourful language or a treatment in store: retailing in a gem minefield

Forum

Delegates will have the opportunity explore the views of the speakers on the impact of new gems, new treatments and new synthetics on the producers, manufacturers and retailers in the gem trade.

Full details and application forms available from the GAGTL on 020 7404 3334

1 November	Visits to the School of Geological Sciences, Kingston University, and to De Beers
17 November	North West Branch. Annual General Meeting

For further information on the above events contact:

London:	Mary Burland on 020 7404 3334
Midlands Branch:	Gwyn Green on 0121 445 5359
North West Branch:	Deanna Brady on 0151 648 4266
Scottish Branch:	Catriona McInnes on 0131 667 2199

GAGTL WEB SITE

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

The annual trade function organized by the GAGTL in 1998 was a formal dinner held at the Café Royal, London, where members and guests were addressed by Geoffrey Munn, the Managing Director of Wartski.

The GAGTL was represented at the annual CIBJO conference in Vicenza, Italy, and members of staff have taken an active part in the CIBJO working group which is revising the rules and nomenclature in the gemstone *Blue Book*. The

GEM TUTORIAL CENTRE

27 Greville Street (Saffron Hill entrance), London EC1N 8TN

15 September	PRELIMINARY WORKSHOP A day of practical tuition for anyone who needs a start with instruments, stones and crystals. Learn to use the 10x lens at maximum efficiency and observe the effects and results from the main gem testing instruments. *Price £44 + VAT (£51.70) – includes a sandwich lunch* *GAGTL student price £32 + VAT (£37.60)*
6 October	PEARLS TODAY The pearl industry has seen enormous changes this century. This one-day course will give you the opportunity to handle a variety of natural, cultured and imitation pearls found in the marketplace today. Ann Margollis will explain the commercial aspects of the pearl industry; laboratory techniques for pearl identification will also be discussed. *Price £80 + VAT (£94.00) – includes a sandwich lunch*
20 October	DIAMONDS TODAY A valuable and concentrated look at all aspects of diamonds: rough and cut stones, treated (laser drilled and filled), synthetic and imitation materials. *Price £104 + VAT (£122.20) – includes a sandwich lunch*
26 and 27 October	SYNTHETICS AND ENHANCEMENTS TODAY Are *you* aware of the various treated and synthetic materials that are likely to be masquerading amongst the stones you are buying and selling? Whether you are valuing, repairing or dealing, can you afford to miss these two days of investigation? *Price £198 + VAT (£232.65) – includes sandwich lunches*
2 November	THE "INS AND OUTS" OF AMBER A rare opportunity to immerse yourself in the fascinating world of amber. Join Andrew Ross of the Natural History Museum and Maggie Campbell-Pedersen in a day devoted to looking at a variety of natural, treated and imitation materials and study the huge variety of flora and fauna inclusions found in amber. *Price £104 + VAT (£122.20) – includes a sandwich lunch*

For further details contact the GAGTL Education Department

Tel: +44 020 7404 3334
Fax: +44 020 7404 8843
e-mail: gagtl@btinternet.com
web: www.gagtl.ac.uk/gagtl

GAGTL had a major presence in the Gemstone Forum area of the International Jewellery Fair at Earls Court in September. The daily GAGTL seminars at the Fair on current issues in the gem trade attracted good audiences.

Ian Mercer visited Taiwan in March 1998 to meet ATC personnel and further the cause of gemmology, and also to set up a new examination centre.

The GAGTL took a stand at the Las Vegas Jewellery Fair in June for the second year running, where Alan Clark and Doug Garrod successfully promoted Gemmological Instruments Ltd and Educational Services. At the Hong Kong Fair in September, Michael O'Donoghue, Brenda Hunt and Lorne Stather promoted the services of the GAGTL. Michael O'Donoghue and Brenda Hunt repeated this promotion later in Shanghai.

At home, the branches in Birmingham, the North West and Scotland, continued with a wide variety of lectures, seminars, updates on courses and field trips, to interest a broad range of members. One of the subjects well covered in 1998 was the new synthetic moissanite and included lectures by Dr Kurt Nassau in London and Edinburgh. Other topics in the London lecture series included an account of gems from India (Mrs S. Fernandes), contemporary gem art in America (Kreg Scully), the early history of enamel (Dr J. Ogden), Chinese snuff bottles (Clare Lawrence), pearls (Christianne Douglas) and Georgian and Victorian jewellery (John Benjamin).

The theme of the 1998 Photographic Competition was *Gems in Fashion*, the winner being Bob Maurer of London. We are most grateful to Quadrant Offset Ltd, who design and print both the calendar and the *Journal of Gemmology*, for sponsoring the prizes. A selection of the entries was made to grace the 1999 calendar, which is circulated free of charge to all members.

The Annual Conference was again held at the Barbican Centre in London, the theme being *Gems in Jewellery*. The speakers were Derek Palmer (De Beers), John Carter (Cellini, Cambridge), Stephen Kennedy (GAGTL Laboratory), Michael Smookler (Vice-President of the London Diamond Bourse and Club) and Chris Welbourn (De Beers Research Department, Maidenhead). A forum chaired by Harry Levy and made up of Ana Castro, Rosamond Clayton, David Davis and Adrian Klein completed the day. The participants at this conference came from no less than thirteen different countries.

The Journal of Gemmology published 22 papers in 1998, with topics ranging from turquoise in China, and rubies in Australia and Cambodia, to emeralds in Zimbabwe. A total of 135 abstracts and 22 book reviews were also included and the Council express their sincere thanks to the Assistant and Associate Editors for all their expert help, comment and advice during the year.

Gem and Jewellery News published jointly with the Society of Jewellery Historians, again contained a wide range of stimulating comment on such issues as synthetic moissanite, radioactive gems, the new exhibition at the Natural History Museum and a recent judgement about an alleged alexandrite.

Gemmological Instruments Ltd is a wholly owned subsidiary of the GAGTL. An additional member of staff was recruited during the year to help consolidate and develop activities so that the range of goods and services may be improved to meet the current demand. The new Megger Tester to identify synthetic moissanite was introduced in 1998 and an improved version of the recently developed Brewster Angle Meter will be available for sale in 1999.

The overall financial picture for the GAGTL in 1998 was not exciting and resulted in a small deficit, mainly due to the financial crisis in several Far Eastern countries where we have been particularly active in recent years. Whilst the turnover in Gemmological Instruments Ltd was down on the previous year for the same reason, the final result was a small profit. The Council of Management has every confidence that the organization is in a strong position to take advantage of any opportunities that arise as the financial position improves globally.

The Council of Management extends their thanks to all the staff for the effort and dedication they have contributed during the year. Also, a special thank you is due to the committees and individual members for their contributions, especially of time, and the many companies and individuals who have generously donated gems and other gemmological items that have been much appreciated and put to very good use.

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8TN, on 21 April 1999, the business transacted included the election of the following:

Fellowship (FGA)

Aho, Jouko, Oulu, Finland. 1999
Blampied, Julie K., St Helier, Jersey, CI. 1999
Chang Kung Jung, Taipei, Taiwan, R.O.China. 1999
Chen Shu-Chuan, Kaohsiung, Taiwan, R.O.China. 1999
Deljanin, Branko, New York, NY, U.S.A. 1999
Edery, Gabrielle J., Hither Green, London. 1999
Goynshor, Frederick Jay, Northbrook, Ill., U.S.A. 1974
Hsu Feng, Taipei, Taiwan, R.O. China. 1999
Koh Hock Heng, Singapore. 1999
Mafara, Ezekiel M., Harare, Zimbabwe. 1999
Oshida, Reiko, Singapore. 1999
Tanaka, Rika, Beijing, P.R. China. 1999
Yoon Sung Hae Kwon, Yangon, Myanmar. 1999

Diamond Membership (DGA)

Cheung Shiu Cheong, Randy, Kowloon, Hong Kong. 1999
Chik Wing Sheung, Hong Kong. 1999
Mak Kin Yeung, Kenny, Fanling, N.T., Hong Kong. 1999

Ordinary Membership

Gregory, Pauline A., Westgate-in-Weardale, Co. Durham
Jacobs, Stephan-Andreas, Trier, Germany
Lai Chih-Liang, Taipei, Taiwan, R.O. China

San-San Chen, Taipei, Taiwan, R.O. China
Travlos, Gary, Ely, Cambridgeshire
Wills, Elle, London
Young, Margaret R., Bearsden, Glasgow

Transfers

Diamond Membership to Fellowship and Diamond Membership (FGA DGA)

Garrett, Frances S.J., Sutton, Surrey. 1999

Ordinary Membership to Fellowship (FGA)

Grech, Carrieann, London, 1999
Panagiotis, Panagiotou, Corfu, Greece. 1999

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8TN, on 19 May 1999, it was unanimously agreed that Professor Chen Zhonghui of Wuhan, P.R. China, should be awarded an Honorary Fellowship in recognition of his services to the development of gemmology in the People's Republic of China. It was also agreed that Professor Dr Hermann Bank of Idar-Oberstein, Germany, be awarded an Honorary Life Membership in recognition of his services to gemmology on the international scene, and particularly for his support for education at GAGTL and in Europe.

The business transacted included the election of the following:

Diamond Membership (DGA)

Ng Kwok Wai, N.T., Hong Kong. 1999
Poon Mei Han, Maggie, Hong Kong. 1999

Fellowship (FGA)

Amarasinghe, Ashan S., Rajagiriya, Sri Lanka. 1999
Banks, Michelle, Leicester. 1998
Chan So Ying, Hong Kong. 1999
Ho Cheuk Fung, Hong Kong. 1998
Ip Kit Ling, Kowloon, Hong Kong. 1999
Kwok Siu Chung, Central, Hong Kong. 1983
Ning Lu, Shanghai, P.R. China. 1999
Pang Chi Keung, Maurice, Hong Kong. 1999
Pavlou, Marios G., Larnaca, Cyprus. 1999
Schmocker, Karin, Brooklyn, NY, USA. 1999
Stąhl, Elone, Malmo. Sweden. 1993
Tang Suk Yee, Hong Kong. 1999

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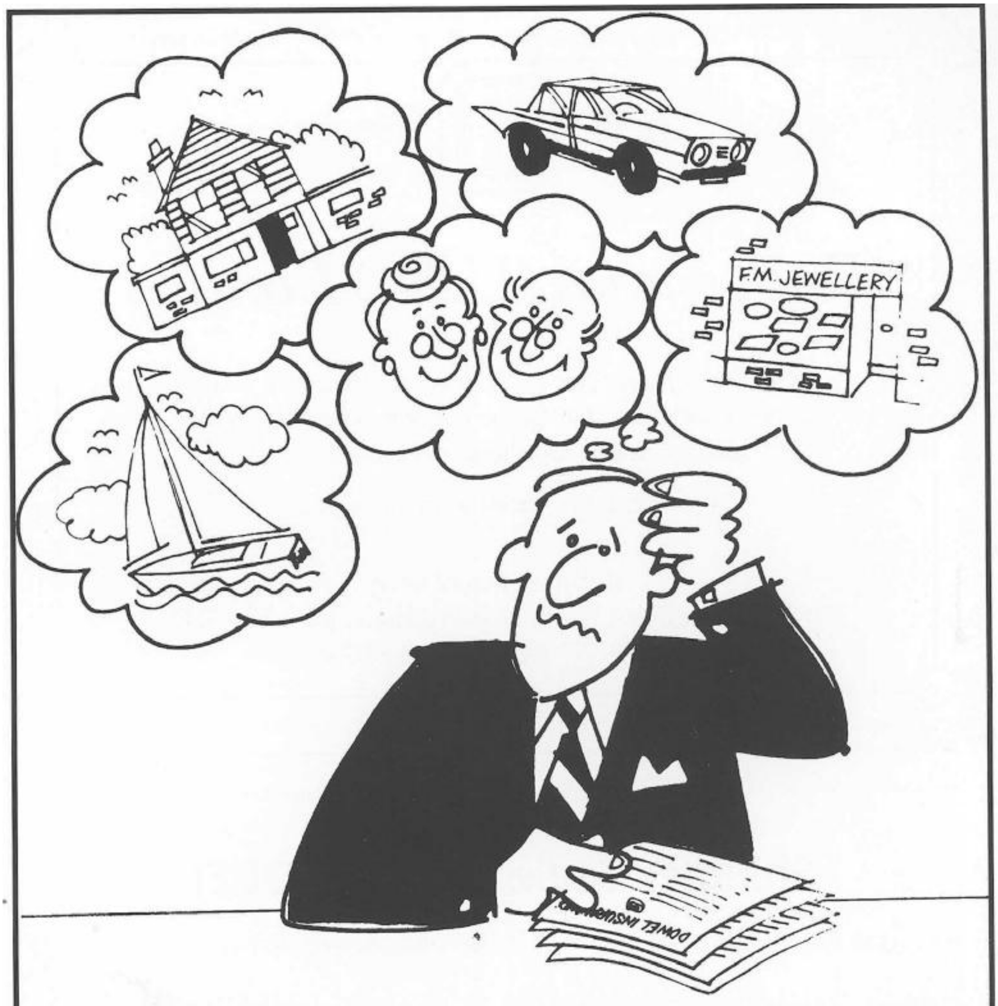
CORRIGENDUM

In *The Journal of Gemmology*, 1999, 26(6), p. 409, first column, the following name should have been added to the list of those who qualified in the Preliminary Examination in Gemmology held in January 1999: Bastos, Ana Pestana, Lisbon, Portugal.

The Editor apologizes for the omission.



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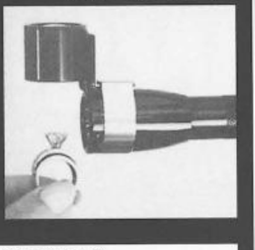

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The Editor is glad to consider original articles shedding new light on subjects of gemmological interest for publication in *The Journal*. Articles are not normally accepted which have already been published elsewhere in English, and an article is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

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

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Gems of the Century
Etched cave diamondscape.
Photograph by Roy Huddlestone.
(First Prize in Photographic Competition, see p.470)

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