The Journal of Gemmology

Volume 27 No. 2 April 2000

Sri Lankan gem deposits

GE POL diamonds

Maw-sit-sit

Lab notes

Emerald classification

The Gemmological Association and Gem Testing Laboratory of Great Britain

Gemmological Association and Gem Testing Laboratory of Great Britain

27 Greville Street, London EC1N 8TN
Tel: 020 7404 3334 Fax: 020 7404 8843
e-mail: gagtl@btinternet.com Website: www.gagtl.ac.uk/gagtl

President:
Professor R.A. Howie

Vice-Presidents:
E.M. Bruton, A.E. Farn, D.G. Kent, R.K. Mitchell

Honorary Fellows:
Chen Zhonghui, R.A. Howie, R.T. Liddicoat Jnr, K. Nassau

Honorary Life Members:
H. Bank, D.J. Callaghan, E.A. Jobbins, H. Tillander

Council of Management:
T.J. Davidson, N.W. Deeks, R.R. Harding, I. Mercer, J. Monnickendam,
M.J. O'Donoghue, E. Stern, I. Thomson, V.P. Watson

Members' Council:
A.J. Allnutt, P. Dwyer-Hickey, S.A. Everitt, A.G. Good, J. Greatwood,
B. Jackson, L. Music, J.B. Nelson, P.G. Read, R. Shepherd, P.J. Wates, C.H. Winter

Branch Chairmen:
Midlands – G.M. Green, North West – I. Knight, Scottish – B. Jackson

Examiners:
A.J. Allnutt, M.Sc., Ph.D., FGA, L. Bartlett, B.Sc., M.Phil., FGA, DGA,
E.M. Bruton, FGA, DGA, S. Coelho, B.Sc., FGA, DGA, Prof. A.T. Collins, B.Sc., Ph.D,
A.G. Good, FGA, DGA, J. Greatwood, FGA, G.M. Howe, FGA, DGA,
B. Jackson, FGA, DGA, G.H. Jones, B.Sc., Ph.D., FGA, M. Newton, B.Sc., D.Phil.,
C.J.E. Oldershaw, B.Sc. (Hons), FGA, DGA, H.L. Plumb, B.Sc., FGA, DGA,
R.D. Ross, B.Sc., FGA, DGA, P.A. Sadler, B.Sc., FGA, DGA,
E. Stern, FGA, DGA, S.M. Stocklmayer, B.Sc. (Hons), FGA, Prof. I. Sunagawa, D.Sc.,
M. Tilley, GG, FGA, C.M. Woodward, B.Sc., FGA, DGA

The Journal of Gemmology

Editor: Dr R.R. Harding

Assistant Editors: M.J. O'Donoghue, P.G. Read

Associate Editors: Dr C.E.S. Arps (Leiden),
G. Bosshart (Zurich), Prof. A.T. Collins (London), Dr J.W. Harris (Glasgow),
Prof. R.A. Howie (Derbyshire), Dr J.M. Ogden (Cambridge),
Prof. A.H. Rankin (Kingston upon Thames), Dr J.E. Shigley (Carlsbad),
Prof. D.C. Smith (Paris), E. Stern (London), S.M. Stocklmayer (Perth),
Prof. I. Sunagawa (Tokyo), Dr M. Superchi (Milan), C.M. Woodward (London)

Production Editor: M.A. Burland

Vol 27, No. 2, April 2000 ISSN: 1355-4565

Occurrences of two new types of gem deposits in the Okkampitiya gem field, Sri Lanka

V. Mathavan[1], S. T. Kalubandara[1] and G.W.A.R. Fernando[2]

1. Department of Geology, University of Peradeniya, Sri Lanka
2. Institut für Geowissenschaften, Mineralogie,
Johannes Gutenberg-Universität Mainz, Germany

ABSTRACT: Two new types of gem deposits have been discovered recently in the Okkampitiya gem field which is situated in south-eastern Sri Lanka. These are (1) the gem-bearing sediments enclosed within (paleo) karstic potholes and channels in marble, and (2) a primary hessonite deposit in a calc-silicate rock. Dissolution of marble by meteoric waters, particularly along joints and fractures, and perhaps subsidence and collapse may have formed the potholes and channels. Subsequently these karstic features may have trapped the alluvial sediments. The physical and chemical properties of the hessonites are similar to pure grossular garnet. It is suggested that the hessonite-bearing calc-silicate rock was formed during the granulite grade metamorphism of marl, rich in grossular-forming components.

Keywords: alluvial deposit, hessonite, karstic potholes and channels, marble, primary deposit

Introduction

Sri Lanka, well known for its wide variety of fine quality gemstones, is, with a land area of 65,500 km^2, the largest producer of gemstones per square kilometre in the world (Gunaratne and Dissanayake, 1995). In recent years, Sri Lanka has been producing large amounts of heat-treatable geuda (a poor quality corundum which could be enhanced by heat treatment). According to Gunaratne and Dissanayake (1995), about 35-40% of the corundum mined in Sri Lanka, belongs to this category. Almost all gemstones from deposits, locally known as 'illam'. They occur as thin, discontinuous layers, in the palaeo and present-day stream beds, and gemstones are also derived from residual or eluvial deposits located on hill slopes (Dahanayake, 1980). Several primary gem mineral occurrences have been reported (e.g. moonstone), but most contribute little to the gem wealth of Sri Lanka. In this paper two new types of gem deposits from the Okkampitiya gem field are described. These are (1) gem deposits enclosed in (palaeo) karstic potholes and channels in marble, and (2) an occurrence of a primary hessonite

ISSN: 1355-4565

Geological setting

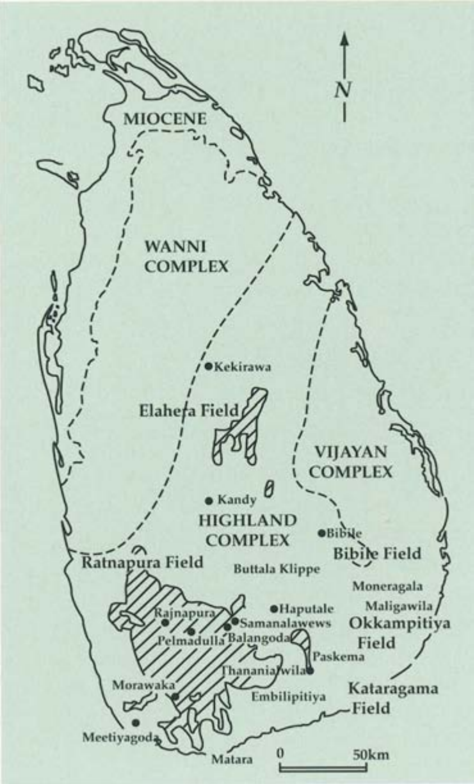


Figure 1: *Sketchmap indicating the three Proterozoic crustal units (Cooray, 1994) and the major gem fields of Sri Lanka (Gunaratne and Dissanayake, 1995).*

Sri Lanka is underlain mainly by Proterozoic high-grade rocks which make-up about 90% of the exposed area. The rest of the area consists of Miocene formations, Quaternary deposits and minor unmetamorphosed igneous rocks including late pegmatites.

The basement rocks have been subdivided into three main units; viz. Highland Complex (HC), Wanni Complex (WC) and Vijayan Complex (VC) (Cooray, 1994) (*Figure 1*). The central, granulite grade HC is a dominantly metasedimentary belt, comprising metasedimentary rocks such as marble, calc-silicate rock, quartzite, pelitic gneiss, khondalite (a garnet-sillimanite schistose rock) and metamorphic rocks of igneous parentage, particularly charnockitic gneisses and orthogneisses. The metasedimentary rocks and certain late unmetamorphosed pegmatites are the major source rocks of the Sri Lankan gemstones despite limited evidence of occurrence of primary gem minerals in them. The possibility should be borne in mind that many gem-rich rocks of the above Complex/es within the original Gondwana may have weathered, eroded away and disappeared in the geological past (cf. Hapuarachchi, 1991). Metasedimentary rocks and pegmatites containing primary gem minerals have been found in several localities (e.g. corundum at Tannahena near Kandy, Haldumulla near Haputale and Kolone near Embilipitiya, moonstone at Meetiyagoda and Balangoda, amethyst at Kekirawa and beryl at Lunugamvehera near Tanamalwila (Gunaratne and Dissanayake, 1995). The HC essentially hosts all the major gem fields of Sri Lanka; viz. the Ratnapura field, the Elahera field, the Bibile field, the Kataragama field and the Okkampitiya field (see *Figure 1*). The Ratnapura field includes the famous gem-producing areas near Ratnapura, Pelmadulla, Embilipitiya and Morawaka. Both the WC and the VC units, which consist mainly of granulite to upper amphibolite grade metamorphic rocks derived from igneous rocks, are practically devoid of gems.

Geological studies have shown that the combined HC-WC unit was overthrust on to the VC, and isolated remnants of the HC rocks occur as 'klippes' or 'outliers'within the VC area. The Buttala 'klippe', which is found near the HC-VC boundary within the VC, is one such occurrence (Kröner *et al.*, 1991) (see *Figure 1*). The Okkampitiya gem field is situated within the Buttala klippe. The area is underlain by marble, pelitic gneisses, quartzite, migmatite, basic granulite and minor pegmatites and calc-silicate rocks, and these rocks are bounded by Vijayan granitic gneisses to the east. Marble is a dominant lithology within the Okkampitiya region. The marble is composed mainly of calcite and dolomite, other minerals present in minor amounts include, forsterite, diopside, phlogopite, and accessory spinel and apatite. The spinel shows a well-developed octahedral habit occasionally up to 10 mm across and it is often of gem-quality. Forsterite in the marble is usually partly altered. Occasionally, the top of the marble is weathered to a beige to buff-coloured saprolite zone, composed of microcrystalline carbonate material and coarse calcite fragments. The marble shows cavernous features in places which are linked to short joints and fractures (<10 m). The gem deposits described below provide further evidence of karstification in the marble. Elsewhere in Sri Lanka, karstic features in marble have caused serious engineering geology problems including massive leakage in the Samanalawewa Reservoir (Gunatilake, 1995).

Geomorphology

The climate of the Okkampitiya is relatively dry and cool (Somasekaram *et al.*, 1997, p.17). The most prominent morphological feature of the Okkampitiya-Maligawila area is an erosional remnant which occurs in the form of a 'turtle back' hill. The rest of the area is generally flat and gently undulating, with a prominent N-S trending ridge (Nilgala-Buttala ridge) to the west and the Karthalhina mountains to the north-east. The tributaries of Kumbukan Oya drain the area. The geomorphological setting of the Okkampitiya area and the surroundings provide ideal conditions for the formation of placer gem deposits. The tributaries of Kumbukan Oya drain the upper areas in the north and then they enter the broad, flat and gently undulating Okkampitiya area in the south and south-east.

Gem deposits in (palaeo) karstic potholes and channels

The main gemstones occurring in the Okkampitiya gem field include geuda-type corundums, sapphires (blue, yellow and colourless), garnets including hessonite, spinel, tourmaline and zircon, in order of decreasing abundance. Additionally, gem ekanite (a radioactive calcium-thorium silicate) is also found in the area (see Arps, 1989). In contrast to the other gem fields, in

Figure 2: *A schematic E-W cross section of the area indicating occurrences of karstic potholes, blind shafts and channels. The enlargements are schematic representations of sedimentary infills in karstic potholes located on the gentle slope (A), on the flood plain (C) and on a bifurcating channel (B).*

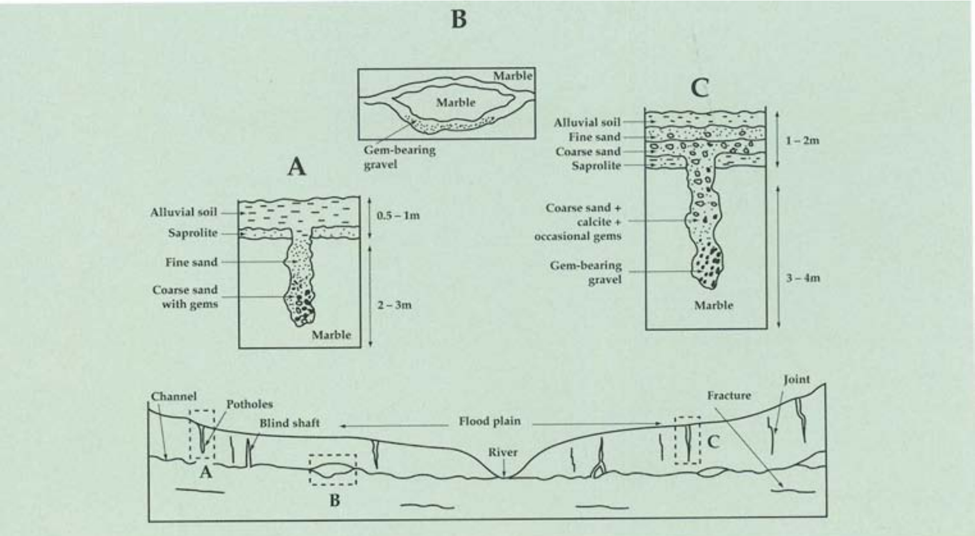


Figure 3: A mined karstic channel in the marble.

the Okkampitiya gem field many of the gem-bearing sediments are enclosed within karstic potholes and channels in the marble (*Figure* 2). The sizes of these potholes range from a few decimetres (on the gentle slopes) up to a few metres (on the flood plains) while the depth ranges up to 3 – 4 m (see *Figures* 2 and 3). Our present data on the subsurface geology is insufficient to comment on the nature of karstic channels, but some may have been sinuous and interconnected (see *Figures* 2 and 4). Dissolution of marble by meteoric waters, particularly along joints and fractures, and perhaps subsidence and collapse would have formed the karstic potholes and channels. Perhaps the palaeo-karstic process may have played a dominant role in the development of the present alluvial flood plains, and in this respect the gem-bearing sediments have calcite and dolomite as the major constituents besides quartz (*Figure* 5).

The dominant gems in the deposits located in the flood plains are geuda-type corundums and sapphires. Their abundance decreases in sites located on the gentle

Figure 4: *Complicated gem mining in a karstic channel in marble.*

slopes, where spinel and tourmaline are more prominent. The corundums invariably show worn crystal faces or rounded surfaces and the quartz pebbles, which are also present occasionally in the gem sediments, have well rounded shapes. These features either indicate long distance of transport before deposition in the potholes and the channel beds, or they represent reworked older sedimentary deposits. Another factor to consider is that karst hydrology can be complicated due to the presence of constrictions along the channel; these can cause reverse flow, resulting in to and fro movements of the sediments (see Jennings, 1971, pp. 92-5). Additionally, swirling of sediments in the potholes could also have contributed the observed rounded features. The rough stratification of the sediments possibly suggests that the karstic plains may have been flooded with gem-bearing sediments (see *Figure* 2). Primary occurrences of corundum in the Okkampitiya area have been observed (Weerawarunakula, 1998, personal communication), but the worn crystal faces of corundums indicate distant provenance further north, possibly from the Bibile region. In contrast to the effects of strong mechanical abrasion shown by corundum, spinel and tourmaline show sharp crystal edges on the spinels and striations remaining on the tourmalines, which are evidence of local provenance. As noted earlier, gem-quality spinel occurs in the host marble, and the local pegmatites may have been the source of the tourmaline. In addition to

Figure 5: *Gem-bearing sediment from a karstic pothole. Note abundant calcite/ dolomite grains.*

Figure 6: *Gem mining activities in a shallow gem pit.*

Figure 7: *Gem-bearing sediments being sieved to remove the fine-grained fraction. This method is adopted when water is scarce in the dry season.*

alluvial deposits, gemstones are also recovered from residual soils (Chandrajith *et al.*, 1998) (*Figure 6*). Karstic marble terrains clearly provide important 'sedimentation traps' for gem-bearing deposits. Small pockets of gemstone-rich deposits, found elsewhere on the island and sometimes referred to as 'gedi illam', may have been formed in a similar manner either in marble or related lithologies. The richness of these (small) deposits may be due to the fact that the relatively heavy gemstones have been prevented from further transportation or dispersal, while the (very) fine grained and lighter particles originally comprising much of the sediments have been washed away.

Gem mining and exploration

The gem mining methods practised in the Okkampitiya gem field differ considerably from the methods carried out in other gem fields of Sri Lanka. This is mainly because the gem-bearing sediments occur at shallow depths of 2-6 m, and many of the deposits are enclosed in karstic potholes and channels. Gem mining activities usually begin in the dry season. An iron rod referred to as 'illam kuru', is sometimes used to locate the potholes or even the normal placer deposits, but many deposits are located accidentally. The gem miners also use the surface characteristics of the 'heavy' minerals in the sediments and their abundance as a guide to identify mining sites.

Once a pothole or channel is located, the top soil layer is scraped off and the sand and gravel layers are removed until the gem-bearing layers are found, usually at the bottom. If the hole is not large enough to accommodate a person, additional space is obtained by widening the wall of the pothole or channel either by using explosives or by drilling. The gem-bearing sediment is collected and piled nearby, and later on the 'illam' are washed, panned and examined for gemstones in the presence of the gem 'mudalali' (usually one who finances the gem mining). The groundwater in the cavity or a nearby water source is used for washing the sediments.

The 'illam' in those potholes located on the gentle slopes are usually dry and contain considerable amounts of fine-grained material, which is removed by sieving (*Figure 7*). Water required for panning and sorting may not be available at such a site, and in these instances the sieved sediment is packed in sacks and taken to the nearest water source.

Primary hessonite deposit

Sri Lanka is the world's main producer of hessonite, a yellowish-brown to red grossular garnet (Cipriani and Borrelli, 1986; Gunaratne and Dissanayake, 1995). Hessonite is recovered from many places in the island but specifically from Ratnapura, Pelmadulla, Okkampitiya and Kataragama (Arps, 1989). However, except for a weathered deposit at Kamburpitiya in Matara (Gunaratne and Dissanayake, 1995) a primary occurrence of hessonite had not been reported until recently. In 1997 gem miners discovered primary hessonite in a calc-silicate rock near Maligawila, and this was briefly reported by Kalubandara and Mathavan (1998) and Chandrajith *et al.*

(1998). This small deposit is now completely exhausted, except for the nongem-quality remains. According to the miners, the inner parts of the deposit yielded the best quality hessonites.

Hessonite from this deposit is characteristically massive (*Figure 8*) and shows colour ranging from pale orange to reddish-brown to red. It exhibits good lustre but the transparency is moderate to poor in the studied samples. The geochemical, physical and optical properties of the studied 'low quality' samples, as well as the data reported by Arps (1989) of the hessonites from Paskema (Kataragama field) and Okkampitiya, are shown in *Table I*. The hessonites are very close to pure grossular in composition, similar to the Paskema hessonites. A thin section study confirmed

***Figure 8:** Massive primary hessonite in a scapolite-rich part of a calc-silicate rock sample.*

***Table I:** Chemical and physical properties of hessonites from Maligawila compared with those from Paskema (Arps, 1989).*

Wt%	Maligawila			Paskema		
	1 Probe	2 Probe	3 Probe	89.1 XRF	G9 Probe	G6 Probe
SiO_2	38.66	38.30	39.23	38.08	39.57	39.49
TiO_2	0.19	0.19	0.01	<0.02	0.02	0.24
Al_2O_3	19.79	19.13	20.29	22.05	22.06	22.40
Cr_2O_3	0.02	0.03	–	–	–	–
Fe_2O_3	5.38	6.56	4.67	1.71	1.19	0.69
FeO				–	0.13	0.75
MnO	0.47	0.60	0.34	0.32	0.19	0.20
MgO	0.07	0.05	0.09	<0.01	0.02	0.02
CaO	34.80	32.87	35.25	36.53	36.66	36.25
Na_2O	0.02	0.06	0.09	<0.02	–	–
K_2O	0.35	0.15	–	<0.02	–	–
P_2O_5	–	–	–	0.28	–	–
F	0.35	0.15	0.18	–	–	–
Cl	0.02	0.04	0.04	–	–	–
Total	100.12	98.13	100.19	98.99	99.84	100.04
End-member composition						
Gross.	94.4	98.1	98.8	94.4	96.5	95.9
Pyr.	0.3	0.2	0.4	0.0	0.1	0.1
Spess.	1.1	1.5	0.8	0.7	0.4	0.4
Andr.	0.0	0.0	0.0	4.6	1.7	2.0
Uvarov.	0.1	0.1	0.0	0.0	0.0	0.0
Alman.	0.0	0.0	0.0	0.2	1.3	1.6
RI.	–	–	1.74	1.732	1.731	1.735
SG.	3.622	3.637	–	3.598	3.622	3.616

NB: Maligawila hessonite compositions were determined by microprobe and SG was determined on crushed grains using a specific gravity bottle.

the presence of calcite and scapolite as inclusions in the hessonites, and this contrasts with Arps' (1989) study which indicated the occurrence of apatite as inclusions in all the samples. The contact rock of the hessonite deposit was not exposed in the field due to intense weathering and soil cover. The nearest outcrop, which occurs about 25 m away, is a migmatitic hornblende-biotite gneiss and this rock contains decimetre scale calc-silicate rock layers. In the hessonite-bearing calc-silicate rock samples, garnet is the predominant mineral and is accompanied by scapolite, diopside, wollastonite, calcite and quartz. These minerals show polygonal granoblastic texture, which indicates that this assemblage was formed by metamorphism of marl, a mixture of clay and calcareous sediment, under granulite facies conditions. The marl may have been rich in grossular-forming components to produce a hessonite-rich deposit. Garnet occurs in two forms; large to porphyroblastic grains, and small coronas or rims interstitial between other minerals in the rock. The rim garnets postdate the porphyroblasts and may have formed following granulite facies metamorphism.

Acknowledgement

We gratefully acknowledge the hospitality provided by Mr A.M. Jayasena, a gem mudalali during our field work. Specific gravity determinations were carried out by Ms Ranaweera, and *Figure 2* was drawn by Mr S.M. Amunugama and Ms J. Wijeyasekera. The paper was substantially improved from the constructive comments of an anonymous referee.

References

Arps, C.E.S., 1989. Hessonites from Sri Lanka; some preliminary results. Proceedings of the XXII International Gemmological Conference, Italy, 1989, 9-12

Chandrajith, R., Dissanayake, C.B., and Tobschall, H.J., 1998. A note on Buttala and Okkampitiya gem fields in Sri Lanka. *Z.Dt. Gemmol. Ges.*, **47** (2) 69-76

Cipriani, C., and Borelli, A., 1986. *The Macdonald Encyclopaedia of Precious Stones.* Little, Brown and Company (U.K.) Limited, London, 1-384

Cooray, P.G., 1994. The Precambrian of Sri Lanka; a historical review. *Precambrian Research,* **66**, 3-18

Dahanayake, K., 1980. Modes of occurrence and provenance of gemstones of Sri Lanka. *Mineralium Deposita,* **15**, 81-6

Gunatilake, J., 1995. Reservoir leakage problem of the Samanalawewa Hydropower Project. In: Dahanayake, K. (Ed.) *Geology and mineral resources of Sri Lanka,* Second South Asia Geological Congress Souvenir Publication, 33-43

Gunaratne, H. S., and Dissanayake, C.B., 1995. *Gems and gem deposits of Sri Lanka.* National Gems and Jewellery Authority of Sri Lanka Publication, 1-203

Hapuarachchi, D.J.A.C., 1991. Significance of cordierite in the Sri Lankan Precambrian. *J. Geological Society of Sri Lanka,* **3,** 15-20

Jennings, 1971. *Karst.* Australian National University Press, Canberra, 1-252

Kalubandara, S.T., and Mathavan, V., 1998. Occurrences of two new types of gem deposits in the Okkampitiya-Maligawila gem field. In: Cooray, P.G. and Dharmagunawaredna, H. A. (Ed.). *Abstracts 15th Annual Technical Sessions.* Geological Society of Sri Lanka, p. 5

Kröner, A., Cooray, P.G., and Vitanage, P.W., 1991. Lithotectonic subdivision of the Precambrian basement of Sri Lanka. In: Kröner, A. (Ed.). *The crystalline crust of Sri Lanka, part I. Summary of research of the German-Sri Lankan Consortium.* Geological Survey Department, Professional Paper **5,** 5-21

Somasekaram, T., Perera, M.P., De Silva, M.B.G., and Godellawatta, H. (Eds.), 1997. *Atlas of Sri Lanka.* Arjuna Consulting Co. Ltd., Dehiwela, Sri Lanka, 1-220

Identification of GE POL diamonds: a second step

J-P. Chalain[1], E. Fritsch[2] and H.A. Hänni[1]

1. *SSEF Swiss Gemmological Institute, Falknerstr. 9,*
Basel, CH-4001 Switzerland
2. *Laboratoire de Physique Cristalline, Institut des Matériaux Jean Rouxel,*
BP 32229, F-44322 Nantes, France

ABSTRACT: An identification method for GE POL treated diamonds in two steps is proposed. First, as almost all GE POL diamonds are type IIa, near colourless type IIa diamonds are separated from other diamonds of similar colour using the SSEF Type IIa Diamond Spotter. Second, a Raman spectrum of these IIa stones is obtained using the 514 nm laser line of a Raman spectrometer. If a luminescence pattern at 3760 cm^{-1} is observed, this proves the presence of a small number of N-V centres in the stones. This is believed to be characteristic of the material used for the GE process, as all studied GE POL diamonds exhibit this emission. Hence, a near-colourless type IIa diamond showing a N-V centre emission is likely to be a GE POL treated diamond. Further samples are necessary to confirm this preliminary criterion.

Keywords: GE POL, HPHT diamond treatment, type IIa, N-V centres (637 nm), luminescence, Raman spectrum

Introduction

General Electric (GE) currently treats certain brownish diamonds to make them more colourless, up to D colour. GE applies this high pressure and high temperature process on essentially type IIa diamonds, which are rare on the diamond market (approximately 1%, only) (Anthony and Casey, in Moses, 1999).

Since April 1999, these treated diamonds have been marketed by Pegasus Overseas Limited (POL) in Antwerp, a subsidiary of a sight holder based in New York City, Lazare Kaplan International (LKI). These stones are known in the trade as Pegasus diamonds, GE POL diamonds and more recently as Monarch™ diamonds (Schmetzer, 1999). LKI markets them at the same price as their untreated counterparts because the treatment is claimed to be undetectable and remain so in the future. While GIA discloses on reports that these diamonds have been only 'processed', CIBJO laboratories disclose 'treated diamonds' in accordance with a CIBJO directive dated May 1999.

GE POL has been subsequently inscribed on the girdle of these diamonds to make them easily identifiable. But unfortunately, GIA has recognised a few GE POL diamonds that were resubmitted for certificates after a repolish of the 'GE POL' inscription. Until now, no gemmological criterion has been proposed to identify this treatment with certainty, thus it is an ongoing challenge for all gemmologists.

ISSN: 1355-4565

A first article from our team described observations under magnification of two GE POL diamonds, as well as some fluorescence bands triggered by the laser of the Raman spectrometer; one of these bands has been attributed to the presence of N-V centres (Chalain *et al.*, 1999). This article demonstrates how this emission may be used for identification of GE POL diamonds. It also describes the SSEF Type IIa Diamond Spotter, a new simple device for a quick identification of all type IIa diamonds and type IaB, an even rarer type.

Type IIa diamond samples

As the vast majority of GE POL diamonds are type IIa, it is important for the trade to be able to separate these near-colourless diamonds, potentially GE POL treated, from those of other types. Laboratories do this on the basis of infrared absorption; however, most jewellers do not have an infrared spectrometer. In addition, the original definition of type I and type II diamonds is based also on transparency to shortwave ultraviolet radiation (SWUV; Robertson *et al.*, 1934). When putting a diamond on top

Method of study

The aim of the current study is to present, compare and discuss the spectra obtained on a Raman spectrometer of these fifteen diamonds. For each diamond of the three groups, the following tests were performed, besides classical gemmological observations (which are not discussed further here, as they did not prove diagnostic in all cases):

- FTIR spectrum to verify that the diamond is indeed type IIa by the infrared spectrum pattern as well as the ultraviolet;
- Raman spectra were obtained at room temperature.

The Renishaw 1000 Raman spectrometer used is equipped with a Peltier-cooled CCD detector and ionised argon laser, with a green ray at 514 nm (Hänni *et al.*, 1997). It is calibrated with the 1332 cm^{-1} diamond peak of a reference diamond prior to each analysis. For better consistency of the results each diamond is set under the laser beam of the Raman microprobe by the same operator who always follows the same procedure. The table of the diamond is rubbed on a clean and dry white sheet of paper to ensure that no grease is present. The diamond is then placed on a glass support and held up by two small pieces of Blutack^{R} placed between the glass and the pavilion of the diamond. The Blutack^{R} is set as far back as possible from the area of interest, because it might induce a non negligible fluorescence. Then, the laser beam is focused on the table using a x20 magnification lens (Olympus: MS Plan 20; 0.46), the beam being perpendicular to the table of the stone. Finally, both sample and Raman microprobe are wrapped in an opaque black fabric to avoid any interference from external lighting. The particular experimental instrument set up parameters are saved in a computer file and loaded before each analysis, so that experimental conditions are always identical. This experimental procedure uses a 25 mW laser power, in the Renishaw 'extended and continuous mode', as well as the 'Gain and Cosmic Ray elimination mode'. Five scans are averaged in the range 100 cm^{-1} to 6500 cm^{-1}. This procedure takes approximately 25 minutes per stone.

Raman spectra were obtained at room temperature on two diamonds in various zones, to ensure that the whole stone is sample tested in a comprehensive way.

of the SSEF Type IIa Diamond Spotter (*Figure 1*), and illuminating it with SWUV, type IIa stones will transmit the radiation, exciting a green fluorescent screen placed underneath the stones. If the screen remains inert, the stone is not type IIa. This is a quick and easy way of recognising type IIa stones without infrared absorption.

Since October 1999, ten diamonds of type IIa, both colourless and brownish, have been recognised by staff of the SSEF laboratory thanks to several diamond dealers who kindly sent them to SSEF for one day. The identification of IIa diamonds is done with the SSEF Type IIa Diamond Spotter. They were further divided into two groups. Group 1 is composed of seven untreated colourless diamonds, all D colour (see *Table I*). Group 2 consists of three untreated diamonds of a brown to brownish hue (see *Table II*). Group 3 is composed of the GE POL diamonds that were submitted to SSEF for research (see *Table III*).

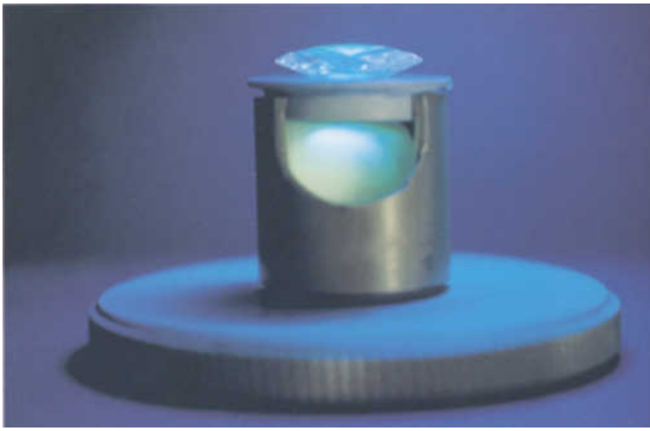


Figure 1: *The SSEF Type IIa Diamond Spotter.*

Results

All the spectra obtained showed of course the first order (1332 cm^{-1}) and second order (2000 to 2665 cm^{-1} approximately) Raman spectrum of diamond. Additional weak

Table I: *Group 1: Untreated near-colourless type IIa diamonds*

Reference	*Weight (ct)*	*Shape & Cut*	*Colour*	*N-V centre (3760 cm^{-1}/637 nm*	*Other noticeable bands (cm^{-1})*
ma048	0.468	marquise, modified brilliant	D	no	3076
ma354	3.54	marquise, modified brilliant	D	no	3073
ma202	2.02	marquise, modified brilliant	D	no	none
pea175	1.751	pear-shaped, modified brilliant	D	no	5966
pea180	1.808	pear-shaped, modified brilliant	D	no	none
pea202	2.028	pear-shaped, modified brilliant	D	no	none
ma161	1.613	marquise, modified brilliant	D	no	none

Table II: *Group 2: Untreated brownish to brown type IIa diamonds*

Reference	*Weight (ct)*	*Shape & Cut*	*Colour*	*N-V centre (3760 cm^{-1}/637 nm*	*Other noticeable bands (cm^{-1})*
RD465	4.650	round, rose cut	L(brown)	yes	4276
ma354	5.838	marquise, modified brilliant	M-Q (brown)	yes	794 4284 2065
rou903b2	9.03	rough, flat	faint brown	yes	5960

Table III: *Group 3: GE POL type IIa diamonds*

Reference	*Weight (ct)*	*Shape & Cut*	*Colour*	*N-V centre (3760 cm^{-1}/637 nm*	*Other noticeable bands (cm^{-1})*
GE POL001	0.75	round, brilliant	E	yes	none
GE POL002	0.56	marquise, modified brilliant	F	yes	794 2073
GE POL003	0.79	pear-shaped, modified brilliant	E	yes	794
GE POL004	0.94	oval, modified brilliant	D	yes	none
GE POL005	0.72	round, brilliant	F	yes	786

signals, interpreted as luminescence on the basis of their already known energy position and associated vibronic structure, are also of interest.

Untreated colourless diamonds

The seven untreated colourless diamonds of Group 1 were confirmed to be type IIa by infrared spectroscopy. None of these diamonds shows the fluorescence of an N-V centre in the Raman spectrum. The corresponding spectra are presented in *Figure 2* and some of their properties are summarised in *Table I.*

Untreated brown to brownish diamonds

Infrared spectrometry confirmed that the three untreated brown diamonds of Group 2 are indeed type IIa. The colour of these three stones ranges from L on the GIA colour grading scale to faint brown. Their Raman spectra reveal the presence of a peak at 3760 cm^{-1} (*Figure 3*). The laser emits at 19435 cm^{-1} (514 nm); the apparent Raman shift therefore corresponds to an emission at 19435 - 3760 = 15675 cm^{-1} (637 nm). This is the position of the characteristic line of the N-V centre, therefore this defect is present in each of the three stones.

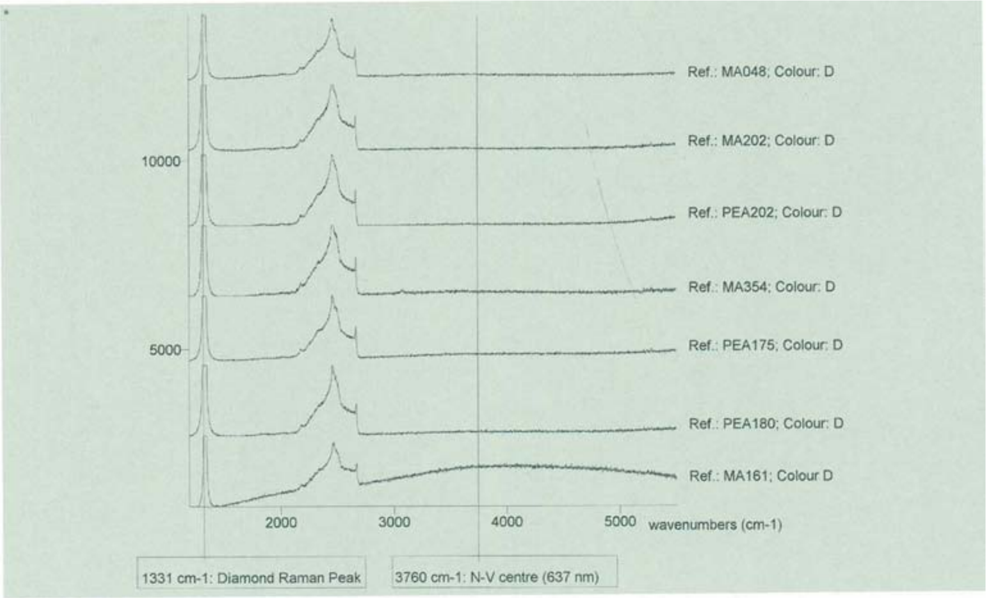


Figure 2: *Raman spectra of seven type IIa near-colourless diamonds. No emission is observed at 3760 cm^{-1}*

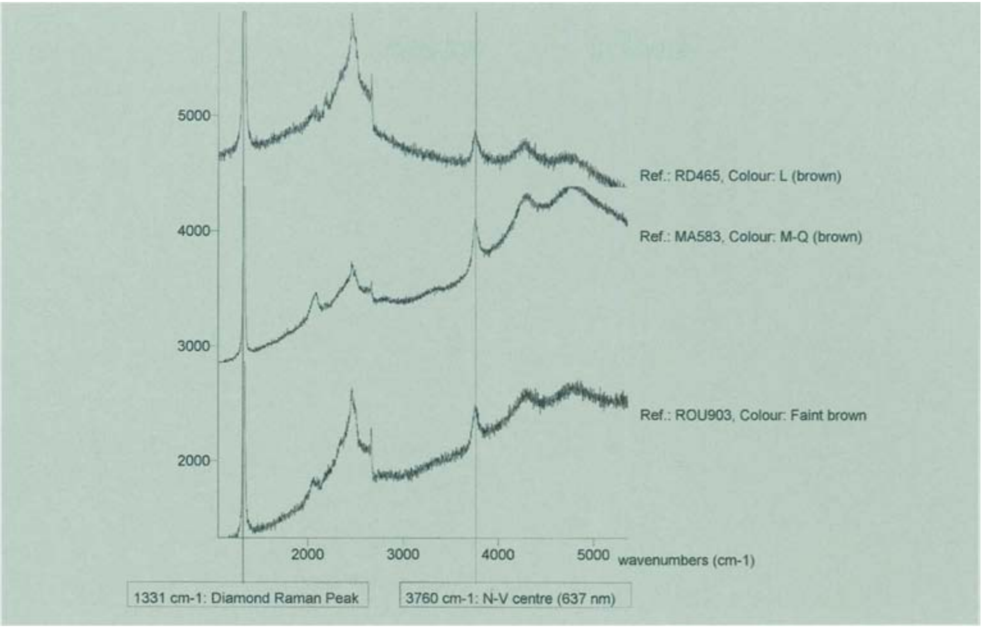


Figure 3: *Raman spectra of three brown type IIa diamonds. They all show an emission at 3760 cm^{-1}, due to the N-V centre.*

The weak band observed around 2060 cm^{-1} corresponds to an emission at 17375 cm^{-1} (575.5 nm) which is a known companion line to the 637 nm peak (Collins, 1982). The properties of these stones are summarised in *Table II.*

Treated GE POL diamonds

As reported from GIA, 99% of 858 GE POL diamonds are type IIa (Moses *et al.*, 1999). The five GE POL diamonds analysed at SSEF are also type IIa as confirmed by infrared spectrometry, and their colours range from D to F. Their Raman spectra also show emissions indicating the presence of N-V centres (*Figure 4*). Their properties are summarized in *Table III.* Note that they are arranged by colour and that the darker the colour, the stronger the 3760 cm^{-1} fluorescence band.

Synthesis of results and discussion

All seven untreated near-colourless diamonds of type IIa show no N-V luminescence. On the other hand, both GE POL and brown diamonds of type IIa all show N-V emission. This luminescence is also found in a rare category of type IIa pink diamonds ('Golconda type', Fritsch, 1998). The original colour of now near-colourless GE POL diamonds has been stated as brown (Rapaport, 1999). Thus, the presence of N-V centres in GE POL diamonds might be a characteristic of the original brown diamonds, prior to treatment. We assume that the treatment removes the brown colour but not the N-V centres. In other words, the presence of N-V centres in GE POL diamonds is not in agreement with the fact that they are near-colourless, because untreated near-colourless diamonds of type IIa have no N-V centres.

The criterion proposed here is based on a small number of samples, perhaps not statistically representative. The reason for this is twofold. First, type IIa diamonds are rare (1% approximately). Second, the work is at a preliminary stage.

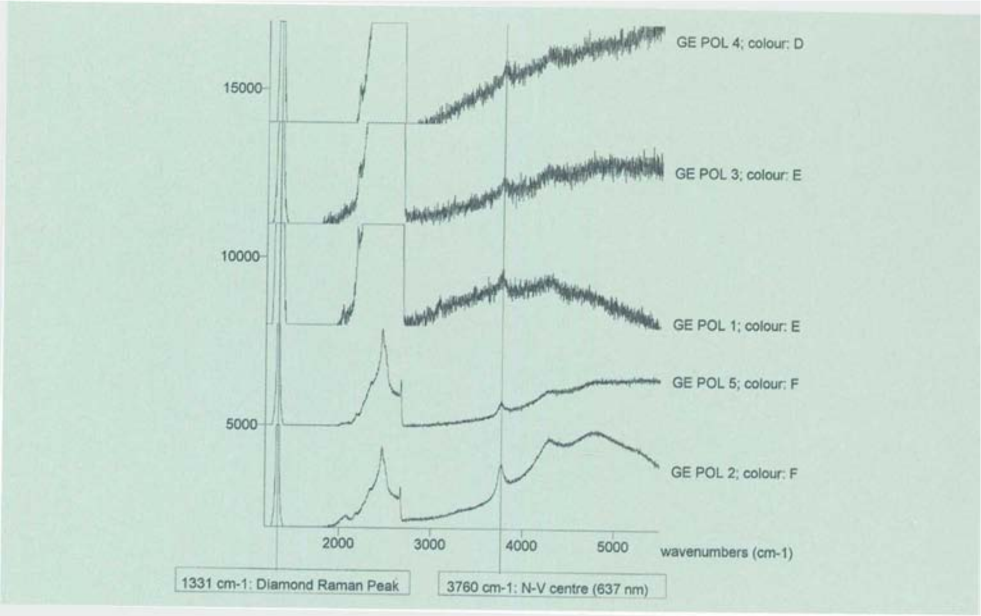


Figure 4: *Raman spectra of five GE POL diamonds, all exhibiting emissions at 3760 cm*$^{-1}$*, due to the N-V centre.*

SSEF will continue to study a selection of type IIa untreated diamonds, both colourless and brown, and endeavour to obtain more GE POL diamonds for comparison.

Conclusion

Five GE POL diamonds and ten untreated diamonds, all type IIa, have been studied. We have shown here that the presence of N-V centres might not be consistent with the fact that GE POL diamonds are colourless. Hence, the presence of a small number of N-V centres, luminescing under the excitation of the 514 nm line of a Raman spectrometer, might indicate that a colourless type IIa diamond has been treated by the GE process. However, because of the scarcity of type IIa untreated and treated diamonds, this identification criterion based on fluorescence spectroscopy must only be considered as a promising hypothesis. But we believe that, if confirmed, this method could be of considerable benefit for the diamond trade.

Acknowledgements

The authors are grateful to the gemmological laboratories and diamond dealers for supplying the samples for this study.

References

Chalain, J-P., Fritsch, E., and Hänni, H.A., 1999. Detection of GE POL diamonds: a first stage, *Revue de Gemmologie* AFG, **138-9**, 30-3

Collins, A.T., 1982. Colour centres in diamonds, *Journal of Gemmology*, **18**(1), 37-75

Fritsch, E., 1998. *The nature of diamonds.* G.E. Harlow Ed. Cambridge University Press & American Museum of Natural History, Cambridge, U.K. pp. 38-40

Hänni, H.A., Kiefert, L., Chalain, J.P., and Wilcock, I.C., 1997. A Raman microscope in the gemmological laboratory: first experiences of application. *Journal of Gemmology*, **25**(6), 394-406

Moses, T.M., Shigley, J.E., McClure, S.F., Koivula, J.I., and Van Daele, M., 1999. Observations on GE-processed diamonds: a photographic record. *Gems & Gemology*, **35**, 14-22

Rapaport Diamond Report 1999. http://www.diamonds.com Consulted from March 1999 to January 2000

Robertson, R., Fox, J.J., and Martin, A.E., 1934 *Philosophical Transactions*, A232, London, pp. 463-535

Schmetzer, K., 1999. Behandlung natürlicher Diamanten zur Reduzierung des Gelb-oder Braunsättigung. *Goldschmiede Zeitung*, **97**(5), 47-8

Notes from the Laboratory

Stephen J. Kennedy, Ana I. Castro and Roger R. Harding

Gemmological Association and Gem Testing Laboratory of Great Britain,
27 Greville Street, London EC1N 8TN

ABSTRACT: The topics discussed are: the use of cathodoluminescent spectroscopy in testing alexandrites; definitions of jet within gemmology; detection and safety considerations of blue irradiated topaz; false reporting of synthetic emeralds; unusual descriptions and trading standard laws; and considerations of phenakite, tanzanite and a scheelite-powellite mineral.

Alexandrite chrysoberyls

The inclusions in two alexandrite chrysoberyls, which were submitted for testing at different times, were not considered typical enough to satisfy us as to their natural origin. We decided to seek corroborating evidence from cathodoluminescence (CL) spectroscopy. On both occasions the stones were sent to Dr Johann Ponahlo at the Natural History Museum in Vienna.

The first alexandrite, weighing 2.36 ct, was found to behave differently under CL to many other natural alexandrites, most of which tend to have relatively low CL. This is evident in *Figure 1* where the spectrophotometric curves of low intensity can be taken as being representative of most natural alexandrites. The green curves in increasing CL intensity are an alexandrite from the Hematita mine in Brazil (AL-HEMA1), an alexandrite from the old Tokowaja mine in the Ural Mountains (AL-U/K9456) and a Sri Lankan alexandrite (AL-SRI/G74N).

In comparison, synthetic alexandrites (melt or flux melt) have a much higher relative CL intensity (see the black curve ALY-KC in *Figure 1*). In 1993 Dr Ponahlo had

Equipment

The equipment used is a cold cathode apparatus Luminoscope^{R} produced in the USA. It is mounted on the table stand of a standard polarising microscope with an attached micro-spectrophotometer. The cold cathode apparatus consists of a large compartment that houses the sample and electron gun that can produce an electron beam of up to 16.5 kV at a vacuum of less than 100 mTorr using a carrier gas (helium or air). The luminescing sample can be observed at magnifications up to 125x. Macro- or microphotos may be taken or CL spectra run at increments of 0.5 to 10 nm.

The whole unit is a computer-assisted assemblage manufactured by Zeiss, enabling the operator to produce not only cathodoluminescence, but also emission or absorption spectra between 380 nm and 950 nm (my thanks to Dr Ponahlo for this information).

The use of cathodoluminescence in coloured gemstone identification has already been described elsewhere (Ponahlo *et al.*, 1986; Ponahlo, 1988, 1989, 1993).

ISSN: 1355–4565

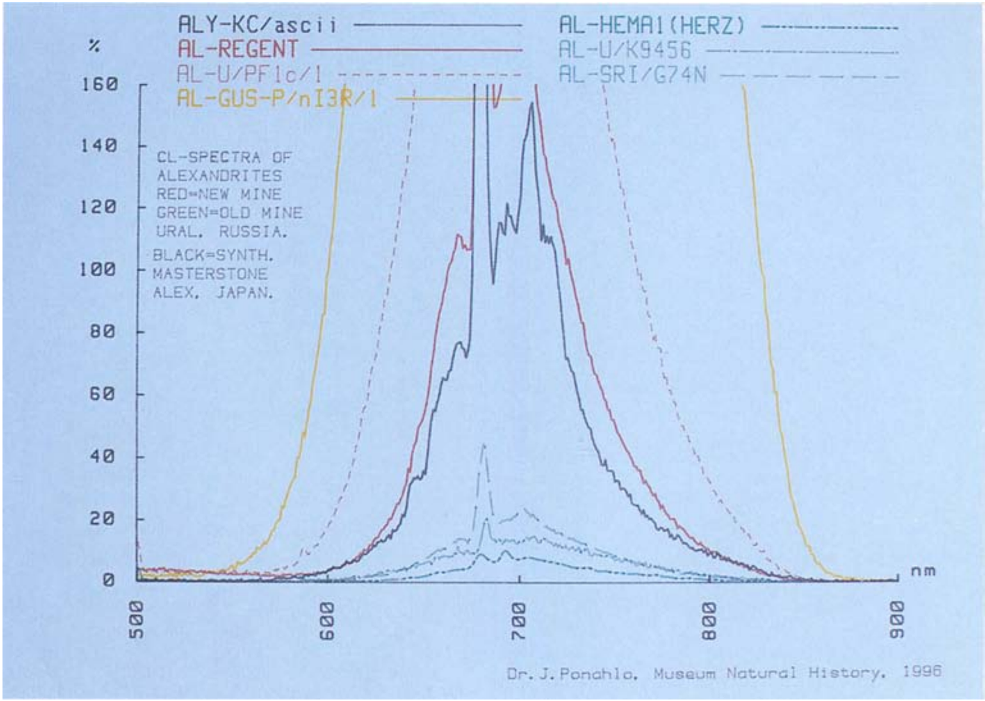


Figure 1: *Cathodoluminescence spectrophotometric curves for natural alexandrites:*

1. *Dash-double dotted green curve – Hematita mine, Brazil;*
2. *Dash-dotted green curve – Sri Lanka;*
3. *Long dashed green curve – old Tokowaja mine, Russia;*
4. *Short dashed red curve and yellow curve – Malisheva mine, Russia;*
5. *Solid red curve – the stone sent to Vienna;*
6. *The black curve is a synthetic alexandrite masterstone for comparison.*

become aware of some natural alexandrites, which were characterised by exceptionally high CL intensities. The dotted red curve (AL-U/PF) is the CL spectrum for a cut natural alexandrite of more than one carat, the yellow curve (AL-GUS) relates to a polished crystal of alexandrite taken from a crystal group. The relative CL intensity of this polished crystal is some 20x greater than that of the synthetic alexandrite masterstone (black curve). Dr Ponahlo believes that these alexandrites are from a mine 80 km south-east of Jekaterinburg (Sverdlovsk), which is reportedly called 'Malisheva'. In Dr Ponahlo's opinion the CL of our 2.36 ct alexandrite was similar to that of alexandrites from 'Malisheva' (AL-REGENT solid red curve). This provided us with the confirmation we sought, enabling a report to be issued stating its natural origin. The second alexandrite, subsequently sent to Vienna proved to have the lower CL intensity typical for alexandrites from other natural sources.

A while ago we were asked for a quick verbal assessment on an alexandrite. The client could allow us time only to study the inclusions, which consisted of tapering exsolved zoning patterns reminiscent of those seen in hydrothermally synthesised emerald (*Figure* 2). Subsequent enquiries to colleagues in the trade and in other laboratories were inconclusive about whether or not alexandrite was being synthesised hydrothermally. We know chrysoberyl has been grown hydrothermally, but has any alexandrite been grown by this method and found its way onto the market or been grown commercially? Because we were not permitted to carry out further work on this stone, its origin will have to remain a mystery. A.I.C./S.J.K.

Jet?

In most gemmological teaching the identification of jet is presented as being relatively straightforward. This tends to be based on the material from two or three localities, but more detailed work has shown that even from these sources jet can show differences in properties (Weller and Wert, 1994). Coal is categorised in various interconnecting ways (Carpenter, 1988). The rank or maturity of the coal is related to the temperatures to which it has been subjected and the geological time involved. The rank increases from lignite, to sub-bituminous, through bituminous coal to anthracite. In coal petrology, the organic components are referred to as macerals and reflect their origins. Examples are vitrinite (chemically reactive - wood and allied tissue), liptinite (waxy and fatty parts of plants, e.g. spores, resin and cuticle) and inertinite (chemically inert charcoal-like material). As the rank of a coal increases (coalification) the liptinites are the first to react, losing volatiles and becoming indistinguishable under the microscope from each other and from vitrinite. Further heating, and increase of rank, leads to the loss of all botanical structure from the vitrinite, until finally in an anthracite the coal may appear almost totally homogeneous with perhaps only a few inertinite fragments visible. A low rank coal contains some 40% of volatile constituents (e.g. hydrogen), which decrease to around 4% in an anthracite.

In geological terms, jet is a form of vitrinite derived from homogeneous logs of wood washed from the land into water, usually the sea. When they become waterlogged they sink into the mud on the sea floor. If the mud is anoxic it will contain the remains of marine algae and plankton which are decaying and generating hydrocarbons (oil). The oil soaks into the wood and reduces its brittleness, producing the more resilient jet rather than the vitrinite that it would normally have become without the oil impregnation.

Figure 2: Growth zoning present in an alexandrite of questionable origin.

In gemmology we probably need to be more pragmatic in accepting jet as being coal of sub-bituminous to bituminous rank, with enough impregnated hydrocarbons to make the black material compact, carvable and durable. Coal that is to be considered as jet also needs to be free of mineral impurities (i.e. high grade) to reduce the chance of any fragmentation of the material. Therefore low ranked lignite, high ranked anthracite and low grade coal should be rejected as being too fragile and/or brittle to be considered gemmologically as jet.

A black bead necklace submitted to us proved to be an example of one of the above reject categories. Three features stopped us calling the material jet. There was an iridescent bloom to the black colour, the material would not burn with a hot point and the material deposited a black streak on unglazed white ceramic when a bead was drawn over it (the streak test). In itself this last feature should not be taken as ruling out the material as being jet, but in association with the other two aforementioned properties it quite rightly created suspicions in our minds.

Staff in the Mineralogy Department at the Natural History Museum kindly liaised with us by running X-ray powder diffraction and electron microprobe analyses, and these indicated that no mineral content was present. A section of a bead was also burned in a test tube: it burned virtually to completion leaving only a small white residue but gave off no smell of coal. By a process of elimination it was considered to be a high ranked coal or anthracite.

We decided to seek the assistance of Dr J.M. Jones, a coal petrologist and jet specialist, recently retired from the Fossil Fuel Department of Newcastle University, in order to obtain a positive identification. A fragment of our material was embedded in resin and polished down to produce a flat surface to carry out a reflectance test, which is commonly used in industry to identify different kinds of coal. The reflectance under oil immersion was 4% (you can measure in air or oil) which, being over 2.5%, accords with what is expected for anthracite (Stach, 1982). Jet has a reflectance of around 0.2%; the reflectance of vitrinite in coal rises with increasing rank from about 0.4% in lignite to over 2.5% in anthracites, and reaches 15% in graphite. Dr. Jones confirmed the anthracite determination by his microscopic examination, which showed only inertinite fragments in a structureless matrix. This structureless matrix is all that remains of the liptinite and vitrinite macerals. The result of anthracite was given to the client. A.I.C/S.J.K.

Irradiation and topaz

The irradiation of gemstones has come under scrutiny within Europe due to Council Directive 96/29/Euratom of 13 May 1996 (396L0029), which under article 6.5 states;

'Member states shall permit neither the deliberate addition of radioactive substances in the production of foodstuffs, toys, personal ornaments and cosmetics nor the import or export of such goods.'

The directive is due to be adopted into national legislation of member states by 13 May 2000. France is in the process of implementing a rather draconian interpretation of the law by forbidding the import and marketing of known irradiated gemstones. In the U.K. the Department of Trade and Industry (DTI) have commissioned a report from the independent National Radiological Protection Board (NRPB). The NRPB has submitted a report to the DTI after liaising with the trade and carrying out some sample testing of gems within the trade, using a geiger counter. A response from the DTI is expected in the next few months.

There have been two occasions when we have used the services of NRPB in relation to irradiated topaz for the identification of radionuclides by gamma ray spectroscopy (Ashbaugh III, 1992). The issue with the first topaz was that the owner wanted to ensure that the stone was safe to wear when mounted in a ring. It is a fair assumption that all commercially available blue topaz is the result of the irradiation and annealment of colourless topaz (Nassau, 1994). On testing the 23.31 ct stone NRPB detected the presence of two radionuclides, tantalum 182 (^{182}Ta) and manganese 54 (^{54}Mn), which were reported as being known to be the result of artificial irradiation. This provided us with the evidence to state categorically that the stone was treated topaz, and that the colour had been artificially produced by heat and/or irradiation. The activity levels of the two radionuclides were low enough for the NRPB to assure our member's customer that these levels did not represent a radiological hazard to anyone wearing the gemstone. It is important that these assurances come from such authorised professionals.

On the second occasion three stones, weighing 4.38 ct, 14.66 ct and 21.63 ct, were sent to NRPB as samples from 135,000 ct of blue topaz, which were presented in parcels

Figure 3: An emerald-cut steely blue topaz in the lower left of the picture was found to be radioactive, registering 20 counts per second on a geiger counter. On its right is a green beryl and the three large stones above are topaz.

of identical colour, all in a suitcase! In this case no evidence of artificial irradiation was found by NRPB, but it was pointed out to the customer that the activity levels of the radionuclides will diminish below the detection level of the analytical equipment if the period since irradiation is long enough. In view of this the concluding sentence of our report stated that, in our experience, the fact that as the topaz were presented in perfectly matched colours it was still fair to assume, for commercial purposes, that they had been artificially irradiated.

I learnt some months later that this concluding sentence had been deleted on a copy of the report. Any reader of an abbreviated report would be left in some doubt as to the colour origin of the stones. It is important to stress that wherever possible original reports should be consulted - beware of photocopies!

Topaz was also involved when we had a visit from some Russians, who were seeking verbal assessments of the stones in their possession. In addition to three large topaz and a green beryl, they had an emerald-cut steely blue topaz (*Figure 3*). The colour prompted us to check the stone on a geiger counter – it produced some 20 counts per second. Without the time to analyse it further, we suggested that they adhere to the regulations for transporting radioactive substances and obtain a detailed report on the activity before selling the stone.

A.I.C./S.J.K.

Trading standards and terminology

In the U.K. there are no trading standard laws relating specifically to the use of gem materials. The jewellery trade is governed by the Trade Descriptions Act of 1968 which, in conjunction with the International Jewellery Confederation's (CIBJO) Gemstone Book guidelines, has provided the means to prosecute false trade descriptions through the courts when it is ajudged to be necessary.

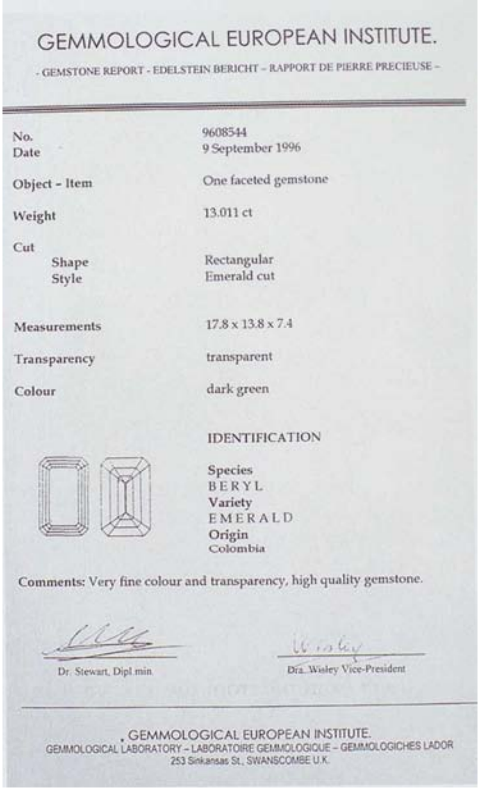
Contacts with our local government trading standards authorities have provided us with invaluable feedback from the jewellery trade across the country. In the last few years I have accompanied trading standards officers on gem surveys of their local jewellery outlets – mainly retail shops but also antique and collectors' markets.

There is nothing particularly unusual in the mistakes that are encountered, which reflect the varying standards that occur the world over with regard to gem descriptions. Some of the situations encountered have been:

- A low quality ruby cabochon described as an 'unusual faux ruby'. The retailer was unsure of the stone's origin so he decided to play safe by using the French word for false, which is very commonly used to replace 'imitation'. His caution was admirable.
- A peridot described on a label as 'zercon' because the retailer did not know how to spell peridot! He had not checked zircon either!
- An artificial glass sphere sold as a quartz crystal ball. The 'new age' retailer who sold it argued with the trading standards officer that since the sphere was made with silica his description should be allowed. He was firmly informed of the essential difference between a natural mineral and a man made product.
- Aquamarine has been synthesised by the hydrothermal method, but the description of 'synthetic aquamarine' is often misapplied to aquamarine simulants such as artificial glass, synthetic spinel and treated blue topaz.
- A chrome diopside was described as a 'Russian emerald'. The trader concerned received a conditional discharge from a magistrate's court but had to meet the costs.
- A lot of stained green quartzite is being sold as jade. Recently a trader received substantial fines for each of three items being misdescribed in this way. S.J.K.

Synthetic emeralds and reports

Three green stones, weighing 9.70 ct, 10.28 ct, and 13.01 ct, were quickly ascertained to be hydrothermal synthetic emeralds. The stones were accompanied with reports claiming that they were natural (*Figure 4*), and it was the address of the Gemmological European Institute, given as Sinkansas Street, Swanscombe, U.K., which intrigued us. There is a Swanscombe in the county of Kent, but Sinkansas Street does not exist there or anywhere else in the UK according to the UK Royal Mail.



GEMMOLOGICAL EUROPEAN INSTITUTE.

- GEMSTONE REPORT - EDELSTEIN BERICHT – RAPPORT DE PIERRE PRECIEUSE –

No.	9608544
Date	9 September 1996
Object - Item	One faceted gemstone
Weight	13.011 ct
Cut	
Shape	Rectangular
Style	Emerald cut
Measurements	17.8 x 13.8 x 7.4
Transparency	transparent
Colour	dark green

IDENTIFICATION

Species
BERYL
Variety
EMERALD
Origin
Colombia

Comments: Very fine colour and transparency, high quality gemstone.

Dr. Stewart, Dipl.min.

Wisley
Dra. Wisley Vice-President

. GEMMOLOGICAL EUROPEAN INSTITUTE.
GEMMOLOGICAL LABORATORY – LABORATOIRE GEMMOLOGIQUE – GEMMOLOGICHES LADOR
253 Sinkansas St., SWANSCOMBE U.K.

Figure 4: *A photocopy of a report, which represents a synthetic hydrothermal emerald weighing 13.01 ct as being natural. The address of the Laboratory could not be found.*

Therefore in this case the origin of the stones was easy enough to determine, but that of the laboratory must remain a mystery.

A.I.C./S.J.K.

Phenakite

Most phenakite is grey or colourless but occasionally it is found in rather beautiful pastel shades. Two coloured phenakites were recently sent to the GAGTL by J. Houran of Springfield, Illinois, USA, and he supplied the following comments:

'Phenakite (Be_2SiO_4) is from the Greek word meaning 'deceiver', in allusion to the mineral's similarity to quartz. Though considered a rare mineral, faceted gems are common among collectors of unusual stones and can be quite large.' 'The ample hardness (7.5 – 8) and imperfect cleavage make phenakite suitable for wear, but the typical lack of colour, vitreous lustre, and low dispersion (0.015) limit its appeal as a commercial gem. Still, the species may be seen in designer jewellery, as the use of rare and unusual gemstones is becoming increasingly popular with artists and the general public.'

'Subtle shades of pink and yellow are occasionally noted in phenakite. The 2.14 ct gem pictured in *Figure 5* is from Mt. Antero, Colorado, and was faceted by John Rhoads (D. & J. Rare Gems, Salida, Colorado). The stone has a yellowish cast that reportedly was much more saturated but faded after cutting, a phenomenon also observed in rose quartz and kunzite. Also pictured in *Figure 5* is a 7.18 ct example from the Takavara Mine in the Ural Mountains of Russia, showing a deep peach colour. The gem was cut by Mark Kaufman (Kaufman Enterprises, San Diego, California). The colour and intensity appear stable and are rare for the species. Kaufman reports that he has seen only forty to fifty comparable gems, and that the deep colour is found only near the centre of the crystal. Consequently, a large crystal is needed to yield stones of any size. This gem was cut from a crystal weighing approximately 120 ct and shaped like a ball about 37.5 mm in diameter.' R.R.H.

Figure 5: *On the left a 7.18 ct peach-yellow phenakite from the Ural Mountains, Russia; on the right a 2.14 ct light pink phenakite from Mt. Antero, Colorado.*

African exploration

From time to time, gem prospectors or gem merchants bring minerals to us for identification because some exceptional feature or quality has excited their interest. In regions of the world that are still relatively unexplored, this is of particular interest to us because there are realistic chances of discovering something new. In this context two highly coloured materials were recently submitted for examination from Tanzania by J.M. Saul.

The first is a rich purple pebble 8 mm across, which was suspected of being, and later proved to be, a zoisite, variety tanzanite. This is not the first occurrence of tanzanite from Tunduru, but confirmation of its identity will stimulate the search for more.

The second specimen is a rich yellow-green, like that of some sphenes, but it was identified as a mineral of the scheelite-powellite ($CaWO_4$ - $CaMoO_4$) solid solution series. Both minerals were confirmed by X-ray diffraction methods at the Natural History Museum by John G. Francis. As far as we know the scheelite-powellite has not been cut, but its hardness of about 5 and its intense colour make it a candidate for cutting as a collectors' stone. R.R.H.

Acknowledgements

We would like to thank Dr Johann Ponahlo for his advice and for sharing his expertise with us; Dr John M. Jones for checking the information given on coal and jet petrology, as well as examining the jet for us; and Cally Oldershaw, John Francis, John Spratt and Gary Jones at The Natural History Museum for their expert help with the various specimens.

References

Ashbaugh III, C.E., 1992. Gamma-ray spectroscopy to measure radioactivity in gemstones. *Gems & Gemology*, **28**(2), 104-11

Carpenter, A., 1988. *Coal classification.* IEA Coal Research/12 (ISBN 92-9029-162-1)

Nassau, K., 1994. *Gemstone enhancement, history, science and state of the art.* 2nd edn. Butterworth-Heinemann Ltd., Oxford

Ponahlo, J., 1988. Quantitative cathodoluminescence — a modern approach to gemstone recognition. *J. Gemmol.*, **21**(3), 182-93

Ponahlo, J., 1989. Mikrospektralphotometrie der Edelstein-Kathodolumineszenz. *Z. Dt. Gemmol. Ges.*, **38**(2-3), 63-84

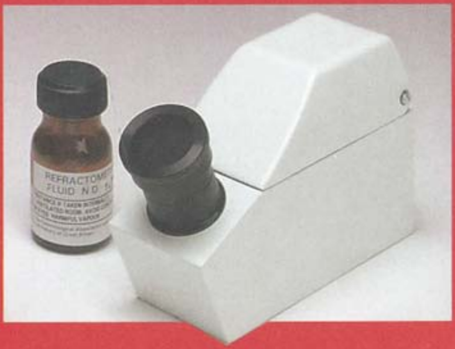
Ponahlo, J., 1993. Kathodolumineszenz (KL) und KL-Spektren von Edelsteinen (Ausgewählte Beispiele) Teil I. *Z. Dt. Gemmol. Ges.*, **42**(2-3), 101-13

Ponahlo, J., 1993. Kathodolumineszenz (KL) und KL-Spektren von Edelsteinen (Ausgewählte Beispiele) Teil II. *Z. Dt. Gemmol. Ges.*, **42**(4), 149-62

Ponahlo, J., and Koroschetz, T., 1986. Quantitative cathodoluminescence of gemstones. *Aust. Gemmol.*, **16**(2), 64-71

Stach, E., 1982. *Stach's Textbook of Coal Petrology.* Lubrecht and Cramer, Berlin

Weller, M., and Wert, C., 1994. Jet: physical and material aspects. *J. of Alloy and Comp.*, **211/212**, 385-9



The mineralogical composition of *maw-sit-sit* from Myanmar

F. Colombo[1], C. Rinaudo[2] and C. Trossarelli[3]

1. Dipartimento di Scienze della Terra, Università di Siena, Via Laterina 8,
53100 Siena, Italy
2. Dipartimento di Scienze e Tecnologie Avanzate, Università degli Studi
del Piemonte Orientale 'Amedeo Avogadro',
Corso Borsalino 54, 15100 Alessandria, Italy
3. Dipartimento di Scienze Mineralogiche e Petrologiche, Università
di Torino, Via Valperga Caluso 35, 10125 Torino, Italy

ABSTRACT: *Maw-sit-sit* has been present on the world market for a few decades and its mineralogical composition and genesis are still not well known. The mineralogical composition of a sample of *maw-sit-sit* consists of albite, chromian-eckermannite, kosmochlor, chromite and natrolite in decreasing order of abundance, and its gemmology, microstructure, and mineral chemistry are discussed.

Keywords: *maw-sit-sit*, mineralogy, mineral chemistry, X-ray diffraction

Introduction

Maw-sit-sit is the name of a village close to Tawmaw (Myanmar) and is the source of a distinctive green rock first reported by Gübelin (1965). The gem quality material is generally described as green with black and white spots and streaks and is inhomogeneous. The mineralogical composition is not, however, well defined, and different authors have reported a range of constituents. Gübelin (1965) described the *Maw-sit-sit* as a rock mainly composed of albite and Cr-jadeite; Manson (1979) identified natrolite and kosmochlor (then known as ureyite), as the main constituents. More recently, Hänni and Meyer (1997) found chromite, kosmochlor, Cr-amphibole as the main, well developed minerals; and zeolites, chlorite, albite and serpentine in minor quantities, commonly

Figure 1: *(a) Front view of sample of Maw-sit-sit; length 45 mm. (b) Rear view of the same sample.*

ISSN: 1355–4565

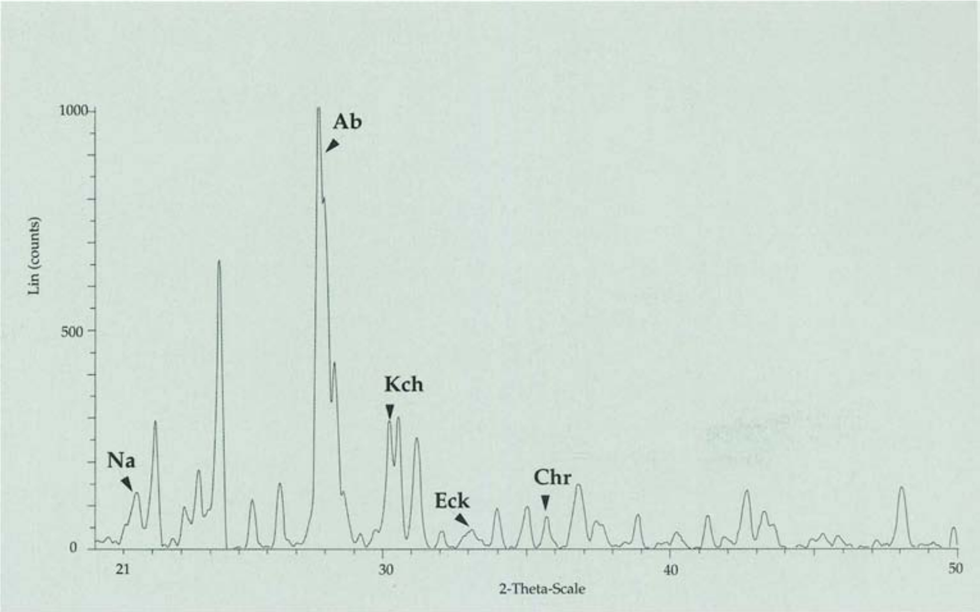


Figure 2: *X-ray powder spectrum obtained directly from the surface of the sample. Ab, albite; Kch, kosmochlor; Chr, chromite; Eck, chromian-eckermannite; Na, natrolite. The peaks of albite are the most intense, indicating prevalence of this phase in the sample.*

intergrown on a fine scale (symplectitic texture). In this paper we describe a mineralogical study performed on a sample from Myanmar, and weighing 62.5 g, measuring 45 × 33 × 4.5 mm, and represented in *Figures 1a* and *1b*.

Gemmology

The specific gravity determined by hydrostatic balance is 2.7. The average refractive index by distant vision is 1.54. The rock is inert under the Chelsea colour filter, and spectroscope examination reveals strong absorption from the red to yellow, and strong absorption from 470 nm, increasing to total absorption at the violet end of the spectrum.

X-ray analysis

X-ray determinations were carried out directly on the surface of the sample. A Siemens D5000 diffractometer equipped with *Göbel Mirrors* was used with Cu Kα radiation. The mirrors are a new device and consist of a graded mutilayered crystal bent to a parabolic shape. Its function is to transform the primary divergent X-ray beam into a single, intense, brilliant, parallel and collimated beam regardless of the distance from the source. The parallel beam allows qualitative analysis to be carried out directly on the irregular surface of a sample without any need to take a powder sample (Chiari *et al.*, 1996; Chiari *et al.*, 1998). The X-ray results are shown in *Figure* 2 and may be summarised as follows:

- The sample consists mostly of albite $NaAlSi_3O_8$, which gave the most intense diffraction peaks in the spectrum (the formulae reported in the text describe the simplified chemical formulae for the analysed mineralogical phases);
- *Kosmochlor* (formerly known as ureyite) $NaCrSi_2O_6$ is the second most abundant mineral;
- The other components are: *chromite* $FeCr_2O_4$, *natrolite* $Na_2Al_2Si_3O_{10}{\cdot}2H_2O$,

and *chromian-eckermannite* $(Na,Ca)_3(Mg,Fe,Al,Cr)_5Si_8O_{22}(OH,F)_2$.

Spectra were recorded from several different parts of the sample, but no significant differences in mineral content or abundance were detected.

Optical microscopy and mineral chemistry

Under the optical microscope the sample appears inhomogeneous as shown in *Figure 3*, and relicts of chromite, often surrounded by kosmochlor *Figure 4* are contained in a fine-grained matrix mainly consisting of albite, chromian-eckermannite and natrolite closely intergrown in a symplectitic texture. Chemical analyses of the areas showing different optical contrasts were carried out using a Cambridge SEM-EDS microprobe. Operating conditions were 15 kV acceleration voltage, beam current 50 nA and 50 s counting time. Natural and synthetic minerals were used as standards. A ZAF correction procedure was performed on-line. Back scattered electron images showing the different brightness responses of the different minerals and their textural relations are shown in *Figures* 5 and 6, and representative chemical analysis of the detected minerals are presented in *Table I*.

Albite (Ab)

Albite is the major constituent of the sample and can be observed either in extended areas (Ab in *Figure 5*) or as symplectitic aggregates intergrown with eckermannite and/or kosmochlor (Ab+Eck+Kch in *Figure 5*). As demonstrated by *Table I*, albite is nearly pure with a small content of Cr, substituting for Al, up to 1.1 wt% in parts.

Kosmochlor (Kch)

All the analyses performed on the pyroxene relicts display a high amount of Cr (up to 31.52 wt%), substituting for Al, and can be classified as kosmochlor. In all the analysed grains, the amount of Cr decreases towards the rim of the kosmochlor crystals (*Figure 6*) or away from the chromite relicts (see *Figure 4* and Chr in *Figure 5*). The content of other pyroxene end-members is negligible.

Figure 3: *Detail of the front of the sample showing its mottled appearance (the mineral association in the middle of the picture is 1 mm long).*

Chromian-eckermannite (Eck)

The analysed amphiboles show a high content of Cr (up to 6.62 wt%) replacing

Figure 4: *Detail of the back of the sample showing, as confirmed by EDS analyses, a relict grain of chromite (dark/metallic) surrounded by a deep green kosmochlor rim and an albite-rich matrix (the mineral association Chr+Kch is 1 mm long).*

Table I: *Representative microprobe analyses of* maw-sit-sit *minerals: albite (Ab), kosmochlor (Kch), chromite (Chr), and chromian-eckermannite (Eck).*

Sample	*Ab 20*	*Ab 26*	*Kch 13*	*Kch 3*	*Chr 1*	*Chr 17*	*Eck 30*	*Eck 31*
SiO_2	67.25	68.45	57.02	53.22	0.41	0.44	57.57	58.02
TiO_2	–	–	–	–	0.06	–	0.07	–
Cr_2O_3	1.11	–	5.42	31.52	56.55	56.33	6.41	6.62
Al_2O_3	18.65	19.25	19.86	1.61	5.72	6.00	3.06	1.58
Fe_2O_3	–	–	–	–	9.07	8.85	–	–
FeO	–	–	1.29	–	20.59	20.86	3.52	3.67
MnO	–	–	–	–	2.24	2.84	0.17	-
MgO	–	–	–	-	1.82	2.32	16.48	16.89
NiO	–	–	–	–	–	–	–	0.37
CaO	–	–	–	–	–	–	0.41	0.11
Na_2O	11.94	12.05	15.03	14.09	–	–	11.02	11.38
K_2O	–	–	–	–	–	0.05	0.19	0.23
H_2O	–	–	–	–	–	–	2.17	2.14
Total	98.95	99.75	98.62	100.44	96.46	97.69	101.07	101.01
Si	2.9829	2.9987	1.9981	1.9917	0.0147	0.0156	7.9662	8.0534
Ti	–	–	–	–	0.0016	–	0.0073	–
Cr	0.0389	–	0.1502	0.9326	1.5988	1.5774	0.7013	0.7265
Al	0.9749	0.9939	0.8202	0.0710	0.2411	0.2505	0.4990	0.2585
Fe^{3+}		–	–	–	0.2440	0.2360	–	–
Fe^{2+}	–	–	0.0378	–	0.6158	0.6180	0.4073	0.4260
Mn	–	–	–	–	0.0678	0.0852	0.0199	–
Mg	–	–	–	–	0.0970	0.1225	3.3990	3.4943
Ni	–	–	–	–	–	–	–	0.0413
Ca	–	–	–	–	0.0027	–	0.0608	0.0164
Na	1.0268	1.0234	1.0211	1.0223	0.1165	0.0927	2.9565	3.0626
K	–	–	–	–	–	0.0023	0.0335	0.0407

Structural formulae are calculated on the basis of: 5 cations and 8 oxygens for albite, 4 cations and 6 oxygens for kosmochlor, 3 cations and 4 oxygens for chromite, 23 oxygens and 13 cations + K + Na + Ca for chromian-eckermannite.

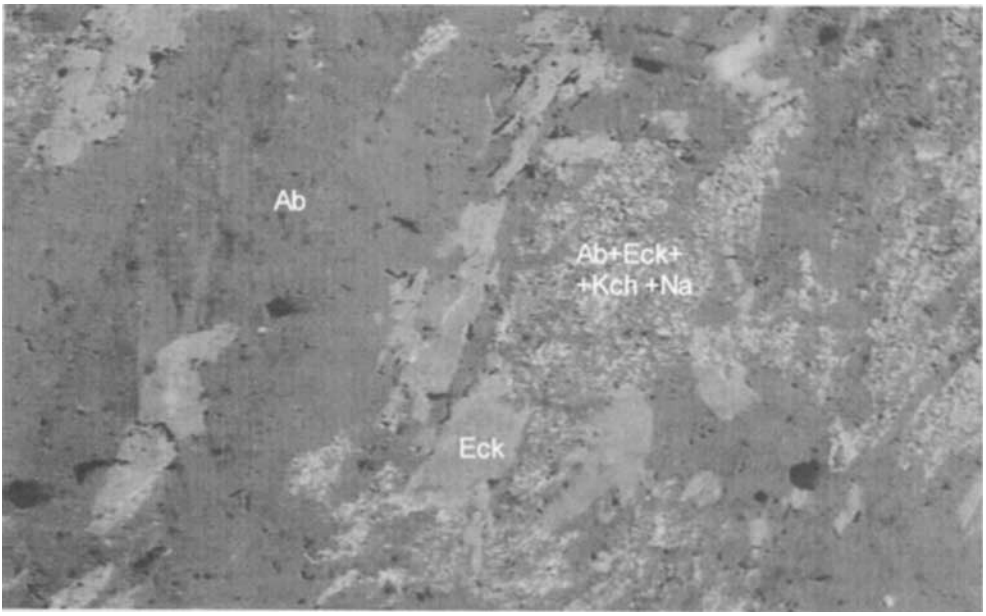


Figure 5: *Electron photomicrograph showing large regions made up of albite (Ab), finer grains of chromian-eckermannite and symplectitic association of albite + chromian-eckermannite + kosmochlor + natrolite (Na).*

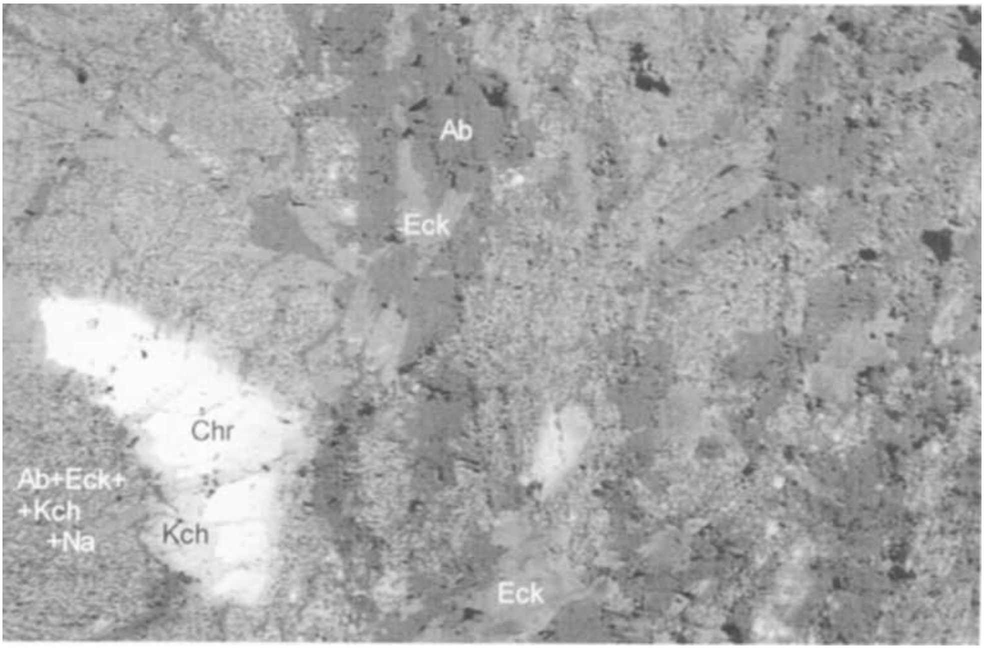


Figure 6: *Back scattered electron photomicrograph showing a relict grain of chromite (Chr, c. 1 mm long) rimmed by kosmochlor (Kch), large crystals of chromian-eckermannite and symplectitic intergrowths of albite + chromian-eckermannite + kosmochlor + natrolite.*

Al and are classified as chromian-eckermannite (after Leake *et al.*, 1997). They are coarse grained crystals or intergrown with albite and kosmochlor as symplectites (see *Figures* 5 and 6).

Chromite (Chr)

The black minerals visible under the optical microscope (*Figure* 4) have spinel compositions, showing a prevalence of chromite (62-66%) over Mg-chromite (10-12%), see *Figure* 6. Minor contributions of other end-members of the spinel group have been identified in all the analysed relicts.

Discussion

The sample of maw-sit-sit shows a brilliant green colour as a whole, but with higher magnification veinlets, spots or streaks of different colours (mainly white and sometimes black) can be observed. X-ray analysis performed directly on the surface confirmed the presence of different mineralogical phases and these were confirmed by EDS analysis, except for natrolite which is too fine-grained. Chromium was detected in all minerals except for natrolite and the relatively high amounts account for the green colour of the rock. On the basis of microstructural relationships between the different rock forming minerals seen by optical microscope and electron microscope, we suggest that the different mineralogical associations reported by various authors are due to the fact that maw-sit-sit is a rock resulting from metamorphism of a heterogeneous parent rock mass. This is consistent with the heterogeneity of jadeite-rich, albite-rich, and amphibole-bearing rocks exposed in the field and described by Gübelin (1965) and Soe-Win (1968). Also the metamorphic processes can generate different mineral assemblages in neighbouring rock volumes, so different rocks can be generated from the same overall deposit.

Acknowledgements

The authors wish to thank Mr A. Scardina who kindly provided the studied sample, Mr C. Sibio for the sample preparation and the Consiglio Nazionale delle Ricerche (P.B. 98.00.668.CT11) for the financial support.

References

Chiari, G., Giordano, A., and Menges G., 1996. Non destructive X-ray diffraction analysis of unprepared samples. *Science and Technology for Cultural Heritage*, **5**(1), 21

Chiari, G., D'Amicone, E., and Vigna, L., 1998. Non destructive X-ray diffraction analysis using Göbel mirrors: an application to Egyptian pigments and glasses. *Actes de la Table Ronde, Ravello, Italy*, 87

Gübelin, E., 1965. Maw-sit-sit: a new decorative gemstone from Burma. *Gems & Gemology*, **11**(8), 227-38

Gübelin, E., 1965. Maw-sit-sit proves to be jade-albite. *Gems & Gemology*, **11**(9), 302-8

Hänni, H.A., and Meyer, J., 1997. Maw-sit-sit (kosmochlor-jade): a metamorphic rock with complex composition from Myanmar (Burma). *26th International Gemmological Conference, Abstract Volume, September 27-October 3, Germany*, 22-4

Leake, B.E., et al., 1997. Nomenclature of amphiboles. Report of the Subcommittee on Amphiboles of the International Mineralogical Association Commission on New Minerals and Mineral Names. *Mineralogical Magazine*, **61**, 295-321

Manson, D.V., 1979. Recent activities in GIA's research department. *Gems & Gemology*, **16**(3), 217-19

Soe-Win, U., 1968. The application of geology to the mining of jade. *Union of Burma J. Sci. and Tech.*, **1**, 445-6

Classification of emeralds by artificial neural networks

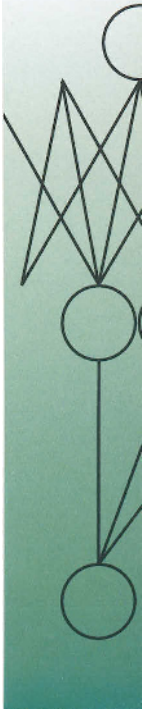
J.M. Dereppe[1], C. Moreaux[1], B. Chauvaux[1] and D. Schwarz[2]

1. Laboratoire de Chimie Physique, Universite de Louvain-la-Neuve, Belgium
2. Gübelin Gem Lab, Lucerne, Switzerland

ABSTRACT: Artificial neural networks (ANN) are structures which are built up from elements that behave like biological neurons. They are used for prediction purposes and for the classification of data into categories. ANN data processing has been applied to the geological origin determination of emeralds. Microprobe data for the elements Si, Al, Mg, Na, Fe, Cr, V, Mn, Ca, K, and Ti of more than 450 emeralds originating from different geological environments have been considered. The sample material has been classified into five categories. Details about the occurrences hosting the different types of emeralds are given by Schwarz and Giuliani (2000).

Emeralds belonging to Category 1 originate from deposits related to granitic pegmatite intrusions and hydrothermal veins in mafic-ultramafic rocks (e.g. Ndola Rural District/Zambia, Sandawana-Machingwe mining area/Zimbabwe, Carnaíba-Socotó and Belmont mine-Capoeirana/Brazil, Ural Mountains/Russia). Emeralds of Category 2 originate from deposits related to tectonism (thrusts, shear-zones, faults) in mafic-ultramafic rocks (Santa Terezinha and Itaberaí, Goiás State/Brazil). Category 3 comprises emeralds from the Swat Valley in Pakistan (talc-carbonate-mica schists) and the Panjsher Valley in Afghanistan (quartz-ankerite-pyrite veins). These deposits are related to oceanic suture zones. The Colombian emeralds representing Category 4 are related to thrusts and faults in sedimentary 'black shale' rocks. Category 5 comprises the emerald mineralisations of the Kaduna-Plateau States in central Nigeria. These are of the so-called 'granite cupola-type'.

ANN data processing makes it possible to separate quickly and reliably Colombian emeralds (Category 4) from non-Colombian emeralds (bad scores 2.6%). A supervised classification into Categories 1, 2, 3 and 5 gave very good results: bad scores 1% and 0% respectively for Categories 1 and 5; for Category 2 acceptable results (bad scores 7%); but for Category 3 scores are rather poor (bad scores 12.5%). The lower 'classification quality' for Category 3 becomes understandable when considering the fact that emeralds from the Swat Valley are found in a (Fe+Mg)-rich environment (talc-carbonate-mica schists), whereas their Afghani counterparts originate from quartz-ankerite-pyrite veins.



ISSN: 1355–4565

Introduction

The origin of a gemstone is an important parameter for its characterisation. Origin determination of gemstones is based, in principal, on the interpretation of data sets obtained through the examination of mineralogical properties. The most important factors used for this procedure are:

(a) internal characteristics (solid inclusions, fluid inclusions, growth structures, etc.);

(b) chemical data (element concentrations and concentration ranges, correlation diagrams, trace element profiles, isotope ratios);

(c) physical data (specific gravity, refractive indices, double refraction);

(d) spectrometric data (UV-vis-NIR spectra; NIR/MIR spectra; Raman).

All these properties depend directly or indirectly on the specific geological and geochemical conditions of the genetic environment during the formation of a gemstone.

Gemstones of one variety are complex solids with similar properties. Of necessity, the analysis of their properties has to be multivariate. To detect the relationship between the totality of the samples and the variables related to them, in an efficient manner, it is necessary to process large quantities of data simultaneously, and not one or two at a time. Modern statistical analytical methods may be used to make a valuable contribution to the origin determination of gemstones. In this paper, the use of artificial neural networks has been applied, for the first time to the best of our knowledge, to the origin determination of emeralds.

Artificial Neural Networks

Artificial Neural Networks (ANN) provide a powerful tool for data processing. In contrast to traditional statistics, the main goal of ANN is not to analyse and to understand series of data, but to use them for prediction and classification purposes. As the name implies, ANN are artificial structures, which are built up from elements that behave like biological neurons, and which are able to successfully emulate the low level mechanisms of the brain.

Historical aspects

A biological neuron is basically composed of a nucleus which has two types of extensions: the dendrites and the axon. The many dendrites receive signals from other neurons or from any kind of sensors. These signals are processed in the cell body and transmitted to other neurons or organs by the axon which branches into several collaterals. The axon or collateral ends in synapses. The signals, essentially electrical in nature, are transmitted from synapses to dendrites by means of a chemical substance called a neurotransmitter. The synapses also modulate the signal flowing through them. The amount of change is called the synaptic strength. The first artificial neuron was produced by the neurophysiologist Warren McCulloch and the logician Walter Pits, but computer technology at that time was too limited to allow much progress. Following an initial period of enthusiasm, the field had to survive a period of disrepute and re-emerged during the late 1970s and early 1980s, boosted by computer developments. Significant progress has been made since then, and ANN are now applied in many different fields, such as industrial process control, data validation, sales forecasting, marketing and interpretation of biomedical data. Today, research is rapidly advancing the field on many fronts, and applications to increasingly complex problems are emerging.

Emeralds: geological environments and mineralogical characteristics

The classification of emeralds performed in this study, by using ANN, is based on microprobe data of more than 450 emeralds collected during several research projects undertaken by one of the authors (Schwarz, 1990 a,b; 1991 a,b; 1992 a,b). These samples

ANN Modes

An artificial neuron is a device with many inputs and one output. The neuron has two modes of operation: the training mode and the using mode. In the training mode, the neuron is trained to fire or generate an output signal, according to a firing rule. The firing rule is an important concept in neural networks and accounts for their flexibility. It is the way to calculate the response of the neuron for any input pattern. In the using mode, the input pattern is presented and the firing rule is used to determine the amplitude of the response.

In an artificial neuron (*Figure 1*), the individual input signals s_i, weighted by a coefficient corresponding to the synaptic strength in the biological world, w_i, are added.

$$\Sigma = w_1 . s_1 + w_2 . s_2 + \Sigma$$

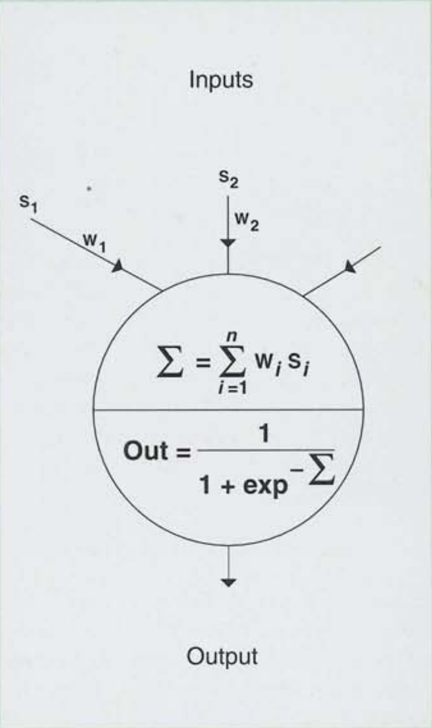


Figure 1: *Artificial neurons (see text for explanations)*

The output signal is obtained by processing Σ with a transfer function. For linear units, the output activity is proportional to the total weighted output. For threshold units, the output is set at one out of two levels, depending on whether S is higher or lower than some threshold value. For sigmoid units, the transfer function is the so-called S or sigmoid function.

$$S = 1/ [1+ \exp - (\alpha \Sigma + \delta)]$$

Sigmoid units bear a greater resemblance to biological neurons than do linear and threshold units, but all three must be considered as rough approximations. Of most importance is the fact that the non-linear relationship between input and output signals, represented by the sigmoid transfer function, also represents a non-linear relationship between properties. This is a task which can only be carried out with great difficulties by other methods. Moreover, α and δ are two parameters that can be used to influence the function of a neuron.

Artificial neurons are assembled in networks. Many kinds of networking strategies have been investigated, the most common being the layered model (*Figure 2*). In a layered model, the neurons are divided into groups or layers. The neurons of the same layer are not interconnected, but are only linked to the neurons in the layer above and below. The first layer is a layer of input units, not considered as neurons as they do not perform any arithmetic operations. They represent the raw information or data to be fed into the network. The input layer is connected to one or more hidden layers of neurons. The activity of each hidden unit is determined by the signal received from the input units, the weight of the connections between input and the hidden units, and the characteristics of the transfer function. The efficiency of the network as a whole is given by the output

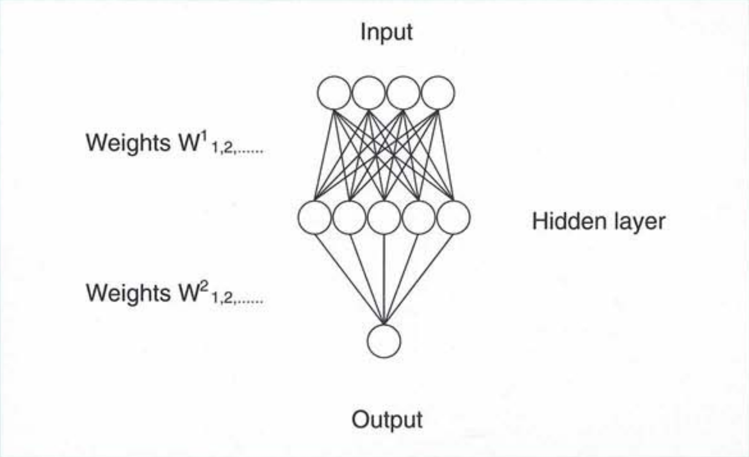


***Figure 2:** Layered network strategy model (see text for explanations)*

layer. The activity of the output unit depends on the activity of the units in the last hidden layer, and also on the weighting coefficients between the units of the hidden layer and those of the output layer.

ANN also contain some form of 'learning rules' which modify the weights of the connection according to the input patterns they are presented with. Initial values of the weights are random values between -0.1 and +0.1. The unsupervised training or learning is based only upon local information. The network self-organizes the input data and detects their collective properties. In the supervised learning, input data are presented and the output is compared with the desired output. The error is used to modify the weight of the connections in order to bring the output close to the desired value. This process is usually performed by using an algorithm known as backpropagation of errors. Because of the non-linearities of the network, convergence is slow and the learning phase is usually a time-consuming process. The training set may have to be presented several tens or even hundreds of thousands of times.

When the network has been trained, it can be tested on data which are not included in the training set. ANN are often used for classification of data into categories; they are especially useful when the link between data and categories is not clear, and when many factors (properties) should be taken into account simultaneously.

originate from a wide range of geological environments in which gem-quality emeralds have grown. The relationship between the different genetic environments, and mineralogical characteristics of the emeralds originating from them, are discussed in detail by Schwarz *et al.* (in prep). A comprehensive review of emerald deposits is given by Schwarz and Giuliani (2000). Two basic types of emerald deposits can be distinguished: type I is related to granitic intrusions, and type II to tectonic events.

The mineralogical properties of an emerald will always reflect the specific conditions of the geological environment in which it has grown. Characteristics like chemical composition (especially the presence of minor and trace elements, the basis of 'chemical fingerprinting'; cf Schwarz and Stern, 2000), spectrometric data, optical values, and internal features, depend directly or indirectly, on the physical and chemical conditions predominant during emerald formation. Factors like the nature of the host rock, as well as composition, pressure and temperature of the solutions involved in the emerald crystallization, will control the appearance of the above-mentioned characteristics.

The emerald sample material used for this study has been classified into five categories 1 to 5. The specific characteristics of the deposits hosting these emeralds are discussed by Schwarz and Giuliani (2000) and can be typified as follows:

Category 1

This category comprises deposits related to granitic pegmatite intrusions and hydrothermal veins in mafic-ultramafic rocks (e.g. Miku-Kafubu in the Ndola Rural District of Northern Zambia; Mweza Range in Zimbabwe; Mananjary region in Madagascar; Ural Mountains/Russia; Itabira-Nova Era region in Minas Gerais/Brazil; Carnaíba-Socotó mining field in Bahia/Brazil).

The emerald mineralizations are located in the immediate vicinity or within the exocontact zones of pegmatite-bearing granitic intrusions. Emerald is generally found in black phlogopite schists, e.g. containing black Mg-rich biotite + greyish talc ± phlogopite ± quartz/albite/muscovite/fluorite veins. Emerald formation is the result of the reaction of fluids which circulate in pre-existing rocks (e.g pegmatite- or granite-related fluids in mafic-ultramafic rocks, like serpentinite, amphibolite, etc.). Micas of the biotite/phlogopite series are the dominant mineral inclusions in most emeralds of Category 1. Tremolite/actinolite inclusions can be present in amounts comparable to mica, or they can even become the most frequent mineral inclusions. Other

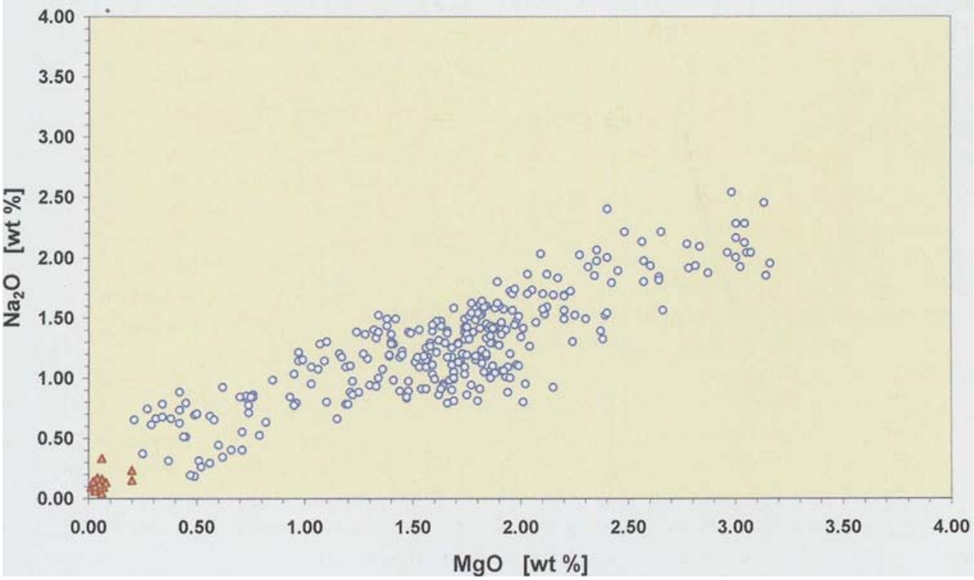


Figure 3: *Na_2O-MgO correlation diagram for Categories 1* ○, *e.g. most African and Brazilian deposits, and 5* ▲, *Nigeria (see text for explanations).*

minerals which may be present are muscovite (margarite), chlorite, talc, spinels, feldspars, quartz, tourmaline, sulphides, carbonates, rutile and apatite. Two types of fissures occur frequently in emeralds of this category: healed fissures with a large variety of cavity fillings (mostly two-phase inclusions of the liquid-gas 'lg'-type), and unhealed fissures. Emeralds belonging to Category 1 exhibit the widest range of optical data (refractive indices and birefringence). The highest values (n_o = 1.60, n_o - n_e = 0.008 - 0.010) have been measured in African emeralds from Zambia and Zimbabwe. The e- and o-absorption spectra of Category 1 emeralds are Cr-spectra with a dominant Fe absorption band in the 700-900 nm range. Chromium is the dominant chromophore element of Category 1 emeralds. Vanadium is of no importance as a chromophore in emeralds of this category. A typical feature of this category is the large variation in iron, magnesium, and sodium contents (compare *Figure* 3).

Category 2

Emerald occurrences of Category 2 are related to tectonism (thrusts, shear-zones, and faults) in mafic to ultramafic rocks. The host rocks of the emerald mineralisations belong to volcano-sedimentary series.

- *Santa Terezinha de Goiás (Campos Verdes Mine), Goiás, Brazil*

  The infiltration of hydrothermal fluids is controlled by tectonic structures such as thrusts and shear zones. Pegmatite veins are absent and the mineralization is stratiform. Emeralds are disseminated in phlogopites and phlogopitized carbonate-talc schists (Gusmão Costa, 1986; Biondi, 1990; Giuliani *et al.*, 1990 a). Talc-schists provide the main sites for thrusting and the formation of sheath folds. Emerald-rich zones are commonly found in the core of sheath folds and along the foliation.

- *Itaberaí, Goiás, Brazil*

  Emeralds are mainly found in metasomatic zones, together with biotite/phlogopite, and in talc-bearing schists. Less important as emerald host rocks are chlorite-talc schists, quartz veins, or altered feldspar veins (Barros *et al.*, 1990).

The most common inclusion minerals in emeralds from Category 2 are biotite/phlogopite, talc, tremolite/actinolite, titanite, pyrite, pyrrhotite, chalcopyrite, pentlandite, quartz, rutile, calcite, dolomite and apatite (Schwarz, 1990 a).

Emeralds from the Santa Terezinha mining area have high RIs with n_o up to 1.60 and n_o-n_e up to 0.010. The data for emeralds from the Itaberaí-deposit are slightly lower: n_o up to 1.59 and n_o-n_e = 0.008 - 0.009.

A quite unusual absorption spectrum is shown by the emeralds originating from the Santa Terezinha deposit: it is a combination of a Cr-Fe absorption spectrum with an intense band in the 780-820 nm range (e-spectrum). Emeralds from Category 2 originate from occurrences where the mineralisations are stratabound and not related to veins. They are distinguished by high contents of magnesium and sodium, with only small variation (compare *Figure* 4).

Category 3

Emerald occurrences of Category 3 are also related to tectonic events. They are encountered in oceanic suture zones.

- *Swat, Mingora, Gujarkili and Barang, Pakistan*

  The ophiolitic melange which contains the emerald mineralizations, is composed mainly of altered ultramafic rocks. Emerald occurs within hydrothermally altered serpentinites, which show some or all of the following metasomatic zones (Dilles *et al.*, 1994): an outer zone composed of talc + magnesite ± chlorite ± micas; an intermediate zone consisting of talc + magnesite with dolomite veins; an inner zone with dolomite + magnesite + talc schists and quartz ± dolomite ± tourmaline ± fuchsite veins. Emerald is disseminated throughout the inner and intermediate zones in or next to veins.

  Sulphide minerals (pyrite, pyrrhotite, molybdenite, pentlandite and

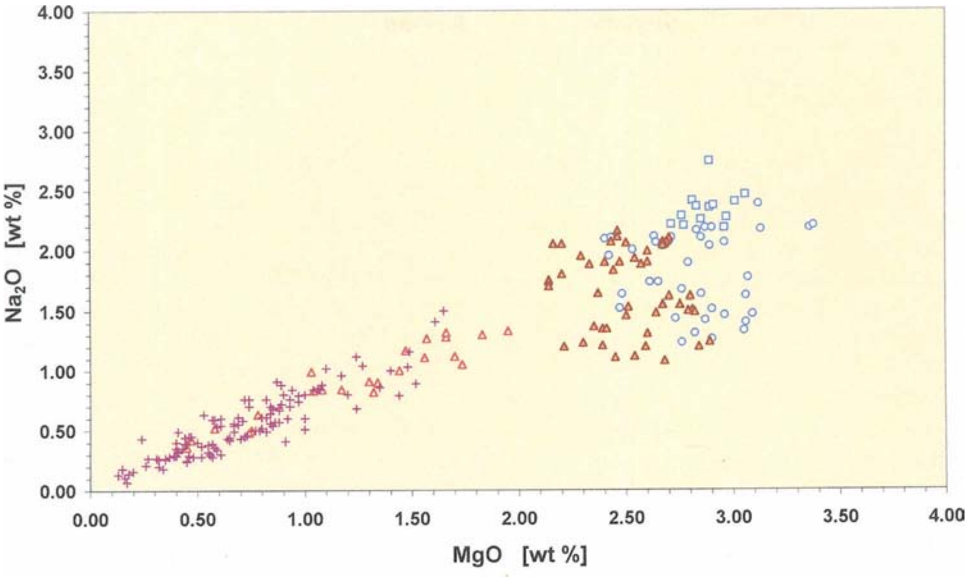


Figure 4: *Na_2-MgO correlation diagram for Categories:*
Category 2 Santa Terezinha/GO ○ *and Itaberaì/GO* □
Category 3 Mingora/Swat, Pakistan ▲ *and Panjsher Valley, Afghanistan* △
Cateogry 4 Cordillera Oriental, Colombia + *(see text for explanations).*

gersdorffite) are quite common in emeralds from the Swat region in Pakistan. The primary cavities show rectangular to jagged outlines or they have elongated tube-like forms. Emeralds from the Swat region are characterized by high values for the optical data (n_o up to 1.60 and n_o - n_e up to 0.010). Their absorption spectra are characterized by the combination of Cr-V-Fe-bands. Magnesium and sodium contents of the Pakistani emeralds from the Swat-region are always high, the variation range of these elements is small (*Figure 4*).

- *Panjsher Valley, Afghanistan*

Emeralds occur along shear zones which cut Palaeozoic metasedimentary rocks (limestones and slates) in veins containing quartz, ankerite and pyrite. Hydrothermal alteration is evident by strong silicification, albitization, carbonatization, and phlogopitization of the host rocks. Typical mineral inclusions are different carbonates (especially dolomite, less frequent are calcite and magnesite). Afghani emeralds from the Panjsher Valley may show elongated cavities with a multi-phase filling (i.e. several s-phases). The Panjsher-emeralds show optical data, which fall into the medium-range (n_o around 1.585 and n_o-n_e = 0.007). Their absorption spectra can be practically free of Fe-bands, or they may show a weak Fe^{2+} and/or Fe^{3+} absorption. The Panjsher emeralds show a large concentration range for magnesium and sodium (*Figure 4*).

Category 4

Deposits hosting emeralds of Category 4 are related to thrusts and faults in sedimentary rocks with high contents of organic matter (the so-called 'black shales').

- *Cordillera Oriental, Colombia*

Emerald mineralisations are found in two areas of Early Cretaceous black-shale series: (a) Eastern emerald zone Gachala, Chivor, and Macanal; and (b) Western emerald zone Coscuez, Muzo, and La Palma-Yacopi. There is a lack of any igneous activity in the genesis of these deposits (Giuliani *et al.*, 1990 b, 1992; Ottaway, 1991; Cheilletz *et al.*, 1994; Ottaway *et al.*, 1994; Cheilletz and Giuliani, 1996). The favoured genetic model involves the interaction, at about 300°C, of basinal fluids with evaporites and organic matter contained within black shales. Fluids in emeralds are derived from the dissolution of primary halite (Banks *et al.*, 1995), and the source of beryllium is local (Kozlowski *et al.*, 1998; Giuliani *et al.*, 1990 b; Ottaway *et al.*, 1994).

The most frequent inclusion minerals are carbonates (mostly calcite/dolomite), quartz, albite and pyrite, together with opaque black particles of carbonaceous shale from the host rock. An inclusion mineral with a locality-specific character is Ca (Ce, La) carbonate parisite.

The Colombian emeralds are well-known for their classic 'slg'-three-phase inclusions with a cubic s-phase (halite). Other phase-combinations, as well as fluid inclusions with organic substances, have been described also. Pronounced growth phenomena are common in Colombian emeralds: growth bands, colour- and inclusion-zoning, growth inhomogeneities with a treacle-like appearance. The Colombian emeralds from the Cordillera Oriental are characterized by low to medium constants for the optical data ($n_o < 1.585$, n_o-$n_e < 0.007$). Typical absorption features of Colombian emeralds are Cr-V spectra, which may show varying Cr/V-intensity ratios. The chemical fingerprints of the Colombian emeralds are characterised by practically equal concentration ranges for the colouring elements chromium and vanadium. Besides this, the Colombian emeralds show lower values for Fe, Mg and Na than those observed in most emeralds from mafic-ultramafic rocks (*Figure* 4).

Category 5

Category 5 comprises the emerald mineralizations of the Kaduna-Plateau states in central Nigeria. They are the so-called 'granite cupola-type'.

Emerald mineralizations are associated with granitic pegmatites of two periods of magmatism (Schwarz *et al.*, 1996): the Panafrican orogeny (600-450 Ma) and the Mesozoic orogeny (190-144 Ma) with the intrusion of alkaline granites belonging to ring complexes which contain important Sn-Nb-Ta-Zn mineralizations (Kinnaird, 1984). In the older pegmatites, emerald is associated with aquamarine, beryl and tourmaline. In the younger granites, emerald is found with quartz, blue topaz and beryl (aquamarine) in pegmatitic pods with biotite and alkaline-feldspar granites. The pods are found in the roof zone of the intrusions and in the margins of the granite cupolas. They are not affected by metasomatism, and emerald formed during late magmatic and early hydrothermal stages. Emeralds from the Kaduna-Plateau states show a rather 'exotic' inclusion mineral association: Fe-Li-rich mica (probably annite-siderophyllite) + albite + K-feldspar + tourmaline + beryl/emerald + quartz + ilmenite + monazite + fluorite + ralstonite + boldyrevite (Schwarz *et al.*, 1996). Fluid inclusions are frequent and present a large variation of phase-combinations (including 'slg'-three-phase inclusions, which show an appearance that is practically identical to that known from the 'classic' Colombian fluid inclusions). Most emeralds from central Nigeria display distinct growth phenomena (growth-bands and -planes; colour-zoning). The Nigerian emeralds distinguish themselves by the lowest optical data observed in emeralds: $n_o < 1.576$, n_o-n_e normally 0.005-0.006. The absorption spectra of the Nigerian emeralds are considered a 'mixed type' consisting of the combination of Cr-Fe emerald spectra with Fe^{2+}-Fe^{3+} aquamarine spectra.

The most striking chemical features of the Nigerian emeralds are extremely low sodium and magnesium contents (compare *Figure* 3).

Materials and methods

The first attempt to classify emeralds according to their geological environments, using ANN is exclusively based on chemical data (contents of minor and trace elements;

Schwarz, 1990; 1991 a,b; 1992 a,b). In the future, it is certainly of interest to include additional data obtained by microscopic and spectrometric techniques. Factors like specific gravity, isotope ratios, nature and aspect of inclusions, or even subjective impressions of the observer (colour, beauty, etc.) could be taken into consideration. A larger volume of data will improve the accuracy of the prediction. Emerald, as a variety of the beryl group, has the general chemical formula $Be_3Al_2Si_6O_{18}$. The oxide concentrations that correspond to this 'ideal' composition are SiO_2 67.07 wt%, Al_2O_3 18.97 wt%, and BeO 13.96 wt%. It has been known for a long time, however, that only in rare cases natural beryls come close to this standard composition. In general, they show

***Table I:** Emerald samples used for ANN processing.*

Continent	*Country*	*Category*	*Code*	*Mine/Area*	*No. of samples*
Africa:	Zambia	1	SAM	(1) Miku-Kafubu	21
	Mozambique	1	MOC	(2) Alto Ligonha	12
	South Africa	1	COB	(3) Cobra Mine	14
	Nigeria	5	NIG	(4) Kaduna/Plateau	13
	Madagascar	1	MAD	(5) Mananjary	16
Asia:	Russia	1	URA	(6) Urals	25
	Afghanistan	3	AFG	(7) Panjsher	31
	Pakistan	3	PAK	(8) Mingora-Swat	41
South America:	Brazil	2	STA	(9) Santa Terezinha	29
		1	CAR	(10) Carnaiba	30
		1	SOC	(11) Socotó	39
		1	ITA	(12) Itabira (Belmont)	39
		1	CAP	(13) Itabira (Capoeirana)	16
		2	IAI	(14) Itaberaí	13
	Colombia	4	YAC	(15) Yacopi	11
		4	CHI	(16) Chivor	17
		4	GAC	(17) Gachalá	8
		4	MUZ	(18) Muzo	20
		4	COS	(19) Coscuez	7
		4	'COL'	(20) 'Cordillera Oriental'	56

Table II

Type	*Training*	*Validation*	*Total*
Non-Colombian NC	2/230 (0.9%)	5/109 (4.6%)	7/339 (2.1%)
Colombian (Category 4)	2/79 (2.5%)	3/40 (7.5%)	5/119 (4.2%)
Total	4/309 (1.3%)	8/149 (5.4%)	12/458 (2.6%)

distinct deviations (a well-known behaviour observed in many minerals). These discrepancies go back to the fact that major components may be substituted by extraneous elements of similar ionic radius (that do not appear in the chemical formula). In the case of emerald, these 'extraneous' elements are mainly magnesium, sodium and, of course, the colouring agents chromium, vanadium and iron. Therefore, the discussion of the chemical characteristics of the beryl variety emerald can be restricted, initially, to these five elements. But in view of geochemical/genetic considerations, it is certainly of interest to include trace elements such as Mn, Ca, K, Ti and Sc.

The microprobe analyses were carried out using an ARL-SEMQ instrument, with wavelength dispersive (WD) spectrometers and an energy dispersive system (EDS, TN2000). The beam diameter was 2 microns, accelerating voltage was 15 kV and specimen current 30 mA. Standards used for the analyses comprised synthetic oxides and some simple silicate minerals. Lighter elements, such as Be or Li, cannot be analysed with the microprobe and were not taken into consideration. Chemical compositions are expressed as wt% of the oxides of Si, Al, Mg, Na, Fe, Cr, V, Mn, Ca, K and Ti. For this study we examined 458 natural emeralds from very different origins chosen to represent the most important commercial sources. Country of origin, mining areas and the number of samples analysed for each mine, as well as reference/category numbers and codes for the mines, are given in *Table I*. Several mines/areas in the original data bank, containing less than 10 samples (e.g. Sandawana/Zimbabwe) were discarded, as training a system with less than 10 samples from the same mining area is considered as non-valid.

Results

In a first exploratory step, an ANN composed of 11 data inputs (corresponding to the chemical components expressed as oxide percent), 20 neurons in the hidden layer and 20 neurons in the output layer (the 20 different mines/areas reported in *Table I*) was used in the unsupervised mode. Approximately two-thirds of the data of each mine/area were used for training the network, and one third for validation of the training. It becomes immediately evident that most Colombian samples (Category 4) were correctly classified in their category and very few non-Colombian samples (NC) were classified in the Colombian category. This suggests that Colombian emeralds would be quickly and successfully separated from non-Colombian emeralds, and the full set of data was presented to ANN of the type 11-20-2 in the supervised mode in order to check the possibility of separation between Colombian and non-Colombian emeralds. The value of the neurons of the output layer makes the decision 'Colombian or non-Colombian origin'. Again, about two-thirds of the samples (332) were used for training and about one third (160) were used for the validation of the network. Several trials were

Table III

Category	*Mine/Area*	*Training*	*Validation*	*Total*
1	1, 2, 3, 5, 6, 10, 11, 12, 13	1/144 (1%)	1/68 (1%)	2/212 (1%)
2	9, 14	1/30 (3%)	2/12 (17%)	3/42 (7%)
3	7, 8	7/47 (15%)	2/25 (8%)	9/72 (12.5%)
5	4	0/9 (0%)	0/4 (0%)	0/13 (0%)
Total:		9/230 (4%)	5/109 (5%)	12/468 (3%)

used in order to find the best training systems. Up to 30.000 epochs (or iterations) were used to train the system. Results are given in *Table II* in terms of bad scores (= misclassifications). Only four out of the 309 samples were not correctly classified in the training step, and eight out of 149 samples were not correctly classified in the validation process. These results show that, after training, the network can be used with a reasonably good degree of confidence to separate Colombian and non-Colombian emeralds.

In a further step, those non-Colombian mines/areas containing at least ten samples were used as input of another ANN, in order to attempt a supervised classification into four categories, based on the first ANN study and on geological-mineralogical criteria. These categories 1, 2, 3, 5 are defined in *Table III*. The ANN used in this step was of the type 11-10-4, where the four neurons in the output layer represent the four categories. Up to 30.000 epochs were used in training the system on a total of 230 samples. Validation was tested on the remaining 109 samples. *Table III* presents the results expressed, as usual, in terms of bad scores.

Discussion

Classification for samples belonging to Categories 1 and 5 in *Table III* is very good with bad scores 1% and 0% respectively. As mentioned above, Category 1 contains emerald deposits which are related to granitic pegmatite intrusions and hyrothermal veins in mafic-ultramafic rocks. The geological environment is very similar for most of these deposits (e.g. the nature of the emerald host-rocks or the nature of the emerald-forming fluids). Consequently, emeralds originating from these deposits show properties which, in most cases, are very similar to each other. It is difficult, and in many cases not possible, to separate emeralds coming from some of these occurrences (e.g. emeralds from Madagascar and Zambia). On the other hand, however, ANN has shown that the separation of Category 1 emeralds from representatives of the other categories is very good.

Category 5 emeralds originate from a unique geological environment in the Nigerian Kaduna-Plateau states ('granite cupola-type'). This results in the appearance of a locality-specific combination of mineralogical properties which distinguishes them from emeralds of all other deposits (see also Schwarz *et al.*, 1996.)

The ANN classification for samples of Category 2 is acceptable (bad scores 7%). Category 2 emeralds considered in the ANN-procedure of this study originate from the Santa Terezinha mining field and from the Itaberaí deposit, both located in the Brazilian Goias state. They are related to tectonism: thrusts, shear-zones, faults in mafic-ultramafic rocks. Santa Terezinha and Itaberaí emeralds show combined high sodium and magnesium concentrations. The Na-contents in Itaberaí emeralds are among the highest observed in emeralds from any source.

In contrast to the former categories, the allocation for samples belonging to Category 3 is rather poor (bad scores 12.5%). Considering, however, the geological background of the representatives in this category, this behaviour becomes perfectly understandable. The members of Category 3 (Swat Valley in Pakistan and Panjsher Valley in Afghanistan) are both found in oceanic suture zones. However, their mineralogical properties (especially their chemical compositions) show some significant differences. The Pakistani emeralds from the Swat region always have high values for magnesium and sodium, the variation range for these elements is only small. On the other hand, the Panjsher emeralds show large concentration ranges for magnesium and sodium. The different chemical features for emeralds from these two deposits becomes quite evident in the correlation diagram shown in *Figure 4*. Emeralds from the Swat Valley are found in a (Fe+Mg)-rich environment (talc-carbonate-mica schists). They show distinctly higher foreign element contents and higher optical data than their Afghani counterparts, which originate from quartz-ankerite-pyrite veins. As can be expected, all this results in a 'classification quality' for the Category 3 which is distinctly lower than that found for the categories 1, 2 and 5.

Conclusions

Artificial neuron networks (ANN) using only chemical data appear to be a rather effective tool for determining the origin of emeralds. It is well-known that the geological environment of a mineral will be reflected by its chemical characteristics, especially by the minor and trace element contents. Many classification studies based on bi- or tri-dimensional correlations have been reported in the literature. The main advantage of the ANN technique is that the entire element signature is taken in a single operation. Another major advantage of the ANN technique is, in contrast to other previously reported techniques, the non-linear behaviour of the method. A major disadvantage is that ANN are 'black boxes', as there is currently no simple way of interpreting the set of weights in the trained systems. This indicates that ANN could be very dangerous. At the present stage of development, ANN should never be used exclusively, but should be used in conjunction with traditional methods. Use of ANN should be considered as a useful supplement to standard gemmological techniques.

The accuracy of ANN could be greatly improved by taking into account more of the same and of different kinds of data, collected by other techniques, such as: refractive indices/birefringence, spectrometric data, inclusion types, and isotope ratios. Research in these directions will continue on other series including larger numbers of samples and more data per sample. Other methods, known as 'data mining' will also be used to reveal any relationships between sets of samples.

Acknowledgements

We would like to thank Mr George Bosshart of Gübelin Gem Lab for reviewing the paper and for constructive discussion.

References

Banks, D.A., Yardley, B.W.D., Giuliani, G., Cheilletz, A., and Rueda, E., 1995. Chemistry and source of the high-temperature brines in the Colombian emerald deposits. In: Pasava, J., Kribek, B. and Zak, K. (eds.), *Mineral deposits: From their origin to their environmental impacts:* Prague, August 28-31, SGA Meeting on Mineral Deposits, p. 557-60

Barros, J.C., Riehl, W.J., and Morais Vasconcelos, F. de, 1990. Esmeraldas e berilos verdes da mina dos Caiados, Fazenda das Lajes, Itaberai, GO. Congr. Bras. Geol. XXXVI, Natal/RN. In Anais: Congresso Brasileiro de Geologia, Goiania. 1403-13

Biondi, J.C., 1990. Depósitos de esmeralda de Santa Terezinha (GO). *Revista Brasileira de Geociencias*, **20**(1-4), 7-24

Cheilletz, A., Féraud, G., Giuliani, G., and Rodriguez, C.T., 1994. Time-pressure-temperature constraints on the formation of Colombian emeralds: A 40 Ar/39 Ar laser-probe and fluid inclusion study. *Econ. Geol.*, **89**, 362-80

Cheilletz, A., and Giuliani, G., 1996. The genesis of Colombian emeralds: A restatement. *Miner. Depos.*, **31**, 359-64

Dilles, J.H., Snee, I.W., and Laurs, B.M., 1994. Geology, Ar-Ar age and stable isotopes geochemistry of suture related emerald mineralization, Swat, Pakistan, Himalayas. In: Geological Society of America, Annual Meeting, Seattle, USA. *Abstracts*, **26** (7), A-311

Giuliani, G., Silva, L.J.H.D., and Couto, P., 1990a. Origin of emerald deposits of Brazil. *Miner. Depos.*, **25**, 57-64

Giuliani G., Rodriguez, C.T., and Rueda, F., 1990b. Les gisements d'émeraude de la Cordillere Orientale de la Colombie: nouvelles données métallogéniques. *Mineral. Deposita* **25**, 105-11

Giuliani, G., Sheppard, S.M.F., Cheilletz, A., and Rodriguez, C.T., 1992. Fluid inclusions and $^{18}O/^{16}O$, $^{13}C/^{12}C$ isotope geochemistry: Contribution to the genesis of emerald deposits from the Oriental Cordillera of Colombia. *Comptes Rendus Acad. Sci.* (Paris), **314**, 269-74

Gusmão Costa, S.A. de, 1986. Correlacâo da sequência encaixante das esmeraldas de Santa Terezinha de Goiás com os terrenos do tipo Greenstone Belt de Crixás e tipologia dos depósitos. XXXIV Congresso Brasileiro de Geologia, Goiania. In: Anais: Congresso Brasileiro de Geologia, Goiania. V.2:597-614

Kazmi, A.H., and Snee, L.W., 1989. *Emeralds of Pakistan.* Van Nostrand Reinhold Company

Kinnaird, J.A., 1984. Hydrothermal alteration and mineralization of the alkaline anorogenic ring complexes of Nigeria. *Journal of African Earth* Sciences, **3**(1/2), 229-51

Kozlowski, A., Metz, P., and Jaramillo, J.H.A., 1988. Emeralds from Somondoco, Colombia: chemical composition, fluid inclusions and origin. *Neues Jahrbuch Mineralogie. Abhandlungen,* **159**(1), 23-49

Ottaway, T., 1991. The geochemistry of the Muzo emerald deposit, Colombia. Master of Science Thesis. University of Toronto, Canada

Ottaway, T.L., Wicks, F.J., Bryndzia, L.T., Kyser, T.K., and Spooner, E.T.C., 1994. Formation of the Muzo hydrothermal deposit in Colombia. *Nature*, **369**, 552-4

Schwarz, D., 1990a. Die brasilianischen Smaragde und ihre Vorkommen: Santa Terezinha de Goiás/GO. *Z. Dt. Gemmol. Ges.*, **39**(1), 13-44

Schwarz, D., 1990b. Die chemischen Eigenschaften der Smaragde. I. Brasilien. *Z. Dt. Gemmol. Ges.,* **39**(4), 233-72

Schwarz, D. 1991a. Die chemischen Eigenschaften der Smaragde. II. Australien und Norwegen. *Z. Dt. Gemmol. Ges.*, **40** (1), 39-66

Schwarz, D., 1991b. Die chemischen Eigenschaften der Smaragde. III. Habachtal/Osterreich und Uralgebirge/UdSSR. *Z. Dt. Gemmol. Ges.,* **40**(1), 103-43

Schwarz, D., 1992a. Die chemischen Eigenschaften der Smaragade. IV. Kolumbien. *Z. Dt. Gemmol. Ges.*, **41**(1), 29-47

Schwarz, D., 1992b. The chemical properties of Colombian emeralds. *J. Gemm.,* **23**(4), 225-33

Schwarz, D., 1994. Emeralds from the Mananjary region, Madagascar: internal features. *Gems & Gemology,* **30**(2), 88-101

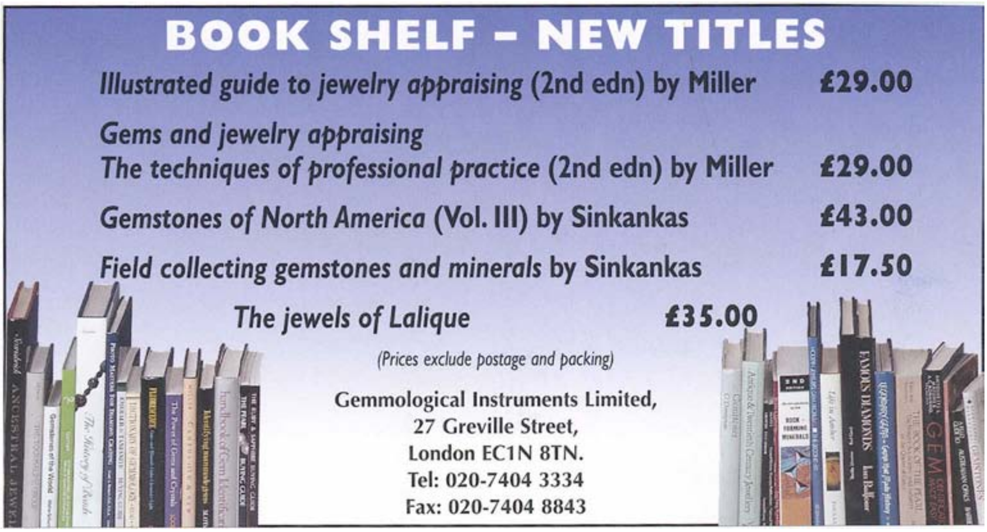
Schwarz, D., Kanis, J., and Kinnaird, J., 1996. Emerald and green beryl from Central Nigeria. *J. Gemm.,* **25**(2), 117-41

Schwarz, D., and Giuliani, G., 2000. Emerald deposits. A review. 31st International Geological Congress, Rio de Janeiro, Brazil. Abstracts Volume

Schwarz, D., and Stern, W., 2000. Chemical fingerprinting as a tool for the characterization of gemstones. 31st International Geological Congress, Rio de Janeiro, Brazil. 2000

Schwarz, D., Schmetzer, K., and Giuliani, G., Emeralds: Chemical and spectrometric characteristics - a review. *Gems & Gemology* (accepted for publication)

Schwarz, D., Giuliani, G., and Zachovay, M. Emeralds: Mineral inclusions and other internal characteristics - a review. *Gems & Gemology* (accepted for publication)



Abstracts

Diamonds
Instruments and Techniques
Gems and Minerals
Synthetics and Simulants

Diamonds

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 185-90.

A 3.07 ct so-called chameleon diamond was submitted for investigation. The stone temporarily became yellow when heated, but returned to its original colour when removed from the heat (an alcohol flame) and exposed to light. Strong orange-yellow fluorescence and phosphorescence.

A 2.41 ct green irradiated diamond was examined and showed a radioactivity approximately twenty times above environmental radiation levels. Stones like these are unsafe to be worn. The radioactivity can be removed by repolishing or acid treatment. E.S.

Magnetic properties of polycrystalline diamonds.

D.W. Collinson. *Earth and Planetary Science Letters*, **161**(1-4), 1998, 179-88.

The remanent magnetism and bulk magnetic properties of two types of polycrystalline diamonds, those occurring with gem-grade diamonds in kimberlite pipes in S Africa, and carbonados in placer deposits in Brazil and the Central African Republic, were investigated. Both types possess measurable remanent magnetization, that of kimberlite diamonds being greater than that of carbonados, and stability tests show the presence of primary and secondary components. Magnetite is the dominant carrier of NRM in the kimberlite diamonds, but very small magnetic mineral content in the carbonados makes carrier identification difficult, possible contributors being tetrataenite, native Fe and cohenite. Anomalous acquisition of isothermal remanence occurs in some carbonados, saturation being unachievable in applied fields > 1 T. The ratio of saturation remanence to initial NRM is anomalously low in some of the kimberlite diamonds, and the possibility of magnetic contamination is investigated. J.F.

Diamonds from Wellington, NSW: insights into the origin of eastern Australian diamonds.

R.M. Davis, S.Y. O'Reilly and W.L. Griffin. *Mineralogical Magazine*, **63**(4), 1999, pp 447-71.

Diamonds (~0.17 ct) from alluvial deposits near Wellington, New South Wales, have been characterized on the basis of their morphology, mineral inclusions, $d^{13}C$ values, N content and aggregation state, and internal structure. The diamonds are of two types. The larger group (group A) is indistinguishable from diamonds found worldwide from kimberlitic and lamproitic host rocks. This group is inferred to have formed in a peridotitic mantle source in Precambrian subcratonic lithosphere. The second group (group B) has unique internal structures which show evidence of growth in a stress field, non-planar facets, unusually heavy $\delta^{13}C$ values, and contains Ca-rich eclogitic inclusions. This group is inferred to have formed in a subducting slab. Diamonds of both groups have external features (corrosion structures and polish) indicating transport to the surface by lamproitic-like magmas. The diamonds show evidence of long residence at the Earth's surface and significant reworking, they are not accompanied by typical diamond indicator minerals. R.A.H.

Microstructural observations of polycrystalline diamond: a contribution to the carbonado conundrum.

S. De, P.J. Heaney, R.B. Hargraves, E.P. Vicenzi and P.T. Taylor. *Earth and Planetary Science Letters*, **164**(3-4), 1998, 421-33.

A microstructural analysis of systematic defects and inclusions in carbonados from Brazil and the Central African Republic (CAR) is reported. TEM shows pervasive defect lamellae, in both CAR and Brazilian carbonados, that are distinct from planar defects observed in synthetic polycrystalline diamond (PCD). EDS analyses of included minerals imply the presence of metallic Fe, Ti and Si, and SiC and Fe-Cr alloys within the diamond matrix: inclusions of the phosphates florencite-goyazite and rhabdophane are also recorded. Results show a close

Abstractors

J. Flinders	J.F.	M. O'Donoghue	M.O'D.	I. Sunagawa	I.S.
R.K. Harrison	R.K.H.	P.G. Read	P.G.R.	P.M. Whelan	P.M.W.
R.A. Howie	R.A.H.	E. Stern	E.S.		

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

ISSN: 1355-4565

genetic relationship between Brazilian and Central African carbonados, suggesting formation within a united landmass during the late Archaean, although the data do not preclude formation by meteorite impact. J.F.

Evidence of fluid inclusions in metamorphic microdiamonds from the Kokchetav massif, northern Kazakhstan.

K. De Corte, P. Cartigny, V.S. Shatsky, N.V. Sobolev and M. Javoy. *Geochimica et Cosmochimica Acta.* **62**(23-4), 1998, 3765-73.

Three fundamentally different models for the formation of micro-diamonds discovered *in situ* in ultra-high pressure metamorphic rocks (UHPM) are briefly discussed, and assessed by further Fourier transform IR spectroscopy which provides information on all the volatile and substutional impurities, particularly N_2. All diamonds have high N_2 contents (4488 ± 20% at. ppm) and are of Ib-Ia A type; the N_2 data are consistent with diamond formation over a narrow T range. The presence of H_2O and carbonate inclusions in the diamonds from garnet clinopyroxenites suggests formation from a C-O-H-bearing fluid. The micro-diamonds are compared to alluvial diamonds from the northern part of the Kokchetav massif; these do not contain carbonate inclusions, show less or no H_2O absorption and have higher N_2 contents than the diamonds from the clinopyroxenites and probably derive from a different host rock. The new study supports a metamorphic origin for the micro UHPM rocks of this massif. R.K.H.

Types, abundances and distribution of kimberlite indicator minerals in alluvial sediments, Wawa-Kinniwabi Lake area, northeastern Ontario: implications for the presence of diamond-bearing kimberlite.

T.F. Morris, D. Crabtree, R.P. Sage and S.A. Averill. *Journal of Geochemical Exploration,* **63**(3), 1998, 217-35.

In response to the discovery of diamonds within modern alluvium in the glaciated area of Wawa, the Ontario Geological Survey carried out a regional programme of surficial mapping and alluvial sediment sampling to assess the potential of the area for diamond-bearing kimberlite. Five kimberlite-derived indicator minerals were recovered, and the compositions of three were evaluated resulting in identification of G10 Cr-pyrope garnet, inclusion field chromite and Mg-ilmenite. The distribution of indicator minerals was examined in relation to the glacial and bedrock geology. Glacial dispersal for non-kimberlitic marker units is restricted (commonly <200 m), and many kimberlite indicator minerals were recovered from samples collected close to cross-cutting faults, and from a strong trend in the bedrock associated with the Kapuskasing structural zone. The results of this survey have provided several potential exploration targets for diamond-bearing kimberlite. J.F.

Compositional study of spinels from Wajrakarur pipe-10 (Anumpalle), Anathapur district and its significance in diamond prospectivity.

A. Mukherjee, K.S. Rao, E.V.S.S.K. Babu and G. Roy. *Journal of the Geological Society of India,* **52**(6), 1998, 677-82.

Spinels from the recently-discovered Wajrakarur pipe-10, Southern India, were analysed, and Q-cluster analysis based on Cr_2O_3, Al_2O_3, TiO_2 and MgO contents indicates the presence of S1, S3, S4, S5 and S10 groups. S1 group spinels are considered to be cogenetic with diamond; they are stable in the mantle within the P-T regime under which diamonds are known to form experimentally. A plot of Cr/(Cr + Al) *vs* Fe/(Fe + Mg) shows that some spinels are from the field of diamond inclusion chromites. This study suggests that the Anumpalle pipe is probably diamondiferous. J.F.

A petrographic and $^{40}Ar/^{39}Ar$ geochronological study of the Voorspoed kimberlite, South Africa: implications for the origin of group II kimberlite magmatism.

D. Phillips, K.J. Machin, G.B. Kiviets, L.F. Fourie, M.A. Roberts and E.M.W. Skinner. *South African Journal of Geology,* **101**(4), 1998, 299-306.

The Voorspoed kimberlite pipe, one of a cluster of 11 kimberlite and related rock intrusives north of Kroonstad, comprises tuffisitic kimberlite breccia and is associated with several hypabyssal sills and dykes. Recent drilling has identified two types of tuffisitic kimberlite breccia and seven varieties of hypabyssal-facies kimberlite. The Voorspoed kimberlite lies between the ~ 120 m.y. Barkly West and ~ 145 m.y. Swartruggens kimberlites. An accurate determination of intrusion age is crucial to evaluation of the group II age progression across southern Africa and models of the origin of group II magmatism. $^{40}Ar/^{39}Ar$ laser probe analyses on six individual groundmass phlogopite grains from an hypabyssal kimberlite autolith all yielded reproducible plateau ages with a mean of 131.8 ± 1.7 m.y. Intra- and inter-grain reproducibility of the data indicates that this age is a reliable estimate for the time of pipe emplacement, and also agrees with recent data from the nearby Lace and Besterskraal kimberlites. These results confirm the regular NE age progression of group II kimberlites across the Kaapvaal craton. Previously models invoking hotspot tracks, subduction of ocean crust, and rafting of the subcontinent over an oceanic lithosphere megalith have been suggested to account for the distribution of group II kimberlites. An alternative model, involving extensional tectonics related to disaggregation of Gondwanaland, is considered here. J.F.

The significance of eclogite and Cr-poor megacryst garnets in diamond exploration.

D.J. Schulze. *Exploration & Mining Geology.* **6**(4), 1997, 349-66.

Whilst eclogite is an important source of diamond in the upper mantle, it is more localised than peridotite, and using eclogitic minerals in kimberlite and diamond exploration is also more problematic than using the well-known peridotite-derived indicator minerals Cr-pyrope and magnesio-chromite. Problems occur with colour similarities of orange garnets from eclogites, Cr-poor megacryst suite garnets (especially increased Na_2O contents), and low abundance of eclogite garnet xenocrysts in most kimberlites. Varieties of orange garnets in exploration samples can be distinguished by their FeO contents, crustal origin having > 22 wt.%, mantle origin having less. Na_2O-bearing garnets from the Cr-poor megacryst suite have higher TiO_2 contents than Na_2O-bearing garnets from diamondiferous eclogites. However, low abundance of eclogite garnet xenocrysts in kimberlites worldwide may dictate that use of eclogite garnets in diamond exploration is restricted to advanced stages of kimberlite exploration and evaluation of kimberlite diamond potential. Cr-pyropes, Mg-ilmenites and Cr-rich chromites are more useful than eclogitic garnets in most stages of diamond exploration. If orange garnet xenocrysts are sought in a kimberlite exploration programme, those from the Cr-poor megacryst suite will be more useful than eclogite-derived garnets because of their typically greater abundance, although they carry no information of the diamond potential of the host kimberlite. New EPMA results are tabulated for 393 Cr-poor garnet megacrysts. J.F.

Gems and Minerals

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 121-7, 12 photographs.

Amongst specimens discussed are a high clarity, olive-green peridot from Eritrea; red tourmaline from Luc Yen, Vietnam, a locality well-known for its corundum deposits; treated stones include dyed rubies, very often to be found amongst cracked specimens which are then sealed with glass and dyed at the same time, some diffusion-treated sapphires where the colour is to be found near the surface; rock crystal clusters as well as faceted rock crystal stones are coloured with a thin layer, producing a rainbow effect. E.S.

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, 48(4), 1999, 185-90.

Notes include star sapphires from Australia; also from Australia an opal with two-phase inclusions. From Sri Lanka some low radioactive green zircons. E.S.

The Zapot pegmatite, Mineral County.

E.E. Foord, A.E. Soregaroli and H.M. Gordon. *Mineralogical Record*, **30**, 1999, 277-92.

The Zapot pegmatite is located in the Gillis Range, north-east of Hawthorne, Nevada, USA. Narrow veins and dikes make up the bulk of pegmatites and some amazonite, smoky quartz and topaz of fashioning-size are described and illustrated together with other species found in the area. M. O'D.

Characterisation of emeralds from the Delbegetey deposit, Kazakhstan.

E.V. Gavrilenko and B. Calvo Pérez. *MDSTAN*, 1999, 1097-1100.

A study of the properties and composition of 12 samples of emeralds and green beryls from the Delbegetey deposit is reported and comparisons are made with emeralds from elsewhere in the world and with synthetic emeralds. The Delbegetey emeralds have a strong bluish green hue, with ε 1.558–1.562, ω 1.566–1.570; D 2.65 g/cm^3; a 9.218, c 9.201 Å, V677.1 Å^3. Averaged EPMA values for 11 emeralds are tabulated; Cr_2O_3 ranges 0.02–1.23 and V_2O_3 0.01–0.19 wt.%; Na, Mg and Fe are low. Primary fluid inclusions have unusual liquid: vapour ratios of 50:50 to 90:10. A.H.

Behandlung von Edelsteinen und ihrer Farbe.

T. Häger. *Aufschluss*, **50**, 349-52, 1999, illus. in colour.

Defines the essential nature of a gemstone with particular reference to colour, including artificial coloration. M.O'D.

Ruby from Tunduru-Songea, East Africa – some basic observations.

G. Hamid, S.M.B. Kelly and G. Brown. *Australian Gemmologist*, **20**(8), 1999, 326-30, 16 illus. in colour, 1 map.

The authors describe some preliminary observations, including gemmological properties and morphological features, made on representative specimens of ruby from the river gravels of the Tunduru-Songea area of Southern Tanzania. Most, but not all, of these 'hot' pink, purplish-red and red corundums marketed in Bangkok appear to have been heat treated to improve their colour and clarity. P.G.R.

Gemmologische Kurzinformationen.

U. Henn. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 165-8, 3 photographs, 1 diagram, bibl.

A Colombian trapiche emerald was identified as treated. The relatively broad dark area between the six emerald sectors surrounding the hexagonal emerald core consisted of a fine-grained substance with a resin as a stabilizer. E.S.

Saphire aus einem neuen Vorkommen im Südwesten von Madagaskar.

U. Henn, C.C. Milisenda and J. Henn. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 201-10, 1 map, 10 photographs, 2 graphs, bibl.

The new occurrences were discovered in 1998. The secondary deposits extend from the south of the Isalo National Park near Ranohira to the town of Sakaraha further west. The mines produce pink, blue, violet, yellow, orange, green, brownish and colourless corundum, spinel, chrysoberyl (including cat's-eyes and alexandrite), aquamarine, tourmaline, zircon, topaz and garnet. Commercially the most important are the blue and pink sapphires, which are sold as rough to Sri Lankan and Thai dealers, and then thermally enhanced to improve colour and clarity. The gemmological properties of the fancy sapphires are similar to those found in the Umba Valley and Tunduru in Tanzania, whereas the blue sapphires are reminiscent of Sri Lankan sapphires. The properties and geological environment are so similar to the alluvial deposits of Sri Lanka and Tanzania that it suggests the idea that they were formed in a single land mass before the break up of Gondwana. E.S.

Die Edelsteinvorkommen Madagaskars.

U. Henn, C.C. Milisenda and E. Petsch. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 191-200, 2 maps, 4 photographs, 2 tables, bibl.

The article describes the large variety of gemstones found in Madagascar and their occurrences, especially beryls (particularly emeralds and aquamarines), tourmalines, quartzes, garnets, feldspars and recently also sapphires. The sapphires are mainly blue or a very fine pink. E.S.

Prevalence and origin of birefringence in 48 garnets from the pyrope-amandine-grossularite-spessartine quaternary.

A.M. Hofmeister, R.B. Schaal, K.R. Campbell, S.L. Berry and T.J. Fagan. *American Mineralogist*, **83**(11–12 Part 1), 1998, 1293-1301.

Weak and undulatory birefringence is ubiquitous throughout a large suite of pyralspites (i.e. garnet solid solutions within the Py-Al-Sp ternary) and quaternary garnets. Birefringence (δ) correlates poorly with the diameter of the garnet crystals, but positively, albeit weakly, with Ca^{2+} coexisting with Mg^{2+}. Overall the undulatory nature of the birefringence suggests that most optical anomalies in quaternary garnets originate through residual strain. P.M.W.

A personal critique of 'Modeling the appearance of the round brilliant cut diamond: An analysis of brilliance', Gems & Gemology, vol. 34, Fall 1998, pp 158-83.

G. Holloway. *Australian Gemmologist*, **20**(8), 1999, 331-5, 338-9, 3 illus.

The computer analysis study of the brilliant cut diamond by T.S. Hemphill *et al.*, which appeared in the Fall 1998 issue of *Gems & Gemology* focused on brilliance as the main factor of diamond appearance. However, the GIA authors concluded that the study should be extended to encompass 'fire' and scintillation (and probably symmetry deviations and colour) as 'any cut grading assessment devised in the absence of this broader picture is premature'.

The critique presents a possible solution, discovered by the author a decade ago, which he believes is supported by data provided in the GIA study. This solution includes a 2:1 relationship between the ideal crown and pavilion angles, in contrast to the GIA 2.5:1 relationship, and a suggestion that assumptions concerning 'leakage' and lighting could be challenged. The critique has been presented to the authors of the GIA paper, and is aimed at provoking collaboration for establishing a standard for cut. Readers are invited to participate in an open website discussion at **diamond-cut.com.au.** P.G.R.

Die Entstehung der Farben in Achaten.

G. Lenz. *Aufschluss*, **50**, 343-8, 1999, illus. in colour.

Discusses the formation and coloration of agate with reference to the mechanisms by which colour arises. M.O'D.

Schatzkammer Alpen: Alpine Edelsteine (1).

W. Lergier and S. Weiss. *Lapis*, **24**(12), 13-20, 1999, illus. in colour, 2 maps.

Locations and types of deposit are given for versuvianite, cordierite and ruby from the European Alps. Most specimens are translucent to opaque. Details and illustrations of gem-set jewellery are given. M.O'D.

Brothers corundum: sapphires in Sri Lanka.

M.M.M. Mahroof. *Australian Gemmologist*, **20**(8), 1999, 321-5.

A history of gemstone mining, cutting and trading in Sri Lanka with particular reference to the sapphire variety of corundum and the treatment of geuda material. P.G.R.

Les septarias de la région d'Orpierre, Hautes-Alpes (F), décadence de leurs minéraux.

R. Martin. *Schweizer Strahler*, **11**, 1999, 509-25. In French and German, illus. in colour.

Fine examples of quartz septarian nodules are reported and described from the Orpierre region of Hautes-Alpes, France. Details of their formation and of the morphology of some individually-occurring crystals are given. M.O'D.

Spessartine aus Nigeria.

C.C. Milisenda and J. Zang. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 223-6, 4 photographs, diagram, table, bibl.

The spessartine garnets are reported to come from an area near Iseyin, north-west of Ibadan in Western Nigeria and resemble the Mandarin garnets from Namibia. Most specimens were rounded crystal fragments, but occasionally there were well-developed crystals up to a diameter of 2 cm. RI 1.801 to 1.803; SG 4.18–4.23. E.S.

The visible absorption spectroscopy of emeralds from different deposits.

I.I. Moroz, M.L. Roth and V.B. Deich. *Australian Gemmologist*, **20**(8), 1999, 315-20, illus, 3 graphs, 1 table.

Rough and faceted emeralds from eleven gem mining areas were studied in the visible absorption region using Perkin Elmer Lambda 15 and Bausch & Lomb Spectronic 2000 spectrophotometers. Emeralds included in the study came from deposits in Afghanistan, Australia, Brazil, Colombia, Nigeria, Mozambique, Russia, Tanzania and Zambia. The absorption spectra of many of the emeralds exhibited a 'mixed type' absorption pattern that was related to an emerald component (Cr^{3+} and/or V^{3+}) and an aquamarine component (Fe^{2+} and Fe^{2+}/Fe^{3+}). However, the relative intensities of chromium and iron bands differed for emeralds from different deposits. When emeralds from the same mining region were examined their optical spectra were found to be identical. As a result of this research it has been possible to classify the emeralds studied into three groups based on the relative intensity or absence of the 810 nm band, and to show that visible absorption spectroscopy is a valuable tool for characterizing emerald and for allowing emeralds from differing sources to be identified. P.G.R.

Business and industry review: gemstones.

M. O'Donoghue. *Britannica book of the year 1999*, **168**, 1999.

A decline in world gemstone trading was due largely to the downturn in Far Eastern economies with resulting lowered consumer spending. By 1998 the downward trend, though not yet reversed, was flattening out: more than one kind of confused situation in Russia seemed likely to affect the German gemstone trade. Strict controls were imposed on gem mining in Tanzania where the Tunduru deposit had been producing fine blue and fancy-coloured sapphires as well as pink and orange spinel and some alexandrite, colour-change garnet and mint-green chrysoberyl. Fine blue tourmaline coloured by copper was found in the Brazilian state Rio Grande do Norte and Madagascar was beginning to re-assert its importance as a source of fine blue sapphire. Synthetic moissanite was a diamond simulant perhaps likely to cause difficulties in the diamond trade. The major salerooms world-wide reported good results, the Hong Kong jadeite sales being especially successful. M.O'D.

Selvino e Zogno: quarzo e fluorite.

F. Pezzotta. *Rivista Mineralogica Italiana*, **23**, 1999, 146-56.

Describes large ornamental-quality crystals of quartz and fluorite found between the valleys of Seriana and Brembana, Bergamo Province, Italy. Fluorite may occur as interpenetrating green or purple twins while rock crystal in sceptre form is reported. M.O'D.

Tränen aus Glas.

C. Pinter. *Lapis*, **24**(12), 21-8, 1999, illus. in colour.

Types of natural glass, including tektites, are described from different locations world-wide. M.O'D.

Der Achat- und Amethystbergbau in der Region Medio Alto Uruguai in Rio Grande do Sul, Brasilien: Eine geologische und technische Betrachtung.

M. Priester. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 211-22, 9 photographs, 1 diagram, bibl.

The mining of agate and amethyst in the State of Rio Grande do Sul is the most important non-agricultural income generator of this region. The article discusses the legal situation of the informal artisanal mining as well as the geological setting and conditions of the geode-bearing basalt layers. These geodes are filled with amethysts, agates, chalcedony, calcites and zeolites. Mostly they are exploited in a semi-mechanised small scale underground operation, using black powder blasting. Raw material production is about 3000 to 3500 tons per year which are exported all over the world after some preparation as collectors' specimens, cutting and polishing as decorative pieces and also as raw material for gem cutting. E.S.

Investigations about the structure of freshwater cultured pearls.

C. Rinaudo, M.A. Digennaro, R. Navone and C. Chatrian. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 147-56, 10 photographs, 1 diagram, 3 graphs, bibl.

Tissue-nucleated freshwater cultured pearls were investigated using various methods: RI, SG, UV, loss on ignition, optical microscopy, SEM EDS and X-ray diffraction powder analysis both on ground material and directly on the surface of half-cut pearls. Only aragonite was detected growing as concentric orientated crystals. The pearls seem to have been formed by the development of a succession of subspherical shells, each separated by a growth discontinuity. E.S.

Tanzanit.

T. Sobczak and N. Sobczak. *Mineralogia Polonica*, **29**, 1998, 121-26.

A review of the occurrence, recovery and testing of the tanzanite variety of zoisite, with a table showing the properties of those gem materials with which confusion may arise. M.O'D.

Fluid inclusion characteristics of sapphires from Thailand.

B. Srithai and A.H. Rankin. *MDSTAN*, 1999, 107-11.

Three main types of fluid inclusion occur in Bo Ploi sapphires: (1) vapour rich CO_2 with $D \leq 0.86$ g/cm^3, (2) multiphase inclusions with several daughter minerals, hypersaline brine and a CO_2-rich vapour phase, and (3) (silicate?)-melt inclusions with immobile vapour bubbles in an isotropic/weakly anisotropic phase of low relief. The bubbles move when heated to > 800°C. These results suggest magmatic sources for these sapphires. R.A.H.

Kamienie szlachetne i ozdobne czech.

J. Stanek. *Minerlogia Polonica*, **29**, 1998, 113-20.

A short review, with some historical notes, of the occurrence of gem and ornamental materials in the former Czechoslovakia M.O'D.

Schleifwürdiger Shomiokit-(Y) von Lovozero, Halbinsel Kola, Rußland.

J. Stefan and V.M.F. Hammer. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 141-6, 3 photographs, 1 graph, 2 tables, bibl.

This is a report of a faceted transparent, rose-coloured shomiokite (Y) weighing 0.61 ct, measuring 7.75 x 5.39 x 3.34 mm. SG 2.64; RI 1.530 – 1.539 with a DR of 0.009. These values are slightly higher than those reported for non-gem-quality samples. E.S.

Models of corundum origin from alkali basaltic terrains: a reappraisal.

F.L. Sutherland, P.W.O. Hoskin, C.M. Fanning and R.R. Coenraads. *Contributions to Mineralogy & Petrology*, **133**(4), 1998, 356-72.

Corundums from basalt fields, particularly in Australia and Asia, include a dominant blue-green-yellow zoned 'magmatic' suite (BGY) and subsidiary vari-coloured 'metamorphic' suites. BGY corundums have distinct trace-element contents (≤ 0.04 wt.% Ga_2O_3, and Cr/Ga and Ti/Ga values < 1). Primary inclusion minerals are typically feldspars, zircon and Nb-Ta oxides, hercynite-magnetite, gahnospinel, rutile-ilmenite solid solution, calcic plagioclase, Ni-rich pyrrhotite, thorite and low-Si Fe-rich glass. Magnetite exsolution, feldspar compositions and fluid inclusion homogenization suggest that some corundums crystallize at 685-900°C. Overlap of inclusion Nb-Ta oxide compositions with new data from Nb-Y-F-enriched granitic pegmatites implies a silicate melt origin for the corundums. The MELTS programme was used on the amphibole pyroxenite xenolith chemistry of basalts to test the feasibility of crystallizing corundum from low-volume initial melting of amphibole-bearing mantle assemblages. Corundum appears in the calculations at 720-880°C and 0.7-1.1 GPa, with residual feldspathic assemblages matching mineral compositions found in corundums and related xenoliths. A model that generates melts from amphibole-bearing lithospheric mantle during magmatic plume activity is proposed for BGY corundum formation. J.F.

Chatoyant tremolite (nephrite).

G.A. Tombs. *Australian Gemmologist*, **20**(8), 1999, 340, 5 illus. in colour.

Examination by the author of a mid-green to dark green-grey high-doomed cabochon (submitted by S. Jenkinson and R. Bauer) yielded a 'spot' RI of 1.60, an SG of 3.00 (measured by Jenkinson) and an estimated hardness of $5^{1}/_{2}$ - 6. LWUV produced a patchy bluish through green to yellow fluorescence, but the stone was inert under SWUV. These properties were consistent with tremolite, and the stone's chatoyancy was caused by a flow-like structure of channels. P.G.R.

Gemstones of New England.

G.B. Webb and F.L. Sutherland. *Australian Journal of Mineralogy*, **4**(2), 1998, 115-21.

Brief details are given of the occurrence of diamond, sapphire, beryl, topaz, garnet, zircon, feldspar, rhondonite, nephrite, peridot and fluorite from this area of NE New South Wales. More than 500 000 ct of diamonds have been produced. Two distinct categories of diamond are recognized: yellow, rounded crystals with a high, uniform nitrogen content, and white internally complex crystals with low, variable nitrogen content. Most of the diamonds have been substantially resorbed; under cathodoluminescence, one shows octahedral growth zones on a resorbed surface. Fine blue sapphires are produced with medium to dark hue, but greenish-blue, yellow and green varieties are also found; colour zoning down the *c* axis is a prominent feature. Beryl with emerald zones perpendicular to *c* giving alternating 'stripes' is illustrated. White and more rarely blue topaz occur in alluvium derived from the granitic rocks of the area. Zircons with a yellow, brown and pink range of colours are shed from basalts and are often obtained in sapphire workings. R.A.H.

The new Mineral and Gem Gallery at the British Museum.

J.S. White. *Mineralogical Record*, **30**, 1999, 373-77.

Continuing the occasional series of *Gallery reviews* former Smithsonian Institution curator John White describes the new mineral and gemstone display gallery at London's Natural History Museum. Commenting that the terms mineral and gem are hard to find anywhere in the Museum (though occurring once in the publicity material), he goes on to show that the dimensions of the cases and the lighting militate against adequate viewing of the admittedly excellent specimens, many of which have become mis-labelled since first being set up and which are also capriciously lit, some being well outside the range of nearest spotlight and thus not lit at all. A flashlight has become an essential tool for viewing. The new displays are contrasted, considerably to their disadvantage, with the adjoining Mineral Gallery, lit by daylight, in which all specimens can be seen perfectly well and where labelling is perfectly satisfactory. M.O'D.

The colour of stones.

M. Wilson. *Transactions of the Oriental Ceramic Society*. **62**, 27-37, 1999, illus. in colour.

Describes the usage of and names given to hardstones, exclusive of the jades, used in Chinese artefacts. Rock crystal, amethyst, smoky quartz and rose quartz names are described with explanations of the Chinese characters used. M.O'D.

Martin Zinn III.

W.E. Wilson. *Mineralogical Record*, **30**, 1999, 311-16.

Short biography of the noted American collector and gem/mineral show organizer Martin Zinn III, including notes on and illustrations of important gem-quality specimens from his collection. M.O'D.

Lavra Berilo Branco: the original 'Sapucaia' rose quartz occurrence, Minas Gerais, Brazil.

W.E. Wilson. *Mineralogical Record*, **30**, 1999, 361-5. 1 map.

The first discovery of crystallized rose quartz was made in 1950-60 from the pegmatite of the Lavra Berilo Blanco [white beryl mine], Minas Gerais, close to the town of Sapucaia do Norte, from which the occurrence has been named. There has been confusion over the name Sapucaia because it has previously been used for a deposit of rare phosphates, only a few km away to the south, during the 1940s. Some of the rose quartz crystals have been considered important enough to have been named. The Berilo Blanco pegmatite forms part of the Lower Precambrian Paraiba Group: the Sao Tome mica schist complex was intruded about 600 ma. ago by a granitic batholith, with a late stage formation of many pegmatite veins in the area of Conselheiro Pena. M.O'D.

Instruments and Techniques

X-ray and spectral characterization of defects in garnets.

A. Lupei, C. Stoicescu and V. Lupei. *Journal of Crystal Growth*, **177**, 1997, 207-10, 1 fig.

X-ray and optical spectroscopy of high temperature (HT) grown YAG and GGG revealed low intensity {222} X-ray reflections, forbidden in the cubic garnet Ia3d space group, with equivalent intensities for the four [111] directions. Structural arguments in connection with optical spectroscopy data on various ions (Nd^{3+}, Tm^{3+}, Pr^{3+}) allow one to assign these reflections (absent in flux grown crystals) to local reduction of symmetry introduced by nonstoichiometric random occupancy of octahedral sites by Y^{3+} or Gd^{3+} ions in HT garnets. I.S.

Kristalle und Polarisationsfarben.

O. Medenbach. *Aufschluss*, **50**, 357-64, 1999, illus. in colour.

The use of polarized light in mineral identification is discussed with reference to the various ways in which experiments can conveniently be conducted. M.O'D.

Modern mineral identification techniques. 1. WDS and EDS.

T. Nikischer. *Mineralogical Record*, **30**, 1999, 297-300.

Describes wavelength-dispersive spectroscopy (WDS) and energy-dispersive spectroscopy (EDS) with short explanations of their roles in mineral specimen identification. M.O'D.

Synthetics and Simulants

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 121-7, 12 photographs.

Treated quartz is used as an imitation of jade; small pieces of opal are mixed with a resin and sold as matrix opal, cabochons or eggs; synthetic spinel is used as an imitation of tanzanite and some rounded sapphire crystals from Sri Lanka turned out to be synthetic. E.S.

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 185-90.

Notes include a Knischka synthetic ruby and some natural/synthetic sapphire doublets, the crown being the natural stone. E.S.

Energie aus farbigen Kristallen: oxidische Laserkristalle-Herstellung, Bearbeitung, Anwendungen.

K. Dupré. *Aufschluss*, **50**, 365-70, 1999, illus. in colour.

The synthetic garnets are examined as part of a general discussion of the growth and coloration of crystals suitable for laser use. M.O'D.

Verneuil synthetic corundums with induced fingerprints.

J. Free, I. Free, G. Brown and T. Linton. *Australian Gemmologist*, **20**(8), 1999, 342-7, 11 illus. (10 in colour).

Quench-cracked Verneuil synthetic ruby and blue sapphire (a by-product of the routine heat treatment of corundums in Chanthaburi, Thailand) are produced by first heating the boules and then plunging them into water to induce fractures. These fractures are then heat-treated in a colourless flux. The resulting flux-healed quench-cracked stones contain 'fingerprints' and 'feathers' similar to those found in their Burmese and Sri Lankan natural counterparts. A study of 6 faceted rubies and 10 faceted blue sapphires showed that they could be discriminated from their natural counterparts by their curved striae/colour banding, checker-board pattern of solid flux filled surface-reaching induced fractures and their increased transparency to SWUV. P.G.R.

Zur Verwendung künstlicher Gläser als Schmuckmaterial: Schwarzes und blaues Glas mit ungewöhnlichen Einschlüssen.

V.M.F. Hammer, J. Stefan and F. Brandstätter. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 157-62, 5 photographs, 2 graphs, table, bibl.

Black beads from a necklace from Asia were shown to be glass with dendritic intergrown fluorite. A new gemstone from Namibia was identified as blue glass with tridymite inclusions. E.S.

Gemmologische Kurzinformationen.

U. HENN. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 163-5, 3 photographs.

The author describes a faceted hydrothermally grown aquamarine weighing 0.85 ct. SG 2.71; RI 1.572–1.580, DR 0.008. Using an immersion-type microscope distinct inhomogeneous growth patterns are visible which are typically found in hydrothermally-grown synthetic beryls including emeralds. E.S.

Gemmologische Kurzinformationen.

U. HENN. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 232-6, 3 photographs, table, bibl.

A faceted, orange fresnoite was examined, weighing 6.11 ct. RI 1.765-1.775, DR 0.010; SG 4.45. Gas bubbles were observed.

A synthetic forsterite has recently been offered as tanzanite. RI 1.635-1.670, birefringence 0.035; SG 3.26. The blue colour is caused by divalent cobalt. Strong pleochroism with violet, blue and purple. Tiny gas bubbles and doubling of facet edges were observed. E.S.

Gemmologische Kurzinformationen.

U. HENN AND C.C. MILISENDA. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(4), 1999, 227-31, 4 photographs, 2 diagrams, bibl.

The short note describes the GE-POL (General Electric/Pegasus Overseas Ltd.) treated diamonds. They are originally brown or brownish type IIa diamonds where colour is removed by a high pressure/high temperature treatment. This modification cannot be identified by present gem testing techniques. GE laser inscribes the girdle surface with 'GE-POL'. A specimen stone of 0.72 ct was graded as G, VS1. E.S.

Gamma-ray diffractometry investigation of dislocation density in massive quartz crystals.

I.I. KALASHNIKOVA, V.S. NAUMOV, A.I. KURBAKOV, A.E. SOKOLOV AND S.S. PASHKOV. *Journal of Crystal Growth*, **177**, 1997, 57-60, 1 table.

Gamma-ray diffractometry, using intense monochromatic gamma-ray radiation from a ^{198}Au source activated by nuclear reactor neutrons, was applied to investigate dislocation density in AT-cut plates of synthetic quartz crystals. The beam cross section was 0.1 x 10 mm^2 with angular divergence of 9 angular seconds. Statistical dynamic diffraction theory was used to calculate dislocation density. Data obtained by this method were compared with those obtained by X-ray topography and etch channel method, giving good agreement. I.S.

Synthetische Quarzkristalle – Kristalleigenschaften, hydrothermale Züchtung und gemmologische Unterscheidung von natürlichen Quarzkristallen.

A. LANDMANN. *Gemmologie – Z. Dt. Gemmol. Ges.*, **48**(3), 1999, 129-40, 7 photographs, 7 diagrams, 3 graphs, bibl.

The proportions of a synthetic quartz crystal differ significantly from those of a natural quartz crystal and can be influenced by varying the growing parameters. This applies also to fluid inclusions in synthetic quartz. Synthetic quartz crystals are grown mainly for the electronic and optical industries, but some synthetic rock crystal, amethyst, citrine and smoky quartz is found on the jewellery market. These can be identified using low temperature infrared spectroscopy. The author describes the large autoclaves used in the production in Russia and China, and his study is based on the synthetic quartz crystals produced by these methods. E.S.

Synthetic andalusite crystals: morphology and growth features.

G.T. OSTAPENKO, V.N. KVASNITSA, L.P. TIMOSHKOVA, N.P. SEMENKO AND B.A. DOROGOVIN. *Journal of Crystal Growth*, **186**, 1998, 420-6.

Using a method by Ostapenko andalusite crystals attaining 1 mm were synthesized under hydrothermal conditions in complex water solutions. Smaller crystals (0.05-0.1 mm) were obtained in pure water. The growth rate of {001} is the highest at 0.04-0.08 mm/day, that of {110} is the slowest at 0.01-0.02 mm/day. The surface microtopographic observations indicated that adhesive type growth mechanism operated for the {001} and the layer-by-layer mechanism for {110}, and apparently for {001} and {101}. I.S.

Crystalline perfection of high purity synthetic diamond crystal.

H. SUMIYA, N. TODA, Y. NISHIBAYASHI AND S. SATOH. *Journal of Crystal Growth*, **178**, 1997, 485-94, 12 figs.

By means of double-crystal X-ray rocking curve measurement, polarization microscopy, topography and Raman spectroscopy, crystalline quality of high purity synthetic diamond crystals (type IIa) with impurities < 0.1 ppm grown by a temperature gradient method under high *P* and high *T* have been investigated. The diamond crystals contain fewer crystal defects, less internal strain and less variation in defects than those of natural diamond or synthetic type Ib diamond. The crystals however contain some line and some plane defects. It is suggested that these highly perfect crystals can be used as seeds to grow diamond crystals of high perfection. I.S.

Growth of diamond on silicon tips.

G. YUAN, Y. JIN, C. JIN, B. ZHANG, H. SONG, Y. NING, T. ZHOU, H. JIANG, S. LI, Y. TIAN AND C. GU. *Journal of Crystal Growth*. **186**, 1998, 382-5.

Diamonds with (111) orientation were preferentially grown on the top of silicon-tip arrays by microwave-plasma chemical vapour deposition. The observed preferential growth can be explained as an effect of chemisorption on the surface. I.S.

BOOK REVIEWS

Ancient Chinese jades (Part 1)

Zacke Auctions Vienna, 1999. pp 207, illus. in colour. Price (for this part) US$26.00

Chapters describing the authentication of early Chinese jades accompany this first part (of a projected three) of a sale catalogue in which 90 items are presented and very well illustrated. The services of a research laboratory (Aventis Research & Technologies, Hoechst, Germany) were called into play and X-ray fluorescence analysis (XRF) played the main part in determining whether or not a particular artefact had been naturally weathered. Atomic absorption spectroscopy (AAS) and electron spectroscopy (ESCA) were also used. The laboratory provides a very interesting presentation of the stages of investigation undertaken: analysis of tool marks and traces of workmanship are given as well as details of how possible weathering is established. This is a sale catalogue with a difference and readers should try to obtain a copy while it is still current. M.O'D.

Lure of the pearl: pearl culture in Australia

B. Aquilina and W. Reed. Kimbooks Pty Lt, Broome, Western Australia, 1998. pp 135, illus. in colour, softcover. ISBN 1 876332 00 X. Price on application.

Excellent and beautifully-produced guide to the culture of pearls in Australia. The culture methods are clearly described and there are a number of clear diagrams and attractive photographs. M.O'D

Catalogue of the Beck Collection of beads in the Cambridge University Museum of Archaeology and Anthropology. 1 Europe

Bead Study Trust, Cambridge. 1997. pp 160: two microfiche in rear pocket, softcover. £16.00 from the Trust at 29 Elliscombe Road, London SE7 7PF.

With a (free) corrected and expanded version of the Beck Collection catalogue available shortly and the second part (on Middle Eastern beads) promised for 2001, readers may feel that the present stop-gap work is unsatisfactory in some way. This is not the case since work on the now historic (*circa* 1945) collection has really only just begun and it was important to get records set out and available to scholars as soon as possible. I recommend anyone with an interest in this type of artefact to buy this very reasonably-priced book and make arrangements to see the collection (after making and keeping an appointment at Cambridge – the museum is Downing Street, Cambridge CB2 3DZ). While the materials may not interest gemmologists quite so much as the history and significance of the beads, there is much to be learnt by consulting this further addition to the renaissance in bead studies. M.O'D.

The drowning dream [A tale]

P. Burke. Fremantle Arts Centre Press, South Fremantle, Western Australia. 1998. pp 264, softcover. ISBN 1 863682 14 7. A$17.50 (includes air postage).

The background of pearling in the Indian and Pacific oceans makes this rousing adventure story of considerable value to readers with an interest in pearls. M.O'D.

Gold in the counties of Cornwall and Devon

S. Camm. Cornish Hillside Publications, St Austell: 1999. pp 116, illus. in colour, softcover. ISBN 0 9519419 7 6, £9.99.

This is an excellent small book for the mineral collector and has been reprinted with minor corrections from a first edition published in 1995. British minerals do not often make the monograph market: this book is well-written by an experienced consultant geologist who has worked for many years in this particular field and has an excellent list of references as well as some good colour photographs illustrating notable specimens. Details of these, their places of occurrence and of mining fill the lucid text. Readers with an interest in the subject should get the book quickly since the print-run may be small. M.O'D.

Memoir of localities of minerals of economic importance and metalliferous mines in Ireland

G.A.J. Cole. The Mining Heritage Society of Ireland Dublin, 1998. Softcover, illus. in black-and-white. ISBN 0 9534538 0 4. Price around £10.

Since publication of the second edition of 'Cole' in 1956 (the first edition came out in 1922 and is virtually unobtainable) this rare survey of an important source of minerals has long been in need of an update (and of finding at all). Ireland has a rich mineralogy and some specimens, notably of sphalerite, are of very high ornamental and even gem quality. The recent cessation of operations at Silvermines and probably elsewhere in the quite recent past makes careful recording even more urgent. A section of pictures of some famous mines has been added to the original text, thus making this, as stated on the verso of the title-page, a third edition: a short history of the book and of Cole himself opens the text, whose main section is arranged first by mineral and then by mine. Very important locality information is given, with copious reference to records which may now have been lost. The Mining Heritage Society of Ireland deserves every possible support in their work of preservation and recording. This reviewer, whose forbears included a least one celebrated Irish man of letters, welcomes a long-awaited survey of his ancestral minerals! M.O'D.

ISSN: 1355-4565

Beautiful opals: Australia's national gem. Special 2000 commemorative edition

L. Cram. The Author, Lightning Ridge, 1999. pp 80, illus. in colour, softcover. ISBN 0 9585414 2 6. $A30.00.

Very beautiful guide to the major Australian opal fields and to the best of their products, the book consists in the main of Len Cram's justly celebrated photographs which must have given an enormous boost to opal collecting and buying. Notes are given on some of the major locations and personal anecdotes give considerable insight into mining conditions and opal trading. M.O'D.

Minerals of Colorado

E.B. Eckel. Updated by R.R. Cobban, D.S. Collins, E.E. Foord, D.E. Kile, P.J. Modreski, J.A. Murphy. Fulcrum Publishing, 1997. pp x, 665, illus. in colour, hardcover. ISBN 1 55591 365 2. Price around £100.

This very large book does justice to one of the most important mineralized areas of the Earth. Sponsored by the Colorado Chapter of the Friends of Mineralogy and by the Denver Museum of Natural History, the book updates Eckel's *Minerals of Colorado*, published as *Bulletin* 1114 of the United States Geological Survey in 1961. Since publication of that work, 329 new mineral species have been recorded from the State of Colorado and of course there have also been fresh localities found for species already described. Early chapters present the growth of mineralogical knowledge in Colorado, a list of selected mineral locations and a section of maps in black-and-white; then comes the main part of the text covering species arranged in alphabetical order. Each entry gives name, chemical composition, crystal system, group membership where relevant, location by county and district, details of occurrences and significant references in the literature. The clear and well-spaced printing is one reason why the book is so large but readers will welcome it, I am sure.

Nothing in the way of colour illustrations occurs until page 326 when a section of colour photographs is found. Quality and clarity are excellent: size and ownership of specimens are given as well as location. There are 118 colour photographs and the remainder of the pictures, up to 145, feature SEM depictions, also of high quality. After this section the alphabetical listing, with addendum, is complete by page 546, at which point it is followed by previously unpublished chemical analyses of some Colorado minerals.

A magnificent bibliography from pages 557-665 completes the book. Readers will be aware that Colorado produces a number of gem-quality minerals and they can be found in the text. The cost is by no means unreasonable and I suspect that the excellent Friends of Mineralogy have helped a great deal here. M.O'D.

Derbyshire Blue John

T.D. Ford. Landmark Publishing Ltd, Ashbourne, 2000. pp 111, illustrated in colour, softcover. ISBN 1 873775 19 9. £5.95.

The ornamental minerals of Derbyshire have not been specially well served by the writers of monographs since the nineteenth century: Trevor Ford, sometime Associate Dean of Science at the University of Leicester, a leading centre for geology and mineralogy, has redressed the balance by this really excellent book which is illustrated in colour throughout and which gives a new meaning to 'value for money'. After an opening chapter in which fluorite is introduced the book continues with descriptions of caverns and mines in which the mineral can be found and with geological accounts of the Derbyshire locations in the Peak District and at Treak Cliff in particular. Blue John mineralogy and Blue John-bearing veins are described.

Recovery of the Blue John has rarely been the subject of published papers and the account here is fully detailed with graphic illustrations. Blue John simulants, fashioning and examples of the use of material in Roman and later times, the work of Matthew Boulton, who used a great deal of Blue John in ornaments and its various uses up to the present time occupy much of the remainder of the text, which also includes details of the different patterns of Blue John which can sometimes show which veins it comes from. There is a survey of places where specimens may be seen and a useful bibliography. I cannot speak too highly of this book. M.O'D.

Gemstones

Grange Books, Rochester, 1998. pp 64, illustrated in colour, hardcover. ISBN 1 84013 136 5. £4.95.

The text is a compilation of material from three other books and while refreshingly cheap, does not quite come off in the sense that some of the photographs let it down: presumably they are copies of copies which themselves may not have been of the best quality. Whatever the reason, some are badly out-of-focus. Each page is devoted to a single species: a laudable idea but the accompanying text is larded with unexplained adjectives which will pass by the readers concentrating attention on the pictures but which will stop the same readers in their tracks as soon as they want to find out more. This is the age-old problem with this kind of book. As always such texts should be submitted to a competent scientific authority before being let loose on the market. M.O'D.

L'émeraude. The emerald. Connaissances actuelles et prospectives

D. Giard (Ed.). Association française de gemmologie, Paris, 1998. pp 229, illus. in colour, softcover, price on application.

A very attractively produced and well-illustrated update on a number of emerald localities and their products, with extensive notes and individual papers on synthetic emerald. Most papers, each written by different authors under the general editorship of Didier Giard, have their own list of references and there is a more general bibliography, covering publications of the 1990's only, at the end of the book. Papers have English abstracts, some of them extended.

The survey comes at an opportune time with the arrival on the world gem markets of emeralds from Madagascar, Afghanistan and Pakistan, among other places, and the papers act as a general and welcome update of Sinkankas (1981) *Emerald and other beryls* with its coverage of earlier and less commercially prominent localities. Readers should have both on their shelves.

Many of the papers show mining districts not often depicted elsewhere and a study of early work on synthetic emeralds includes photographs of specimens grown by Hautefeuille in 1888 - the first time I have seen pictures of this material in colour. A paper on the hydrothermal growth of emerald in China also includes interesting photographs of autoclaves in action and of the inclusions visible in the product.

There are treasures everywhere: this is an essential book for the gemmologist, for those likely to be searching for emerald in the field and for the student of crystal growth. The editor, authors and publishers can be proud.
M.O'D.

The glass beads of Anglo-Saxon England, *c.* AD 400-700

M. Guido, 1999. The Boydell Press, Woodbridge, Suffolk, for the Society of Antiquaries of London. pp (xi) 361, illus. in colour. Hardcover. ISBN 0 85115 718 1. (Reports of the Research Committee of the Society of Antiquaries of London. no. 56. ISSN 0953-7163.) £50.

Edited and with two chapters by Martin Welch and subtitled *A preliminary visual classification of the more definitive and diagnostic types,* this study of Anglo-Saxon beads is based on examination of all the glass beads recovered from known British sites and is the first-ever national survey of the subject. Guido realised that research on glass beads would not only enlarge our knowledge of the development of this kind of artefact but also throw additional light on the post-Roman and early Saxon periods in Britain. The main text begins with a descriptive analysis of the beads by type, mainly their colour, and continues with schedules which are preceded by a topographical index placing sites of recovery in alphabetical place-name order, both describing and showing what the particular finds were and the present locations of the artefacts. The schedules themselves are arranged by type of bead, following the characteristics set out in the descriptive analysis in the first part of the text.

A section of eight colour plates presents beads grouped by colour and shows how attractive they can be. Finally an extensive and authoritative bibliography brings the reader up-to-date with work in this field: many items described could be hard to find were it not for their inclusion here.

The very reasonable price of the book reflects the considerable help made available from a number of sources, notably The British Academy. Production has not been skimped and my only very slight anxiety over sustained use is the thinness of the paper (acid-free, though). While jewellery historians in particular will be grateful for this book, it will also be very useful to those historians who depend upon artefacts like these to amplify their knowledge of social history and local economics.
M.O'D.

Classicism to neo-classicism: essays dedicated to Gertrud Seidmann

M. Henig and D. Plantzos (Eds). Archeopress, Oxford, 1999. pp iv, 232 illus. in black-and-white, softcover. ISBN 1 84171 009 1. (*BAR International Series* 793). £32.40.

Several papers in this festschrift dedicated to the distinguished Oxford antiquary and authority on the glyptic arts deal with set gemstones of the classical and post-classical taste in European ornamental artefacts during the succeeding centuries. Of particular interest are the accounts of gem collections now lost or dispersed. Chapters cover a wide range of topics and have their own useful lists of references: a bibliography of Seidmann's own works is included.

Readers with an inclination towards the use of the gemstones in earlier times should consult the published list of *BAR* (*British Archeological Reports*) available from Oxford.
M.O'D.

Madagaskar: das Paradies der Mineralien und Edelsteine

Christian Weise Verlag, München, 1999. pp 96, illustrated in colour, softcover. ISBN 3 921656 50 8. *extraLapis* no 17. DM34.80.

With this monographic multi-author treatment in the now accepted *extraLapis* form, the minerals and gemstones of Madagascar take another step towards regaining the international recognition and admiration that they have lacked since the 1950's and previous years when specimens used to come in profusion to Europe via the Compagnie Générale de Madagascar. When Alfred Lacroix published *Minéralogie de Madagascar* (Paris, 1922) mineralogists became familiar with some of the world's richest pegmatites and they are reviewed here with some splendid illustrations of rose quartz, beryl, tourmaline and many other gem-quality species. As always every page is a delight both to read and to the eye: I should have liked a bibliography (and a copy of Lacroix!) but I have to warn readers that issues of *extraLapis* are becoming scarce quite shortly after publication so get this one as soon as possible.
M.O'D.

Famous jewelry collectors

S. Papi and A. Rhodes, 1999. Thames & Hudson, London. pp. 208, illus in colour, hardcover. ISBN 0 500 01960 6. £29.95.

This well-produced and attractive book takes the reader into the jewellery collections of some of the most celebrated figures of the expiring century. Useful short biographies as well as details of the pieces depicted accompany the photographs and details of sales are given in appropriate cases. There is a short bibliography.

Collectors chosen for inclusion include royalty, stars of the concert room, cinema and theatre: details of some major gemstones can also be found in the text which will interest equally the gemmologist, the jewellery historian and the recorder of 20th century social life in Europe and the United States. The standard of the photographs is high and the price very reasonable. The book would make an ideal Christmas or birthday present. M.O'D.

Portrait der Edelsteinmetropole Idar-Oberstein

This small booklet was published on the occasion of the 1999 Intergem exhibition. It is an illustrated account of 500 years of the local gemstone industry. In the 15th century the first local agates were worked using local water power. The development of the lapidary, stone cutting and carving, and jewellery industries is briefly described. E.S.

Gemmology

P.G. Read, 1999. Butterworth-Heinemann, London. pp 326, illus. in black-and-white and in colour. £21.99.

The second edition of this most excellent text-book is very much a repeat of the first edition with various additions to bring it up to date.

Well-written and quite explicit, it covers the subject admirably. A few minor spelling errors were detected (e.g. taafeite for taaffeite, aparite for apatite, managanese for manganese) due almost certainly to careless typesetting. Moissanite, the latest diamond simulant, is dealt with briefly but adequately in the main text, but does not appear in appendix D nor in the index. Mr Read's Brewster-angle meter is described in some detail and has advantages over the normal refractometer in that no contact fluid is needed and hence there is no limit to its range.

The author still uses the term metamerism for the colour change in alexandrite. My Chambers' dictionary defines the word as 'a particular form of isomerism in which different groups are attached to the same central atom'. I think it is wrongly applied to alexandrite.

Appendix C now contains a number of rare gem species which do not appear in the current Gemmological Association Syllabus for Examinations. So much the better for these rare stones do exist.

Perhaps the most amazing fact is that this edition is far cheaper then the first one (which did appear later in paper-back). This has been achieved by using a limp cover, a slightly smaller type-face and by drastically reducing the size of most of the profuse illustrations. This reduction is in no way detrimental to their interpretation however.

Colour illustrations of jewellery are very good and two pages of coloured diffraction-grating spectra are welcome. Altogether the book is eminently readable and should be regarded as a very reasonably priced text-book deserving a place in any student's library. R.K.M.

Black opal fossils from Lightning Ridge: treasures from the Rainbow billabong

E. Smith. Kangaroo Press (imprint of Simon & Schuster), 1999. East Roseville, NSW. pp 112, illus. in colour, hardcover. ISBN 0 86417 909 X. A$39.95.

There seems to be no end to the succession of beautiful opal books from Australia. This one describes and illustrates fossils in which black opal with play-of-colour is found replacing plant, shell or skeletal material. The text opens with a brief description of how the fossils of Australia came about and what types there are. The author then gives an account of mining experiences in the Lightning Ridge area and how she began to collect fossils. This section is followed by an introduction to the ways in which opal can form and to the various types of opal pseudomorphs after fossils: this section includes a useful evolution and time chart. The next section deals with opal replacements of different types of material, beginning with plants and going on to include primitive animals and again begins with an introduction to the appropriate commoner fossils. The book closes with a useful glossary and a bibliography.

The reader will want above all to know how good the photographs are and whether or not they arouse a desire to see (if not collect) them. The pictures are uniformly good and the display of colours is exceptionally fine, with the specimens in most cases shown against a black background: sizes are given, too! Some locations are depicted, giving an idea of the prevailing geology. The book's simple text is designed to accompany a fine set of pictures rather than to provide a palaeontological or gemmological study: it succeeds admirably. Credit is also due to the excellent series of marginal diagrams showing 'how the fossils once were'. M.O'D.

Von Ammoniten und Zwillingen (catalogue of the 1999 München Mineralientage)

Oberhaching, Germany, 1999. pp 287, illus. in colour, softcover. Price on application.

The catalogue of the annual München Mineralientage is always a beautiful production. In 1999 the theme of the show was fossils, with special attention given to ammonites, and to twinned crystals which are described and discussed by several authors on pages 29-111, this large section thus forming a serious study of twinning, with many high-class photographs and diagrams. Sources of especially fine examples are identified: some of the crystals highlighted are of gem and ornamental quality (chrysoberyl, quartz). The different types of twinning are clearly shown both in diagrams and photographs. Readers should try to obtain these catalogues: with a different theme each year and the wealth of directory and advertising information it is hard to see why more gemmologists do not possess them. M.O'D.

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

OBITUARY

Howard Blackmore (D.1957 with Distinction), Caterham, Surrey, died on 24 November 1999. An obituary was published in the March issue of *Gem and Jewellery News.*

Syed Jafer Ali (D.1979), South Norwood, London, died recently. We are most grateful to his widow for the donation of his collection of gemmological books and instruments.

Helge R. Westgaard (D.1995), Kragero, Norway, died in 1999.

MEMBERS' MEETINGS

London

On 15 February 2000 at Imperial College, South Kensington, Dr R.F. Symes gave a talk on *Some sites of precious minerals in England.*

On 15 March at Imperial College, Stephen Webster gave a talk entitled *Chalcedony – 21st century girl's best friend.*

Midlands Branch

On 28 January 2000 at the Earth Sciences Building, University of Birmingham, Edgbaston, a Bring and Buy Sale and a Quiz were held.

On 25 February at the Earth Sciences Building, Ian Mercer gave a talk entitled *Gem trails from the Orient to Germany.*

Gem Playgroups were held at Barnt Green on 30 January and 27 February.

North West Branch

On 16 February 2000 at Church House, Hanover Street, Liverpool 1, Wendy Simkiss gave a talk entitled *Amber – different varieties and ages from around the world.*

On 15 March at Church House, Alan Hodgkinson gave a talk and demonstration on the identification of synthetic moissanite.

Scottish Branch

On 1 March 2000 at the British Geological Survey, Murchison House, Edinburgh, Drew Burrell gave a talk entitled *The diamond pipeline.*

NEWS OF FELLOWS

Alan Hodgkinson has been honoured by the Accredited Gemologists Association in the USA with the Antonio C. Bonanno Award for Excellence in Gemology.

The winner of the award was announced at the AGA Gala Dinner and Awards Ceremony in Tucson, Arizona, during the international gem show. The citation on the sculpted bronze relief reads: 'Awarded by the Accredited Gemologists Association to Alan Hodgkinson, February 3rd, 2000. For your invaluable contribution to the detection of synthetic emerald, and for the development of simple instrumentation and identification techniques known as *Visual Optics.*'

Michael O'Donoghue gave a six-lecture lunch-time course at the Bishopsgate Institute, London, in January and February 2000. The subject was *The classic gemstones.*

Cally Oldershaw is leaving the Natural History Museum where she has worked for almost 13 years and has been the Museum Gemmologist for the last ten years. She will be taking on the job of Researcher and Parliamentary Liaison Officer for the Geological Society, which is based in Burlington House, Piccadilly. Cally will not be leaving gemmology, but will continue as a Scientific Associate at the Museum, a freelance author, editor and consultant for the earth sciences, and as an examiner with the GAGTL.

ISSN: 1355-4565

DONATIONS

The Council of Management are most grateful to the following for responding to the appeal for donations to enable the Association to meet the challenges of the 21st century. A list of those who have responded to the appeal follows:

Stephen P. Alabaster, Birmingham, West Midlands
A.H.G. Armstrong, Bridge of Allan, Stirling
Kathryn L. Bonanno, New York, U.S.A.
Henrietta A.E. Bouman, The Hague, The Netherlands
Dr Rui P. Branco, Viseu, Portugal
Sheila Burgoyne, Totteridge, London
Burton A. Burnstein, Los Angeles, California, U.S.A.
James K. Cairncross, Perth, Perthshire
Maurice W. Carter, Toronto, Ontario, Canada
Miguel J. Caycedo, Ilford, Essex
Dr Morley Sheng-Hong Chang, Taichung, Taiwan, R.O. China
Chi Ho Cheung, Kowloon, Hong Kong
Norman V. Clarke, Cockburnspath, Berwickshire
Cropp & Farr Ltd., London
Suzanne P. De Souza, Stamford, Connecticut, U.S.A.
Lester N. Doulis, Troy, Michigan, U.S.A.
Luella Dykhuis, Tucson, Arizona, U.S.A.
Robert P. Fessel, Paulding, Ohio, U.S.A.
Roger Francis, Coventry, West Midlands
Mary Garland, London, Ontario, Canada
Robert B.R. Gau, Taipei, Taiwan, R.O. China
Alan Gay, Coventry, West Midlands
Michael and Bernice Gay, Romsey, Hampshire
Gwyneth Green, Birmingham, West Midlands
Norman H. Harding, Wivelsfield Green, West Sussex
Hayo W. Heckman, Apeldoorn, The Netherlands
J.A.M.T. Heetman, Rotterdam, The Netherlands
Joannes G. Heetman, Rotterdam, The Netherlands
Ann F. Hill, Fairview Park, South Australia
Dr Arthur E. Hill, St Saviour, Jersey
Andrew F. Hinds, F. Hinds Ltd., London
Dr Angela S.L. Hong, London
Chak Lun Hui, Kowloon, Hong Kong
Hajime Ishii, Uji-shi, Kyoto-Hu, Japan
David C.B. Jones, Meggen, Switzerland
Anders B. Kallner, Stockholm, Sweden
Susan M.B. Kelly, Brisbane, Queensland, Australia
Harold Killingback, Oakham, Rutland
Prof. Won-Sa Kim, Daejon, Korea
Charmain E.M. Lander, Rickmansworth, Hertfordshire
Lorna M. Lang, St Kilda, Victoria, Australia
Michael L. Langford, Hereford
Glady Lau, Shatin, Hong Kong
Lin Hsin-Pei, Taipei, Taiwan, R.O. China
Joan A. Logan, Hounslow, Middlesex
Maxon A. Logsdon, Wethersfield, Connecticut, U.S.A.
Sylvia J. Lowe, Harrow, Middlesex
Kieran J. Lynch, Coventry, West Midlands
Marcus A. McCallum, London
Robert B. McDowell, Damascus, Maryland, U.S.A.
Caroline E. MacLachlan, Edinburgh
The Hon. Jasper May, Birmingham, West Midlands
Helena Michon-Bordes, Grenoble, France
Unni Mitteregger, Djursholm, Sweden
Stefanos Mourtzanos, Rethymno, Crete, Greece
Sara Naudi, London
Sousan Niroo, London
Paule Nolens-Verhamme, Sint Truiden, Belgium
Hin Eng Alice Ou, Singapore
Mark A. Porter, Hook, Hampshire
Maggie Yuk Ling Pun, Kowloon, Hong Kong
John S. Pyke, Birkenhead, Merseyside
Caroline E. Quy, Croxley Green, Hertfordshire
Gerard Raney, Redwood City, California, U.S.A.
Peter G. Read, Bournemouth, Dorset
David M. Robinson Ltd., Liverpool
Thomas and Bebs Roper, Rokeby, Tasmania, Australia
Alan F. Rowlands, Calgary, Alberta, Canada
David J. Sayer, Wells, Somerset
Arlette Schatzle-Pariso, Pully, Switzerland
Larry Schreier, Skokie, Illinois, U.S.A.
Jack Seibert, Columbus, Ohio, U.S.A.
Richard and Keri Slater, Westbury, Wiltshire

Benjamin H. Smith Jr, Wilmington, North Carolina, U.S.A.
Geertruida J. Spiro-Haccou, Jakarta, Indonesia
Edward Stanley, Denton, Manchester
Elias Stassinopoylos, Athens, Greece
Tang Wai Chun, Kowloon, Hong Kong
Helen M. Thomis, Halifax, West Yorkshire
Sunny K. Tsui, Melbourne, Victoria, Australia
William J. Tucker, Douglas, Isle of Man
John O. Vince, Banbury, Oxfordshire
Elizabeth R. Warriner, Solihull, West Midlands
Masahiro Watanabe, Kurayoshi City, Tottori-Ken, Japan
Malcolm H. Webb, Chatham, Kent
Anthony E. Wilkins, Bridgwater, Somerset
Donald K. Williams, Phoenix, Arizona, U.S.A.
Wong Hon Chung, Kowloon, Hong Kong

EXAMINATIONS IN GEMMOLOGY

In the Examinations in Gemmology held worldwide in January 2000, 119 candidates sat the Preliminary Examination of whom 92 qualified. In the Diploma Examination, 100 candidates sat of whom 53 qualified.

Diploma

Qualified with Distinction
Johnson, Janet, M., Friern Barnet, London
Joyner, Louise, London
Shin, Mina, Seoul, Korea

Qualified
Al-Buflasa, Hanan Mubarak, Isa Town, Bahrain
Ancemot, Alex, Nantes, France
Antenen, Didier, Lausanne, Switzerland
Balzan, Cortney G., Fairfax, California, U.S.A.
Bawa, Mohammed S.R.M., Harrow, Middlesex
Bin Luo, Wuhan, Hubei, P.R. China
Bolissian, Inge Sahr, London
Brown, Mary J., Yangon, Myanmar
Chambers, Sara, Cardiff
Chaohui Lu, Wuhan, Hubei, P.R. China
Cheong Ly Karine, London
Chiu Mei-Hsiu, Taipei, Taiwan, R.O. China
Chongjie Pan, Wuhan, Hubei, P.R. China
Criado Friesch, Romina, Madrid, Spain
Dickson, Rebecca, London
Dwane, Christine, Montreal, Quebec, Canada
Ellis, Nigel, Lune River, Tasmania, Australia
Fu Sheng, Sushou, P.R. China
Geung Wan Yin, Hong Kong
Hicks, Suzanne C., Yardley, West Midlands
Hsu Miao Chu, Taipei, Taiwan, R.O. China
Johnson, James P., Friern Barnet, London
Koers, Jessica, Schoonhoven, The Netherlands
Kong Bei, Guilin, Guangxi, P.R. China
Lain Yu Wen, Taichung, Taiwan, R.O. China
Lan Wang, Wuhan, Hubei, P.R. China
Liying Lu, Wuhan, Hubei, P.R. China
Poon Wai Kong, Singapore
Pratt, Jonathan J., Guildford, Surrey
Qu Han, Guilin, Guangxi, P.R. China
Schonberg, Alessandra, Lugano, Switzerland
Sedore, John D., Vancouver, B.C., Canada
Sharma, Rashmi, Johannesburg, S. Africa
Sharples, James, Bolton, Lancashire
Shi Yinghong, Pudong, Shanghai, P.R. China
Shiwei Yu, Hong Kong
Si Ji Ma, Beidajie, P.R. China
Simpson, Peter R., Richmond, Surrey
Thompson, Ian, Wood Green, London
van Dam, Anita, Maasland, The Netherlands
Wang Xuan, Guilin, Guangxi, P.R. China
Watanabe, Hanaco, London
Xinyuan Li, Wuhan, Hubei, P.R. China
Yen Chien Kuo, Taipei, Taiwan, R.O. China
Yeo See Yee Clara, Singapore
Yibai Li, Wuhan, Hubei, P.R. China
Yuan Gao, Wuhan, Hubei, P.R. China
Zin Min, Yangon, Myanmar
Zini, Grazia, Ferrara, Italy

Preliminary

Qualified
Anderson, Meredith, Chertsey, Middlesex
Andrade, Fabiana, London
Au Mei Ling Joyce, Hong Kong
Axarlian, Sergio, Piraeus, Greece
Ayukawa, Yasuyo, London
Balzan, Patrick B., Piedmont, California, U.S.A.
Barber, Emily A., London
Berner, Peter, Gelterkinden, Switzerland
Blachier, Helene, London
Breckon, Donna L., York
Bruce-Lockhart, Simon, London
Burrow, Helen J., Rochester, Kent
Cai Shi Mei, Guilin, Guangxi, P.R. China
Chalmers, Marie L., Boston, Lincolnshire
Chan See Lan Shirley, Hong Kong
Chang Wen Shion, Taichung, Taiwan, R.O. China
Chao Chung Hsiao, Taipei, Taiwan, R.O. China
Chen Peijia, Guilin, Guangxi, P.R. China
Chen Jijuan, Guilin, Guanxi, P.R. China

GIFTS TO THE ASSOCIATION

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

Tayyo Adolphus, Mintabie, South Australia, for 4 pieces of opal within matrix.

Maggie Campbell Pedersen, London, for a blue jade and 6 resin beads with insects.

European Gemmological Laboratory, New York, U.S.A., for a chamber for the production of synthetic diamond.

Vesta de Poli, South Kensington, London, for 355 specimens for teaching.

Peter Dwyer-Hickey, South Croydon, Surrey, for 21 specimens including diamond with burnt polish, sapphire, topaz, quartz, ivory and a garnet-topped-doublet set in a brooch.

John R. Fuhrbach, Amarillo, Texas, U.S.A., for a collection of crystals, stones, slabs and rough, including rough heat-treated quartz from Zambia, emerald and amethyst from Brazil, bytonite from Texas, calcite from Colorado, rhodochrosite, a piece of deer antler and some small faceted stones.

Rod Griffin, Yowah, SWQ, Australia, for a piece of korite stone.

Marie-Irene Hicter, Grenoble, France, for a synthetic opal cabochon.

R. Holt & Co. Ltd., London, for a brown enstatite crystal weighing 38.15 ct.

Marcus McCallum, London, for a jadeite doublet.

Mrs C.M. Ou Yang, Hong Kong Institute of Gemmology, Hong Kong, for a jadeite butterfly from a Russian mine.

Wilma van der Giessen for a doubly terminating quartz crystal and packets of topaz and emerald crystals.

Susanna van Rose, Northwood, Middlesex. for a piece of talc from Luzenac, French Pyrenees.

Chen Hui-Mei, Taichung, Taiwan, R.O. China
Chen Shenqing, Shanghai, P.R. China
Cheng Mei Yun, Yangon, Myanmar
Cheung Yee Ming, Wesley, Hong Kong
Comar, Ankush, London
Cooke, Caroline, London
Corcoran, Moya A.M., London
Diment, Katharine L.C., Worthing, Sussex
Domenjod, Jean, Toulon, France
Douvis, George, Athens, Greece
Dwane, Christine, Montreal, Quebec, Canada
Fan Li, Shanghai, P.R. China
Fang Liang, Guilin, Guangxi, P.R. China
Faustmann, Alexandra, London
Goyal, Neha, Coimbatore, India
Greslin-Michel, Valerie, London
He Jiamu, Guilin, Guangxi, P.R. China
Htay Yin, Yangon, Myanmar
Hudson, Lawrence, London
Ito, Eiko, New Southgate, London
Jo, Midori, London
Kaung Nyunt Thar, Yangon, Myanmar
Knapp, Fiona, London
Kyam Myint, Yangon, Myanmar
Laing, Natasha, London
Liao Chun-Yan, Taipei, Taiwan, R.O. China
Liou Mun-Feng, Taipei, Taiwan, R.O. China
Long, Charles O., Richmond, Surrey
Long Chang Zheng, Guilin, Guangxi, P.R. China
Lu Ho Sheng, Taichung, Taiwan, R.O. China
Lu Zhiqing, Liu Zhou, Guangxi, P.R. China
Ma Li, Guilin, Guangxi, P.R. China
Ma Rui, Guilin, Guangxi, P.R. China
Maartens, Krÿn, Veghel, The Netherlands
Miu So Lim, Hong Kong
Moh Moh Win, Yangon, Myanmar
Molesworth, Helen, Rotherhithe, London
Mon Mon Myat Lwyn, Yangon, Myanmar
Murray, Jason, Longfield, Kent
Nakagawa, Eriko, London
Oaten, Lance I.H., Southall, Middlesex
Pajor, Matthias, Gelterkinden, Switzerland
Parmar, Sejal, Beckenham, Kent
Pwint Phue Lwin, Yangon, Myanmar
Rajap, Azeena, Beckenham, Kent
Seo Soo Hyang, Seoul, Korea
Shaw, Lisa A., Milnerton, South Africa
Shi Kai, Guilin, Guangxi, P.R. China
Sims, Amanda J., Stoke-on-Trent, Staffordshire
Soe Pa Pa, Yangon, Myanmar
Song Xiaohua, Guilin, Guangxi, P.R. China
Soucy, ReJeanne, Montreal, Quebec, Canada
Squires, Caroline A., Tring, Hertfordshire
Su Nan, Guilin, Guangxi, P.R. China

Sun I-Ching, Tracy, Harrow, Middlesex
Sutton, Collette S., Solihull, West Midlands
Tam Yin Yu, Hong Kong
Thackrah, Merle, Great Horkesley, Essex
Thein Lwin Oo, Yangon, Myanmar
Thi Han, Yangon, Myanmar
Toullic, Nathalie, Ealing, London
Tseng Ai Chen, Taichung, Taiwan, R.O. China
Turpeenniemi, Kalevi, Karesuvanto, Sweden
Wade, Tony T., Faversham, Kent
Wang Cheng-An, Taipei, Taiwan, R.O. China
White, Mark, York
Wong Kwok On, Hong Kong
Wong, Vina, Hong Kong
Wong Po Chun, Hong Kong
Wu Yu Yong, Shanghai, P.R. China
Xu Minyan, Guilin, Guangxi, P.R. China
Yedunath, R., Chennai, India
Zhu Ya Lin, Guilin, Guangxi, P.R. China

MEMBERSHIP

The following have been elected to membership during December 1999, and January and February 2000:

Fellowship and Diamond Membership (FGA DGA)

Baynes (neé Tose), Christine, Oldham, Lancashire. 1977/1982
Grey, Alan P., London. 1969/1970

Fellowship (FGA)

Chan Wai-Mang Eva, Annemasse, France. 1999
Dines, Rachel S., London. 1999
Horniblow, Kathy, Henfield, West Sussex. 1996
Jianqing Zhu, Shanghai, P.R. China. 1999
Jones, David M., Ascot, Berkshire. 1966
Li Rutian, Guilin, Guangxi, P.R China. 1999
Lin Wanxia, Guilin, Guangxi, P.R China. 1999
Liu Jiewen, Guilin, Guangxi, P.R China. 1999
Lopez Perez, Jose M., Sedavi, Spain. 1999
Qin Bin, Guilin, Guangxi, P.R China. 1999
Qiu Jian, Guilin, Guangxi, P.R China. 1999
Tezapsidou, Eleni, Thessaloniki, Greece. 1999
van Spaendonck, Anouk D., Amsterdam, The Netherlands. 1999
Vanderburgh, Amy E., Nobleton, Ontario, Canada. 1999
Zhou Wenhao, Guilin, Guangxi, P.R China. 1999

Diamond Membership (DGA)

Bhatia, Umesh, Faridabad, India. 1999

Ordinary Membership

Alonso Selma, Karina, Barcelona, Spain
Boehm, Edward, Solana Beach, California, U.S.A.
Boustany, Denise M., London
Cohen, Joseph, London
Cristol, Agata, Marseille, France
Dawoodjee, Suleiman, Edgware, Middlesex
Eensaar, Karin, Tallinn, Estonia
Fadlun, Lucy R., Hendon, London
Fish, Diane M.G., Kemnay, Nr. Inverurie
Fukui, Eriko, London
Gaynor, Geoffrey, Stamford, Lincolnshire
Hudson, Lawrence, London
Hyrsl, Jaroslav, Kolín, Czech Republic
Inegbenebho, Rosemarie, Holborn, London
Inoue, Mika, Setagaya-ku, Tokyo, Japan
Ito, Kayo, Gose City, Nara Pref, Japan
Jara, Gonzalo U., Bogota, Colombia
Kanai, Yoshiko, Osaka City, Osaka, Japan
Kuncovsky, Martin R., Cardiff, Glamorgan
Lai Tan-An, Larry, Taipei, Taiwan, R.O. China
Lemon, Alexander M., Hampstead, London
Longanza, Wayemba, London
Mabe, Kanako, Sakado City, Saitama Pref., Japan
Mamiya, Hiroko, Sakai City, Osaka, Japan
Matsuzaki, Riho, Taito-ku, Tokyo, Japan
Maulavé, Xavier R.L., Yangon, Myanmar
Miyazaki, Tomohiko, Takarazuka city, Hyog Pref., Japan
Murakami, Yuriko, Toyonaka City, Osaka, Japan
Nakayama, Akira, Higashi, Osaka, Japan
Narayanan, S.S. Laxme, Trichirapalli, Tamilnadu, India
Omote, Takahiro, Osaka City, Osaka, Japan
Ord-Hume, Christopher, Braintree, Essex
Pandor, Yunous Mohammed, Lusaka, Zambia
Ratiu, Alexandra, London
Rogers, Kevin, Topsham, Exeter, Devon
Saikyo, Kunihiro, Hirakata City, Osaka, Japan
Sasaki, Mayumi, Nagoya City, Aichi Pref., Japan
Saskai, Takako, Hirakata City, Osaka, Japan
Shand, David, Aberdeen
Shirasaki, Tadahiro, Fukui City, Fukui Pref., Japan
Stevenson, Pollyanna, London
Stubbs, Annaliese J.C., London
Tamimoto, Sakae, Ichikawa City, Chiba Pref., Japan
Tanaka, Keiichi, Osaka City, Osaka, Japan
Tolley, Elinor H., North Leigh, Oxfordshire
Tseng, Sue-Fay, London
Vodden, Ross John, Surbiton, Surrey
Wada, Natsuko, Takarazuka City, Hyogo Pref., Japan
Waghela, Sunita, London
Ward, Julie E., Upper Belvedere, Kent
White, Oliver L., London

FORTHCOMING EVENTS

28 April	**Midlands Branch.** ***Gwyn Green*** – *Treated gemstones*
28 April to 1 May	**Scottish Branch Millennium Conference, Perth.** *Keynote speaker:* ***Ken Scarratt***
4 May	**London.** *Famous diamonds and conceptual jewels.* ***John Nels Hatleberg,*** *New York, U.S.A.*
10-12 May	**London –** Kingston. User school in Raman analysis for gemmologists
18 May	**London.** *The Rose – nature's jewel as a decorative emblem.* ***Corinna Pike***
21 May	**Midlands Branch.** ***Memory Stather:*** *Sources of inspiration and samples of her work.*
	Gem identification with a 10 × lens.
5 June	**The Millennium Trade Dinner**. *Guest speaker:* ***Gary Ralfe,*** *Managing Director of De Beers.* Goldsmiths' Hall, London. Fully booked.
14 June	**London**. Visit to Treasures of the 20th Century exhibition
21 June	**North West Branch**. *Pocket sculptures – gemstone carving?* ***Memory Stather***
24 June	**Midlands Branch.** Summer supper
26 June	**London.** AGM, Reunion of Members, and Bring and Buy Sale
12 July	**London.** *Faceting revolution.* ***Roger Young***
30 July	**Midlands Branch.** Gem Play Group
27 August	**Midlands Branch.** Gem Play Group
20 September	**North West Branch.** *History of English watches from verge to lever.* ***Peter McIvor***
18 October	**North West Branch**. *Minerals and gems at the Great Exhibition of 1851.* ***David Lancaster***
29 October	**London.** Annual Conference
	Keynote speaker: ***Professor Al Levinson,*** *Calgary, Alberta, Canada*
30 October	**London.** Presentation of Awards
15 November	**North West Branch.** *AGM* followed by *Gem collection and anecdotes.* ***John Pyke Snr.***

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

PHOTO COMPETITION 2000

**The Light Fantastic:
optical effects in gems**

Members are reminded that the closing date for the 2000 Photo Competition is **30 April.**

Letter to the Editor

From Ian C.C. Campbell

De Beers synthetic diamonds

I refer to my recent article relating to six De Beers synthetic diamonds (*J.Gemm.*, 2000 **27**(1), 32-44). Access to information, new to me since having written that article, has caused me to amend my view relevant to the assumed nickel content in the two *near-colourless* De Beers synthetic diamonds reported on.

I have since been informed, on good authority, that there is not a presence of nickel in either of those stones – and that if there was, it would produce a green hue, not the colourless or near-colourless appearance seen in them. I am unaware of what metal catalyst was actually used by De Beers – this is understandably a sensitive issue – but based my assumption at the time on other reports of nickel catalysts being used which were allied to the selective electrical conductivity reported to be seen in different productions of colourless to near-colourless synthetic diamonds.

Boron is responsible for the blue colour in natural type IIb diamonds, which are semi-conductors of electricity as a result of it. I (and no doubt others) have also detected electrical conductivity in natural, *apparently near-colourless,* diamonds that contain *minute* traces of boron – insufficient to cause any noticeable blue colouring, but sufficient to produce electrical semi-conductors. One is thus forced to ask the question to what extent boron plays in the growth of these synthetic diamonds insofar as producing colourless to near-colourless stones? Current information appears to indicate colourless to near-colourless synthetic diamonds with electrical properties as being classified as type IIa. Obviously a more in-depth study is required in this context – which, unfortunately, I am unable to do in the context of these particular stones.

I do therefore apologize, as a result of the information received, for the apparent incorrect message I was unwittingly giving to the readers of this report, relevant to the nickel aspect. I will in fact be grateful for any additional information in this context from any researcher who will be willing to enlarge on what I have said above.

Ian C.C. Campbell
Independent Coloured Stones Laboratory
Randburg, Republic of South Africa

Pearls Coral Amber Bead Necklaces Carvings Cameos Mineral Specimens

Opal Precious Topaz Ruby Star Ruby Sapphire Star Sapphire Tourmaline

Gemstones Aquamarine Alexandrite Amethyst Emerald Jade Lapis-Lazuli

The World of Gemstones

Ruppenthal (U.K.) Limited

Gemstones of every kind, cultured pearls, coral, amber, bead necklaces, hardstone carvings, objets d'art and 18ct gold gemstone jewellery.

We offer a first-class lapidary service.

By appointment only
1a Wickham Court Road, West Wickham, Kent BR4 9LN
Tel: 020-8777 4443, Fax: 020-8777 2321, Mobile: 07831 843287
e-mail: roger@ruppenthal.co.uk, Website: www.ruppenthal.co.uk

Modern 18ct Gem-set Jewellery

The Journal of
Gemmology

Back Issues
SPECIAL OFFER

Extend your personal library by purchasing back issues of The Journal at discounted prices

Volume 26*
Usual price £10.00 per issue
SPECIAL PRICE: £8.00 per issue

Issues up to and including Volume 25*
Usual price £4.00 per issue
SPECIAL PRICE: £3.00 per issue

*Subject to availability

For details of issue availability and
an order form contact
Mary Burland at the GAGTL on
020 7404 3334 (Fax 020 7404 8843)

Offer ends 1 July 2000

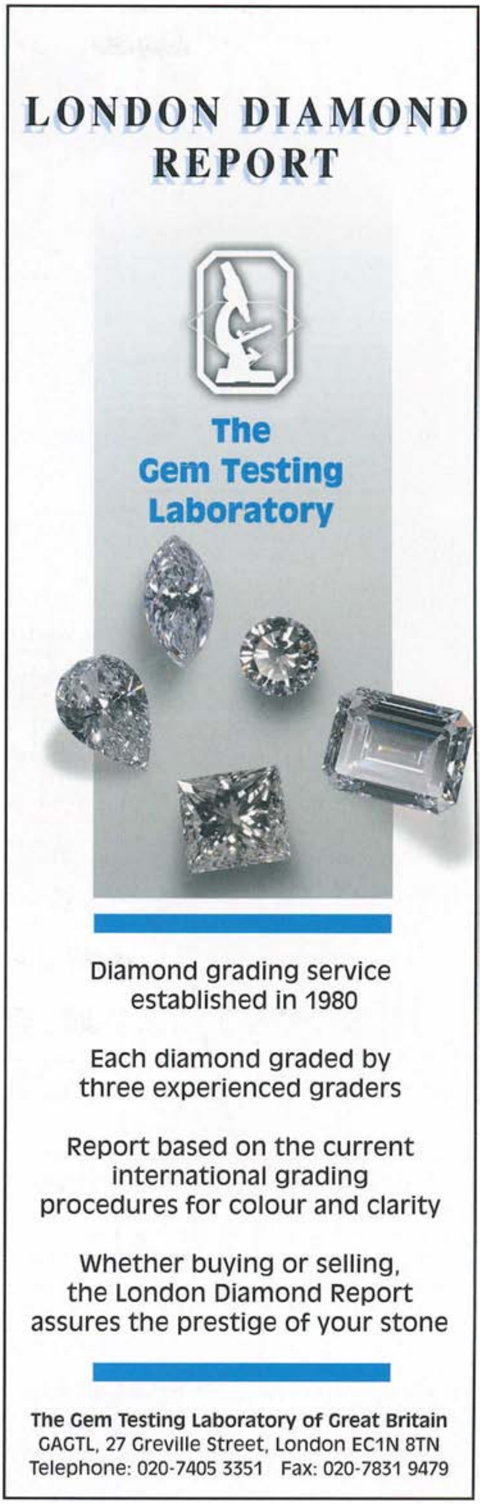
Museums,
Educational Establishments,
Collectors & Students

I have what is probably the largest range of genuinely rare stones in the UK, from Analcime to Wulfenite. Also rare and modern synthetics, and inexpensive crystals and stones for students. New computerised lists available with even more detail. Please send £2 in 1st class stamps refundable on first order (overseas free).

Two special offers for students:
New Teach/Buy service and free stones on an order.

A.J. French, FGA
82 Brookley Road, Brockenhurst,
Hants SO42 7RA
Telephone: 01590 623214


F.M. JEWELLERY



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

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

Typescripts Two copies of all papers should be submitted on A4 paper (or USA equivalent) to the Editor. Typescripts should be double spaced with margins of at least 25 mm. They should be set out in the manner of recent issues of *The Journal* and in conformity with the information set out below. Papers may be of any length, but long papers of more than 10 000 words (unless capable of division into parts or of exceptional importance) are unlikely to be acceptable, whereas a short paper of 400–500 words may achieve early publication.

The abstract, references, notes, captions and tables should be typed double spaced on separate sheets.

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

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

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

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

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

A **This is a first level heading**

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

B *This is a second level heading*

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

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

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

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

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

Notes and References Authors may choose one of two systems:

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

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

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

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

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

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

Volume 27 No. 2

Volume 27 No. 2

Contents

The Journal of
Gemmology

Registered Office: Palladium House, 1–4 Argyll Street, London W1V 2LD

ISSN: 1355–4565

Designed & Produced by Harley UK