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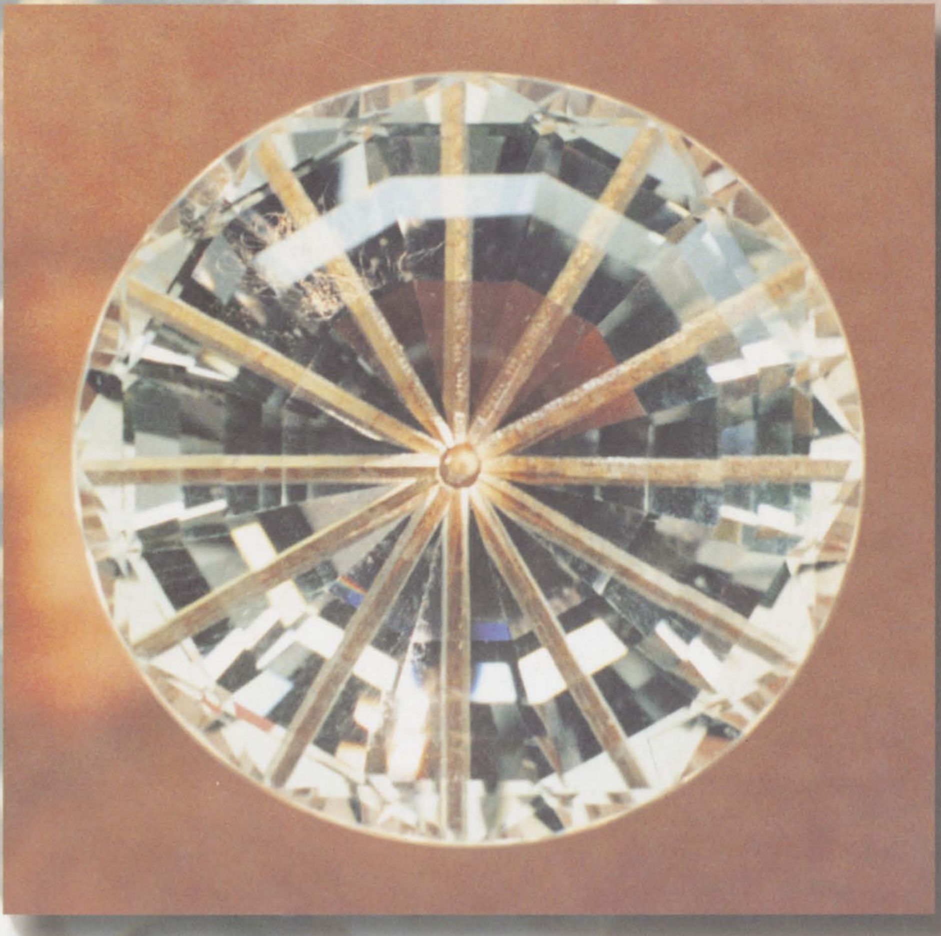

Spessartine
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Gems of
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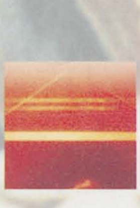

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A new find of spessartine garnets in Nigeria

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ABSTRACT: The physico-chemical and microscopic features of spessartine garnets from a new occurrence in Nigeria are presented. Chemical analyses show that these garnets have a very high spessartine component of 89-95% with varying small amounts of pyrope and almandine. Variation of the almandine component between 1% and 6% is responsible for a variation of colours between yellow, golden yellow and brown-orange. Absorption spectra of the yellow and golden yellow specimens (type a spectra) are very similar to those of spessartine from Kunene (Namibia), while those of brown-orange colour (type b spectra) are similar to those from Ramona (USA). The main inclusions in the Nigerian spessartines are healed cracks representing thin liquid-filled cavities or fingerprint-type feathers.

Keywords: spessartine garnet, Nigeria, physico-chemical properties, internal characteristics

Introduction

Spessartine garnets of gem quality are relatively rare compared to other species of the garnet solid solution series. Both quantity and quality of the material from different sources such as Ramona County, California, Macon County, Virginia, Minas Gerais, Brazil, Madagascar, Sri Lanka and Kenya, have been very erratic, and therefore spessartine garnets have been a collector's gemstone rather than a stone suitable for jewellery industry purposes.

This whole picture changed, when in 1992 an occurrence of spessartine garnet was discovered on the northern edge of Namibia, near the border with Angola (Lind *et al.*, 1993, 1994).

The material from this occurrence is of a fine, bright orange colour which is easily distinguished from all hitherto known spessartine garnets. These gem garnets were first designed as 'Kunene spessartine' after the boundary river between Namibia and Angola, but became widely known in the jewellery industry under the trade name 'mandarin garnet'.

Figure 1: *Cut spessartine garnet of 2.68 ct from a new occurrence in Nigeria.*

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Production from this source has been continuous, and has made spessartine garnets popular among gem dealers and jewellers. Unfortunately, sizes of cut stones generally are small, and faceted gems of more than 1 ct are already relatively rare. For sizes of 2-3 cts and up, a regular supply cannot be maintained, even at high prices.

Recently, a new source of gem quality garnets of fine yellow-orange colour was discovered in Nigeria, West Africa (Bank *et al.*, 1999). The material from this new occurrence complements the range of sizes available for fine orange spessartine garnets, as sizes of 2-3 ct and more can now be supplied to jewellers (*Figure 1*).

Refractive index and specific gravity

Refractive indices of 20 specimens were measured using a Rayner refractometer and fluid with an RI of 1.81 and the results varied between 1.801 and 1.803. Specific gravities measured using the hydrostatic method varied between 4.15 and 4.22.

Table I compares values of measured gemmological data for spessartine garnets from Nigeria with values for spessartine garnets from other occurrences described in the literature.

Table I: *RI values and SG values for gem quality spessartine garnets from Nigeria compared with published work.*

Locality	*n*	*SG*
Nigeria[6]	1.801-1.803	4.15-4.22
Rutherford Mine, Virginia[1]	1.802(3)	-
Taita Hills, Kenya[2]	1.795-1.809	-
Minas Gerais, Brazil[3]	1.803-1.805	4.15
Ramona, Calif.[4]	>1.81	4.17
Kunene, Namibia[5]	1.801-1.803	4.15-4.22

1. Sinkankas and Ried, 1966
2. Medenbach *et al.*, 1978
3. Bank *et al.*, 1970
4. Tisdall, 1962
5. Lind *et al.*, 1993, 1994
6. this work

Composition

Garnets are a group of minerals with extended isomorphous solid solution between its end members. Although solid solution of five and more components is common, usually 80% of the crystal is built up of only two or three main constituents, and all garnets can be broadly subdivided into the two solid solution series *ugrandite* (with end members uvarovite, grossularite and andradite) and *pyralspite* (with end members pyrope, almandine and spessartine).

Pyralspite garnets with spessartine being the main component are called spessartine in

Table II: *Microprobe analyses of spessartine garnets from Nigeria.*

	ligr324	*ligr325*	*ligr326*	*ligr327*
Wt%				
MgO	0.67	0.99	0.96	0.85
FeO	0.62	2.77	1.44	2.44
CaO	0.27	0.09	0.19	0.35
MnO	40.38	37.67	39.36	37.76
Al_2O_3	21.21	21.40	21.36	21.48
Fe_2O_3	0.00	0.00	0.00	0.00
V_2O_3	0.00	0.00	0.00	0.00
Cr_2O_3	0.07	0.03	0.05	0.02
TiO_2	0.07	0.01	0.08	0.09
SiO_2	36.68	37.04	36.55	37.02
Total	99.97	100.00	99.99	100.01
Mol%				
Pyrope	2.8	4.1	3.9	3.5
Almandine	1.4	6.5	3.3	5.7
Spessartine	95.0	89.1	92.1	89.7
Grossular	0.6	0.2	0.4	1.0
Uvarovite	0.2	0.1	0.2	0.1

the trade. Gem-quality spessartine garnets are usually members of two mainly binary solid-solution series:

1. spessartine-almandine series (pyrope and grossular < 10%);
2. spessartine-pyrope series (almandine and grossular < 15%);

(see Sinkankas and Ried, 1966, Bank *et al.*, 1970, Jobbins *et al.*, 1977, Medenbach *et al.*, 1978, and Lind *et al.*, 1993, 1994).

Compositions of spessartines from the new occurrence in Nigeria are shown in *Table II*.

Figure 2 shows the position of investigated samples from the new occurrence within the composition triangle of pyralspite garnets, together with analyses of garnets from pyrope-spessartine solid solution series from the literature and unpublished data of Lind (1999, in prep.)

As can be seen from this diagram, the garnets from the new occurrence in Nigeria have very high spessartine contents of 89-95%, with varying small contents of both pyrope and almandine.

Figure 3 shows typical visible absorption spectra of specimens with low almandine content (a) and high almandine content (b). Spessartines of spectra type (a) show yellow-golden colour, while type (b) spectra are typical for stones of more brownish-yellow colours.

Type (a) spectra are dominated by spin forbidden bands of $Mn^{2+[8]}$. Type (a) spectra are very similar to those of Kunene material (Lind *et al.*, 1993, 1994), although extremely weak $Fe^{2+[8]}$ bands can also be identified.

Type (b) spectra show bands of $Mn^{2+[8]}$ and $Fe^{2+[8]}$, which are superimposed on a strong charge transfer band system, which causes continuously increasing absorption from the red part of the spectrum towards the ultraviolet region, and which is the reason for the brownish-yellow colour of these spessartines. Type (b) spectra resemble those of material from Ramona.

Positions of absorption bands are given in *Table III*.

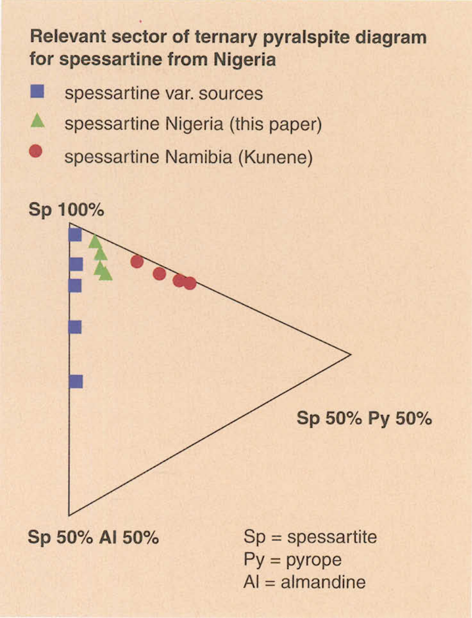

Figure 2: *Relevant part of ternary pyralspite diagram for spessartine garnets from different sources and from the new find in Nigeria.*

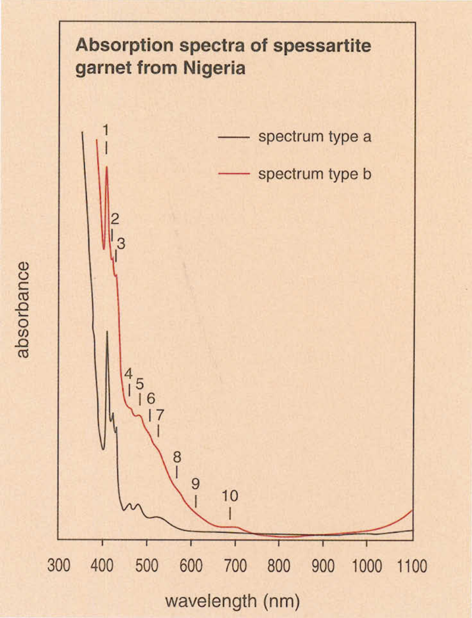

Figure 3: *Absorption spectra of spessartine garnet from Nigeria. Numbers refer to bands listed in Table III.*

Figure 4: *Healed cracks in spessartine from Nigeria.*

Internal features

The main inclusions in the Nigerian spessartine garnets are healing-cracks representing thin liquid-filled cavities or fingerprint-type feathers *(Figure 4)*. A distinct tabby extinction is visible under crossed polarizing filters *(Figure 5)*. The tiny black inclusions and hollow-tubes which are typically present in Namibian spessartines have not been found.

Table III*: Absorption bands (nm) in spessartine from Nigeria (this work) compared with those in Namibian stones (Lind et al., 1993, 1994)*

Band	*Spessartine Nigeria [nm]*	*Spessartine Namibia [nm]*	*Assignment*
1	406	408	Mn^{2+}
2	420	420	Mn^{2+}
3	428	430	Mn^{2+}
4	457	457	Mn^{2+}
5	480	483	Mn^{2+}
6	503	n.f.	Fe^{2+}
7	524	527	Mn^{2+}, Fe^{2+}
8	566	n.f.	Fe^{2+}
9	566	n.f.	Fe^{2+}
10	607	n.f.	Fe^{2+}
11	686	n.f.	Fe^{2+}

Figure 5: *Tabby extinction visible under crossed polarizing filters.*

Conclusion

Chemical analyses and absorption spectra show that the spessartine garnets from the new occurrence in Nigeria fall between the binary series spessartine-almandine and spessartine-pyrope. Variation of the almandine component between 1% and 6% is responsible for the variation of colour between yellow, golden-yellow and brown-orange with the latter containing the higher almandine component.

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Imperial topaz from Ouro Preto, Brazil: chemical character and thermal behaviour

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ABSTRACT: Imperial topaz from two mining fields near Ouro Preto have been investigated by thermal analysis and X-ray diffraction. It was found that no changes in the composition occurred on heating up to 1000°C, but the colour changed from reddish-brown to colourless. A first loss of mass, ascribed to the release of OH groups occurs at about 1200°C, and a second loss occurs at 1320°C at which mullite was formed.

Keywords: Imperial topaz, thermal stability

Introduction

The mineral topaz is a fluorine aluminium silicate, with chemical formula $Al_2SiO_4[(OH)_{1-x}F_x]_2$, where the hydroxyl group can replace fluorine up to ~ 30 mol% (Barton, 1982). A fully hydrated topaz has been recently synthesized at high temperatures and pressures (Wunder *et al.*, 1993).

There are two major types of geological occurrences of topaz producing precious stones: (a) pegmatite, and (b) hydrothermal veins in carbonate rocks. In the first case, the topazes are associated with minerals such as quartz, feldspar, muscovite and cassiterite. The colours of these topazes are pale blue, pale green, colourless or, rarely, pale yellow. The topazes from pegmatites are known as common topaz or simply topaz, are common in weights more than 1 kg and may attain 100 kg. As there are many occurrences of this mineral in the world, it is considered a common gem.

In the second case, topaz from hydrothermal veins can be associated with quartz, dolomite, and sometimes, in smaller amounts, muscovite, hematite, euclase, and rutile. Topaz from hydrothermal veins can be found in a broad range of colours including orange-yellow, brownish-orange, orange-pink, violet, and, rarely, as green or colourless. Except for the green and colourless topaz, these variations are called imperial topaz. The crystals of imperial topaz usually weigh less than 200 g, and, only very rarely have these crystals been found with a weight exceeding 1 kg.

In fact, imperial topaz is rare, and, today, mining of this mineral is taking place only in two localities in the world. One is Chundao Hill, in Pakistan, and the other is near the historic town of Ouro Preto, Minas Gerais, Brazil.

The two most important mining sites of imperial topaz in Ouro Preto are Capão, and Vermelhão. These mines and the characteristics of their imperial topaz varieties have been described elsewhere (Olsen, 1971; D'Elboux and Ferreira, 1975; Cassedanne and Sauer, 1987; Menzies, 1995; Sauer *et al.*, 1996).

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The typical colours of imperial topaz from the Ouro Preto area range from yellow-orange to reddish-brown. Some of the reddish-brown crystals can be heat treated to pink, which is appreciated in the gem market. The heat treatment of imperial topazes from Ouro Preto has been performed at a few mines (Sauer *et al.*, 1996), and has also been a subject of scientific research (Sabioni *et al.*, 1997). This work was performed in this context, and deals with the study of the chemical and thermal behaviour of imperial topaz during heating. The chemical composition and structure changes are investigated, and a chemical formula for the Capão topaz is calculated.

Materials and methods

Topaz samples

This work was performed using two samples from the Capão Mine (samples C1 and C2) and two samples from the Vermelhão Mine (V1 and V2). The two samples from each mine were orangy-yellow and brownish-red as shown in *Figure 1* for the samples C1 and C2.

The refractive indices of these imperial topazes lie in the ranges α, 1.629, ß 1.632 and γ1.637, and the specific gravity is about 3.54.

Figure 1: *Orangy-yellow and brownish-red imperial topazes from the Ouro Preto region (samples C1 and C2). Actual size. (Photo by A. Liccardo.)*

Chemical and thermal characterization

Typical values for transition metal elements found in these topaz varieties are shown in *Table I*, and the most significant variation is related to the chromium content. Chromium is a chromophore and its amount increases from the orangy-yellow topazes to the brownish-red varieties. The elements V and Ni are also chromophores and may play some role in the topaz colour.

Fourier-transform infrared spectra (FTIR) were collected in a Nicolet spectrophotometer in order to characterize the presence of hydroxyl groups in both natural and thermally treated samples. The pellets were prepared by grinding about 1 mg of the sample with 100 mg of KBr.

The water content of the topaz was determined by titration using the Karl-Fischer method after heating at 1200°C. The principle of this method is described elsewhere (Skoog *et al.*, 1992).

Powder X-ray diffraction patterns (XRD) were taken to check the effect of the thermal treatment on the topaz structure, and for the determination of the fluorine content. The diffractograms were collected by using a Rigaku Geigerflex diffractometer with Cu Kα radiation and a graphite monochromator. The scans were done in the range of 15° - 70° (2θ) at a speed of 1° min^{-1}. For the quantification of fluorine the method proposed by Ribbe and Rosenberg (1971) was used. This method is based on the shift of the (021) topaz diffraction line, which was shown to be proportional to the fluorine content. For these experiments, sodium chloride was mixed with the samples and the scans were done in the rate of 26° - 33°C at a speed of 0.25° min^{-1}. Peak positions were determined by fitting the numerical profiles with a Pearson VII function.

Simultaneous thermogravimetric analysis (TGA) and differential thermal analysis (DTA) were performed in a Du Pont SDT2960 module. The temperature ranged from 25°C to 1380°C, using a constant flow of nitrogen or synthetic air (100 ml/min) and a heating rate of 10°C/min. All runs were

Table I: Contents of transition metal elements (ppm) and fluorine (%) in imperial topazes

Sample	Colour	Fe	Mn	Cr	V	Ni	Co	F
C1	Orangy-yellow	2150	<10	280	116	22	<5	18.0
C2	Brownish-red	3100	<10	660	114	12	<5	16.2
V1	Orangy-yellow	5000	46	160	60	15	<5	17.1
V2	Brownish-red	4400	40	380	56	10	<5	15.1

performed with powders as well as with crystals about 3 mm in size.

Results and discussion

Chemical characteristics

The fluorine contents were first determined using the specific ion electrode method at a commercial laboratory, but the results were much lower than those predicted by the chemical formula of topaz. The reason is assumed to be associated with the method of preparation of the samples for this type of analysis. Therefore an alternative method based on X-ray diffraction was used to estimate the fluorine contents. According to the method, proposed by Ribbe and Rosenberg (1971), the fluorine content in topaz is given by:

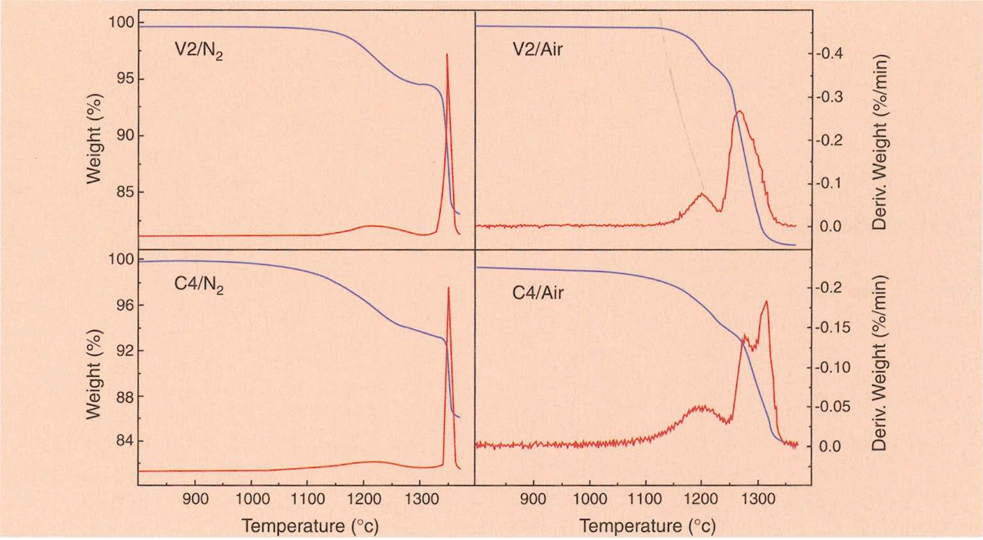
$$(\%\ \mathrm{F}) = 155.6 - 35.7\ \Delta_{021},$$

where $\Delta_{021} = 2\theta_{\mathrm{NaCl}\ 200} - 2\theta_{\mathrm{topaz}\ 021}$ and is measured in degrees.

The results obtained for the fluorine contents in the topaz samples C1, C2, V1 and V2 are listed in *Table I*. The total error, considering an uncertainty of about 0.05° in Δ_{021}, is about 1%.

The water contents of samples C1 and C2, were determined using the Karl-Fischer method and gave results of 1.73% and 1.84%

Figure 2: *Thermogravimetric curves of topaz samples from Capão and Vermelhão mines.*



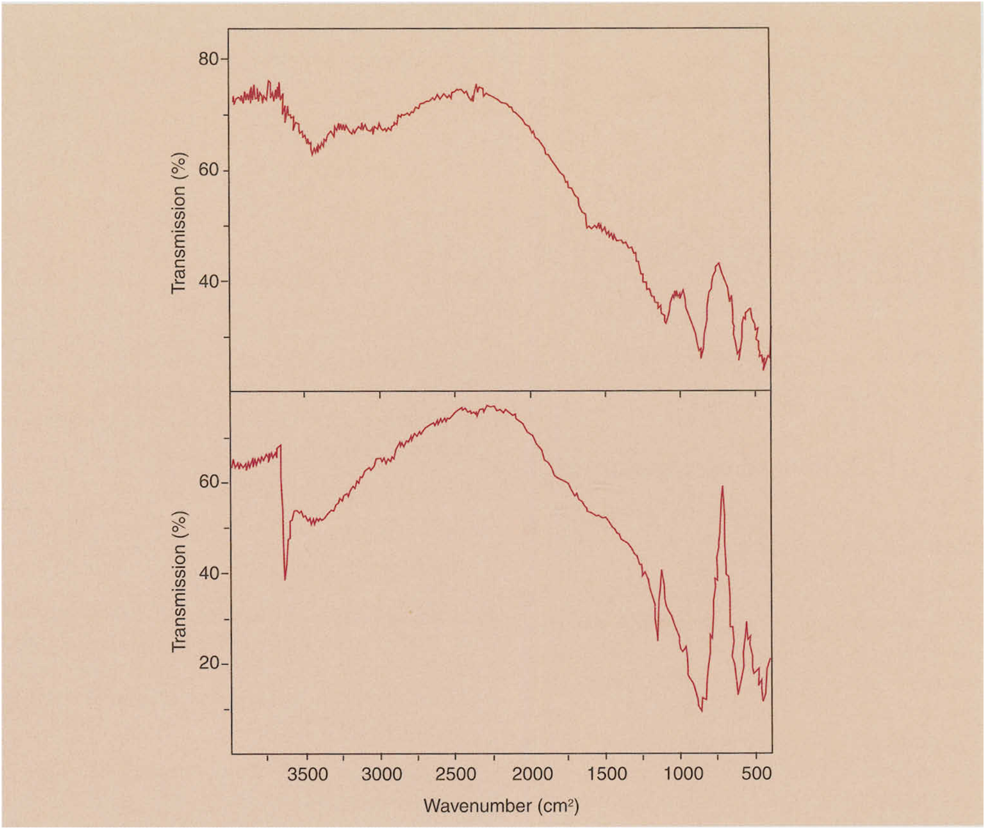


Figure 3: *Infrared spectra of sample V2 before (bottom) and after thermal treatment at 1230°C (top).*

respectively. Using the above results for the F and H_2O contents in the samples from Capão Mine, it was possible to deduce the value x~0.80 in the chemical formula $Al_2SiO_4[F_x(OH)_{1-x}]_2$. This result is similar to the value of 0.75 reported by Barton (1982) for a topaz sample from Ouro Preto.

Thermal characteristics

Typical thermogravimetric curves of samples from Vermelhão (V) and Capão (C) in different atmospheres are shown in *Figure 2*. A common feature for all samples is the thermal stability up to temperatures of 1000°C. All samples show an endothermic loss of mass of about 5% in the vicinity of 1200°C, and a second endothermic loss ranging from 8% to 15% at temperatures about 1320°C.

The atmosphere used in the experiments plays an important role in the overall shape of the thermogravimetric curves, but the loss of mass is generally not so affected. In some samples the high temperature peak clearly splits in two depending on the atmosphere used. All these results show that the interpretation of these curves is not straightforward, and only a general proposition can be made at this stage: the low temperature peak is due to the loss of OH groups, probably as water, or as $Si(OH)_4$, whereas the other one is due to the loss of fluorine.

Further evidence that the first loss of mass at about 1200°C is due to the release of OH groups was found from the following experiment: the TGA was repeated for sample V2, but the run was interrupted at

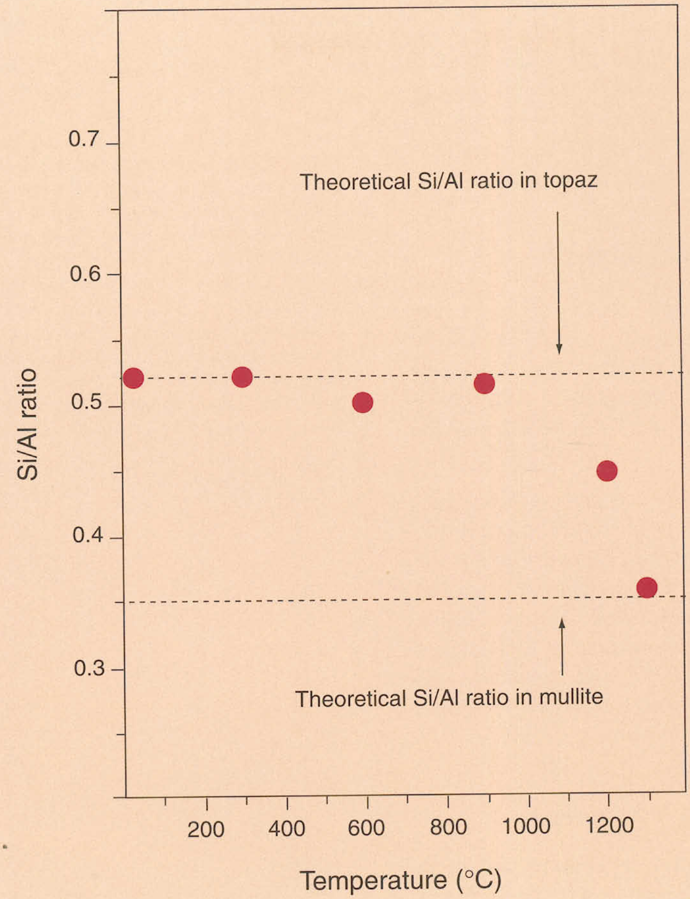


Figure 4: *Effect of the thermal treatment on the Si/Al ratio of sample CI.*

1230°C (air atmosphere). The infrared spectra of both the original and heated sample were collected, and are displayed in *Figure 3*. The sharp peaks at 3460 cm^{-1} and 1166 cm^{-1} are attributed to the stretching and bending modes of OH groups (Shinoda and Aikawa, 1997), and these peaks are clearly reduced in the heated sample. However, the loss of about 5% of mass is not in agreement with the value determined from both the Karl-Fischer method (H_2O) and XRD (fluorine), and therefore it is likely that more than one reaction is taking place at this temperature.

From the above discussion it is seen that the mechanism for the thermal decomposition of topaz in not yet clear. The product obtained after heating the sample at 1380°C was identified by XRD as mullite ($Al_6Si_2O_{13}$), which means that silicon has been released from the topaz structure, perhaps as SiF_4.

This assumption is corroborated by *Figure 4*, where the Si/Al ratio for identical topaz samples from Capão mine was plotted after heating from room temperature to 1380°C, during one hour, in an air atmosphere. It is seen that the Si/Al ratio approaches that of mullite as the annealing temperature increases, in good agreement with the results obtained by XRD.

Concerning the colour changes of the

topaz samples during the thermal analysis, it was found that up to 300°C no change in the reddish-brown or orangy-yellow topaz occurs. However, at 600°C a pink colour developed, which disappeared after further heating at 900°C. At higher temperatures a white and opaque material was formed.

Conclusions

Imperial topazes from Ouro Preto have been chemically and thermally characterized. From determination of F and OH contents, a representative formula of $Al_2SiO_4[F_{0.8}(OH)_{0.2}]_2$ was calculated for the Capão topazes.

Thermogravimetric studies indicate that heating of topaz up to 1000°C apparently causes no change in the composition, but the colour changes from reddish-brown or orange-yellow to colourless. A first loss of mass, ascribed to the release of OH groups occurs at about 1200°C, and a second loss occurs at 1320°C. At this temperature, mullite is the only crystalline phase present.

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Somaliland – a potential gem producer in the Mozambique Belt

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ABSTRACT: Gem-quality minerals such as emerald, ruby, sapphire, aquamarine, garnet and amethyst have been found recently in Somaliland. The majority of the gemstones are derived from pegmatitic host rocks, which are related to late granite intrusions in the Mozambique orogenic belt. The pegmatites occur in an east-west zone through the centre of Somaliland. Where pegmatites cross-cut biotite and amphibole schists, emeralds may occur, whereas when pegmatites cross-cut migmatites and granite gneisses, aquamarines are more common. Not all the gemstones described have been collected from production sites, and minerals such as rubies, sapphires, opal and pyrope or almandine garnet are likely to have originated from a range of different rock types. Most gemstones are being extracted from solid unweathered rock and recovery methods are unsophisticated.

The importance of gems in the Mozambique orogenic belt has previously been noted within Kenya, Tanzania, Sri Lanka, India and Madagascar. The recognition of the extension of the Mozambique belt into Somaliland is therefore of considerable interest as it means there is potential for the production of a wide-range of gemstones, and this remains to be fully assessed.

Keywords: amethyst, aquamarine, emerald, extraction, garnet, geology, Gondwana, Mozambique Belt, opal, pegmatites, sapphire, Somaliland, titanite, vesuvianite, zircon

Introduction

The discovery of gemstones in Somaliland and their subsequent recovery only began in 1990. It is surprising, considering the widespread distribution and range of gemstones, that they were not noted previously during the excellent field mapping undertaken by the Geological Survey Department during colonial rule. Sustainable development of natural resources is being investigated and the gemmological potential of Somaliland may provide an important income generation in this country where many will earn only $10 per month. This article presents more detailed information than appeared in a preliminary note introducing Somaliland as a new gem source. (Kinnaird, 1999). It is based on mineral samples shown and donated by various mining groups and is not necessarily representative of the types

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of material, or the quality of stones available. It also emphasizes that the majority are derived from pegmatite host rocks.

Location and access

Somaliland lies in the Horn of Africa. It is a hot country with a varied scenery ranging from upland plateaux to forested mountainous regions and a hot coastal plain fringed by white sands. On independence in 1960, the British protectorate joined with the Italian protectorate to form the new State of Somalia, but civil war between the two factions soon followed. Despite the declaration of independence in 1991 and the restoration of NW Somalia as Somaliland, there have been local disputes and occasional upsurges in clan-related violence. Generally however, it is now quite safe to visit most gem-bearing areas, although their remote location, coupled with local suspicion, means that an arranged guide from the appropriate area is essential, and permission from the Ministry of Water and Minerals should also be sought. Access into any area is by four-wheeled drive vehicle, which can be hired in the capital Hargeisa. Hire includes a driver who can act as an interpreter. Roads have suffered badly during the war, and few bridges remain intact, which requires deviations through stream valleys. Only the main roads from Hargeisa to Berbera, Hargeisa to Borama and Hargeisa to Sheik are in relatively good condition, the remainder are dirt roads of poor quality. To reach the emerald-bearing localities to the north of Bawn, for example, requires a ten-hour return journey by road from Borama. Also, individual localities may be a long walk or climb from access tracks as the gem localities are often in mountainous terrain. The difficulty of access means that the miners must camp away from their home village.

Variety of gemstones

During a visit to Somaliland, a number of minerals were shown to one author (JAK) by collectors and traders in Hargeisa, Borama, Berbera and Sheik. These vary from common low-value minerals like garnet and amethyst and rarer mineral species, to minerals such as emerald, ruby, sapphire and aquamarine (*Table I*), which contain a proportion of gem-quality material that has definite potential for the overseas market.

Table I: *Minerals from Somali pegmatites, or in the collections of miners and traders.*

Silicate	*Non-silicate*
beryl: aquamarine	apatite
emerald	cassiterite
diopside	chalcopyrite
epidote	chrysoberyl
garnet: pyrope	corundum: ruby
almandine	sapphire
grossular	hematite
hornblende	pyrite
opal	rutile
quartz varieties (including amethyst and rock crystal)	spinels ('pleonaste')
titanite	
topaz	
tourmaline	
zircon	

Other mineral varieties like phenakite, alexandrite and heliodor were reported though were not seen, and it is unwise to place too much reliance on local gem identification as most producers or traders are only just beginning to learn to identify the minerals. Occurrences reported as 'tanzanite', either turned out to be purple fluorite or lilac vesuvianite. Similarly, a supposed emerald from a gem-producing area was found to be quartz coloured green by secondary copper minerals. Green epidote and diopside are frequently confused as tourmaline or peridot. Unfortunately, there is also a widespread belief among the inhabitants that there is an abundance of diamonds in the country. This is based on the mis-identification of quartz by certain traders using gem-testing equipment incorrectly. The abundant small quartz crystals common in small cavities in rocks are called 'sugar-diamonds' by these traders.

Geology and occurrence

The geological history spans a long period of time even by geological standards. The oldest rocks are more than 1800 Ma (Kröner *et al.*, 1989), whilst basaltic flows have erupted in the last 30 Ma with the opening of the Gulf of Aden. It is possible that rare rhyolite horizons within these basalts may be the source of opals which are being mined in NW Somaliland. The extensive Mesozoic and Cenozoic sedimentary succession deposited in the last 200 million years does not contain gem minerals.

The crystalline basement of Somaliland crops out at the surface in a discontinuous belt about 600 km long and 30 km wide, running parallel to the Gulf of Aden and covering an area of around 30,000 km^2 *(Figure 1)*. It comprises an older Precambrian crust in the west, which has been through several geological events, and a simpler Pan-African terrain in the eastern sector which has evolved in one geological period from around 700-500 Ma. Altogether, the basement consists of five metasedimentary sequences interrupted by two different phases of igneous activity *(Table II)*. Single zircon age dates on samples from the Hargeisa-Sheik-Burao area give very precise ages for these rocks (Kröner and Sassi, 1996).

The Palaeoproterozoic Qabri Bahar Complex was originally dominantly sedimentary sandstones and mudstones. These were metamorphosed and deformed several times. In contrast, the overlying Mora Complex (Gebile, Borama and Mora Series)

Figure 1: *Geological map of part of the northwestern Somaliland, showing the older rocks of the Qabri Bahar and Mora Complexes, and the Neoproterozoic rocks of the Mozambique orogenic belt, with important pegmatite localities. The younger rocks shown in yellow are Jurassic, Cretaceous and Tertiary sandstones, siltstones, limestones, evaporites and Tertiary to Quaternary basalts.*

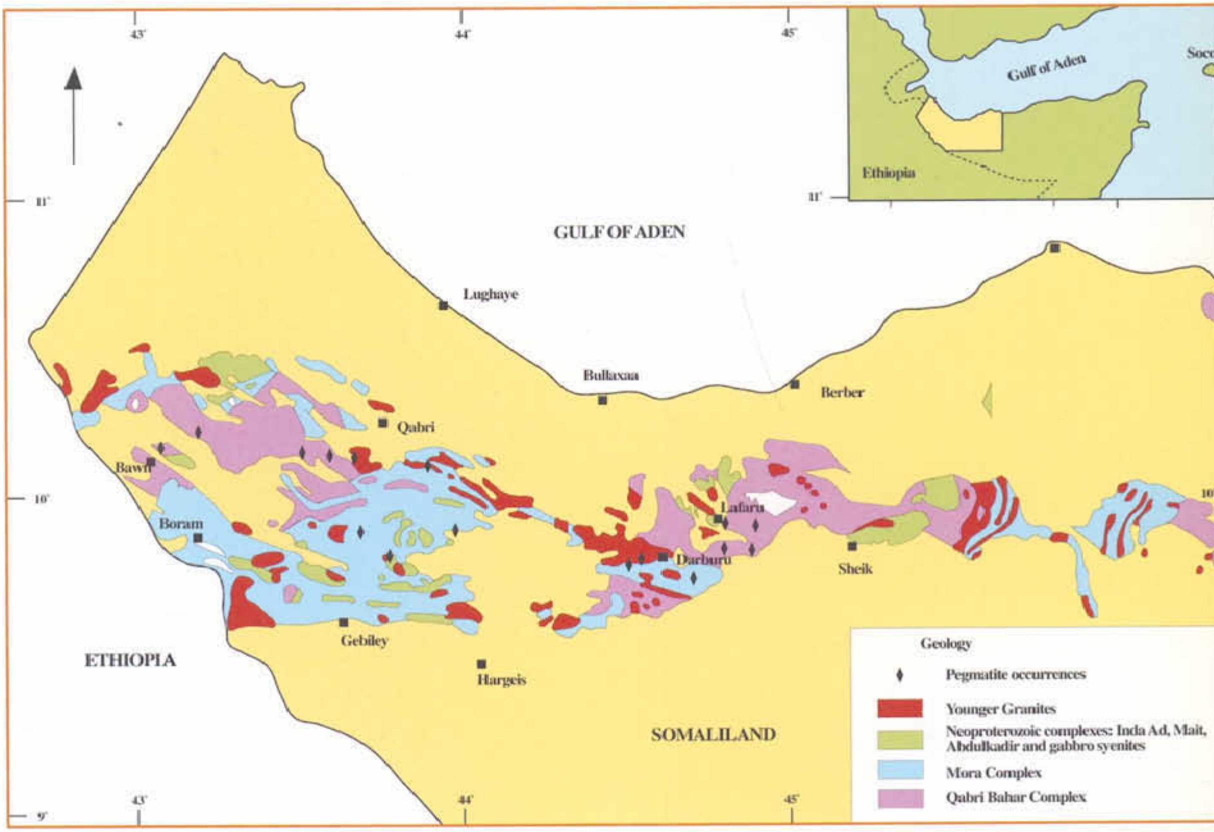


Table II: The subdivisions of the Somaliland Basement.

Chronometric subdivision	*Complex*	*Age*	*Lithologies*
Cambrian	Younger granite complexes	500 – 550 Ma (S)	Unfoliated subalkaline to alkaline granites with aplites and pegmatites; massive to foliated calc-alkaline granites.
Cambrian	Inda Ad Complex	500 – 550 Ma (S)	Low to very low grade metasedimentary turbiditic sequence of conglomerates, sandstones, silts and mudstones. The sequence has been interpreted as molasse sediments derived from erosion of a volcanic arc in Saudi Arabia (Abbate *et al.*, 1985).
Neoproterozoic	Mait Complex	640- Ma (S)	Pillow to massive basalts and associated deposits, muds and sands and occasional carbonate units which have been metamorphosed to greenschist facies to form a greenstone belt.
Neoproterozoic	Abdulkadir Complex	640 ± 67 Ma (S) 772 ± 40 Ma (S)	Volcano-sedimentary sequence with greenschist facies pelites and acid and basic volcanics which were deposited unconformably on the older Mora Complex (Warden and Daniels, 1983). Most of the contacts appear to be faulted.
Neoproterozoic	Gabbro-syenite	~700 Ma (F) 778 – 814 ± 7 Ma (K&S)	Deformation and low-grade metamorphism. Granitoid magmatism 720 Ma (K&S) to 697 Ma (Sassi *et al.*, 1989). Gabbros, diorites and syenites (778 – 814 ± 7) emplaced at a relatively high crustal level during crustal extension (Abdalla *et al.*, 1996) early minor alkaline granites at 842 ± 4 Ma (K&S).
Mesoproterozoic	Mora Series	1400 Ma	Dominantly marbles with metaquartzites and pelite intercalations.
?Mesoproterozoic	Borama-Ubali Pelitic Series (F)		Pelites with intercalated amphibolites.
?Mesoproterozoic	Gebile Psammitic Series (F)		Dominantly psammites with minor amphibolites, schists and marbles (Warden & Horkel, 1984).
Palaeoproterozoic	Qabri Bahar Complex	1710 Ma-1822 ± 5 Ma (K&S) migmatised at ~ 840 Ma	Medium to high grade, polymetamorphic basement of migmatites, gneisses, paragneisses, granite gneisses, amphibolites and rare calc-silicate rocks. Relics of granulite facies remain within a dominant amphibolite facies metamorphism retrograded to greenschist facies.

N.B. The terminology used is that of the Geological map of Somalia (1994), Frizzo (1993) (F in table), Warden and Horkel (1984). Age data from Sassi *et al.* (1989) (S in table) and Kröner and Sassi (1996) (K&S in table). The ages are not necessarily the complete time span of the series shown, but give ages of samples dated from the sequence. Chronometric subdivisions are from the International Commission on Stratigraphy (Plumb, 1991).

is dominated by carbonates with some sandstones and mudstones, which do not appear to have undergone the same multiphase deformation events. Field evidence suggests that the Mora Complex is in tectonic contact with the Quabri Bahar and the migmatites separating these two complexes are interpreted as a high strain zone. The Mora and Qabri Bahar Complexes were intruded by gabbro-syenite bodies (Daniels *et al.*, 1965) about 700 Ma ago (Ferrara *et al.*, 1987; Kröner and Sassi, 1996).

A second phase of plutonism affected the whole Precambrian basement in the period 550-500 Ma with the intrusion of two granitic series: an older, sometimes foliated series affected by a late orogenic deformation and a younger post-orogenic group which has associated aplitic and acid pegmatite intrusions (*Table II*). These pegmatite intrusions (very coarse-grained igneous rocks) are widespread (*Figure 1*) and are the main source-rocks of the gemstones found in Somaliland.

Pegmatites occur in two sectors in an east-west zone (*Figure 1*). In the western sector, which is approximately 30 km wide by about 100 km long, and extending from Bawn to northwest of Hargeisa, pegmatites cross-cut biotite and amphibole schists of the Mora Complex. The eastern sector lies between Hargeisa and Berbera, and is approximately 30 km wide and 50 km long (*Figure 1*). These pegmatites cross-cut migmatites, granitoids and paragneisses of the Qabri Bahar complex. Elsewhere scattered pegmatites occur, e.g. in the highest part of the Sheik pass south of Berbera, numerous pegmatites cross-cut the basement and comprise quartz, microcline and muscovite, with neither ores nor gem minerals.

The pegmatites occur in swarms, with individual bodies typically between 1 and 3 m wide and 100-200 m long, although the largest may exceed 1 km in length. Generally, they have a dyke-like form, dipping 70° to vertical, typically oriented NW-SE, NE-SW and N-S, sub parallel to the main faults. Irregular masses and pegmatitic sheets also occur but are less common than dykes.

Although most of the gemstones are recovered from the pegmatites, rubies and sapphires probably also occur in basalt flows in the Molis area, 50 km north of Hargeisa, although it proved logistically impossible to visit the locality. The opals, by analogy with the Ethiopian occurrences may come from rhyolite horizons within young volcanic rocks.

Pegmatite petrology

The majority of the pegmatites have a simple mineralogy comprising quartz and microcline with minor accessory muscovite, but some of the pegmatites are more complex and are clearly zoned. In the Hargeisa and Borama district these zoned bodies have an inner core of white quartz, which is typically several metres wide and up to 100 m long, surrounded by coarse-grained quartz, K-feldspar, albite and muscovite sometimes with accessory beryl and columbite, or garnet or zircon. There may be an outer zone of feldspar intergrown with wedge shaped quartz. Although the core widens at depth, beryl disappears. In some pegmatites the quartz core is transparent rock crystal which has potential for its piezo-electric nature, and

Figure 2: *Gem-bearing pegmatites can be seen on the hillside near Heiwena as thin white cross-cutting bands. Eastern Daarburuq-Larfarug pegmatite area.*

Figure 3: *Working in an aquamarine-bearing pegmatite near Heinwena with an iron bar, the only tool available at the site apart from a pick-axe.*

in the period 1977-78, at one locality, 200 tonnes of pure quartz were extracted from a trench 5-6 m deep. In other pegmatites, coarse crystalline amethyst may occur in vugs in the central core, associated with smoky quartz.

Clearly, the pegmatites are of more than one type. For example, in the Aliheley area north of Bawn, there are two types exposed, one of which is very white, quartz-poor, saccharoidal feldspathic pegmatite with emerald and aquamarine, while the other is pink, coarser-textured, more quartz-rich with accessory coarse zircon and garnet.

Figure 4: *View across an emerald site at Aliheley, north of Bawn. This was the only site visited with a compressor and a range of equipment.*

Recovery of the gem-quality minerals

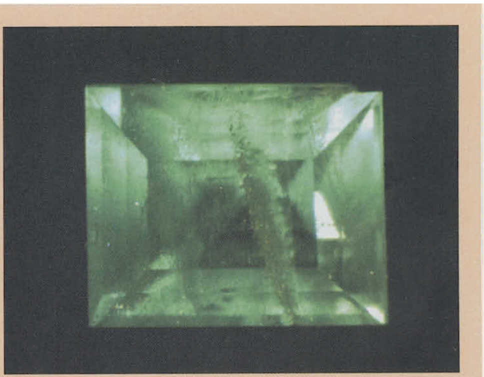
Most gemstones in Somaliland are being extracted from solid unweathered rock, often with primitive tools such as pry bars made from car axles (*Figure* 3). Extraction is all the more difficult because the pegmatites are very hard and have not undergone the process of albitisation like the gem-bearing pegmatites in Nigeria for example, which has rendered the feldspar soft and crumbly. Explosives are hardly available, and only in one locality of more than 30 visited, was a compressor being used (*Figure* 4). Extraction is extremely hard work, and as money is so very limited, even protective gloves are too expensive to buy. The open pits are typically less than 5 m deep and recovery is by simple hammering and hand-picking of the crystals, many of which are damaged in the process. Any production estimates of the gemstone varieties would at present be very speculative.

Description of minerals and gemstones from Somaliland

Beryl

Beryl occurs as euhedral crystals up to 1 m long and 30 cm across. It appears that wherever milky white quartz occurs in large masses, beryl is also present. Only small parts of many beryl crystals are transparent, but some are zoned with a blue core and

Figure 5: *Emeralds being extracted at Aliheley. Stringers of pegmatite facies form fingers into the friable black biotite-schist. The majority of emeralds occur within the schists close to the contact with the pegmatite band or the pegmatitic fingers.*

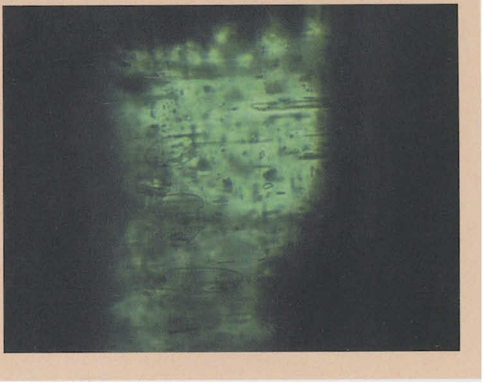


Emeralds from Aliheley

Figure 6 (above): *Mid-green emerald partly covered with flecks of phlogopite.*

Figure 7 (above right): *A cut emerald weighing 0.15 ct showing two-phase growth disturbance swathes.*

Figure 8 (right): *Rounded phlogophite inclusions in emerald.*



white rim. Green varieties occur on the margin of the pegmatites, while blue beryl occurs in the quartz core.

Emeralds have been encountered in pegmatites in both the western pegmatite sector, and in the eastern Lafarug sector. However, emeralds are much more abundant in the west where pegmatites cut biotite and amphibole schists of the Mora Complex than in eastern Daarburug-Lafarug pegmatite belt, where the pegmatites cross-cut the Qabri Bahar complex. The chromophores (chromium, and more rarely vanadium), that are responsible for the coloration of emerald are of low concentration in pegmatitic fluids, and these colouring agents are more likely to have been derived from the mafic-ultramafic basement, so it is where the pegmatites cut biotite-rich schists of the Mora Complex that the emerald localities are more common. In the Aliheley area northwest of Bawn, near the Djibouti road, where there are two types of pegmatites; the emeralds appear to be associated with the later, whitish pegmatites. Stringers of this pegmatite facies form fingers into the friable black biotite-rich schist *(Figure 5)* where the emerald crystals often have a thin coating of phlogophite *(Figure 6)*. The emeralds are a mid-green colour *(Figure 7)* and lack the depth of colour and clarity of the finest Colombian emeralds. Typically, the colour distribution is irregular; e.g. a 17 mm diameter emerald crystal from Bawn has a pale yellow beryl core and a 3 mm rim of emerald. Stones are flawed with natural cracks and inclusions, and a 0.15 ct cut stone contained two phase growth disturbance zones *(Figure 7)* and thin platy crystals of phlogopite *(Figure 8)*. This stone had refractive indices of 1.568 - 1.574, a bi-refringence of 0.006, and a specific gravity of 2.76. In contrast to the zoned crystal which was inert, this stone showed red under the Chelsea colour filter signifying a greater chromium content.

Aquamarine is more abundant than emerald. Commonly it occurs as perfectly-shaped hexagonal crystals in the milky quartz core of pegmatite particularly in the Heinweina area to the east of Larfarug where crystals in excess of 8 cm have been recorded. The hardness of the quartz makes it difficult to extract the aquamarine without damage and furthermore, the aquamarines are characterized by numerous cracks across the crystal. These cracks are a natural characteristic of the aquamarines and have nothing to do with the rough mining methods, but nevertheless, they affect the potential size of any cut stones. Irregular colour distribution is also a natural characteristic of the stones, caused by the variation in iron content throughout the crystal. The colours of the crystals examined range from medium blue to pale pastel hues (*Figure 9*). A 0.18 ct cut stone, for example, still retains a good but pale tone (*Figure 10*); it has RIs of 1.572 and 1.579, birefringence of 0.007 and an SG of 2.69.

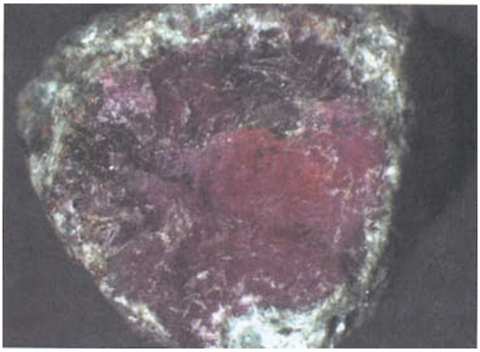


Figure 11: *Translucent ruby crystal, 1 cm in diameter, surrounded by fuchsite, a chrome-bearing muscovite.*

Corundum

Sapphires are generally dark green and translucent rather than transparent because of the large number of inclusions. Although most of the sapphire in Somaliland is not particularly transparent or deep blue, some of the material should be tested with heat to determine whether a deep blue colour enhancement can be obtained. Bluish corundum, has been observed in a quartz-poor, muscovite-rich pegmatite west of Hargeisa on the Gebily road. Many of the crystal fragments however, which were shown by traders in Hargeisa, showed residual truncated hexagonal pyramidal faces and smooth resorption features characteristic of corundum from alkali basalts rather than from pegmatites.

Ruby: some Somaliland ruby is of good quality although both ruby and sapphire seem less abundant than emerald and aquamarine. The rubies are typically colour banded with natural cracks and inclusions, and are often surrounded by a rim of dark amphibole or a bright green rim, presumed to be zoisite. This is very similar to the ruby in chromiferous zoisite amphibolites known from the Matabatu Mountains near Longido in Tanzania (Keller, 1992). In Tanzania, ruby-bearing amphibolites are intimately associated with serpentine and the latter rock type may act as indicator for similar ruby deposits in Somaliland. Another similar ruby specimen was found to be coated with the green chromium muscovite fuchsite, and associated with tiny grains of red rutile (*Figure 11*).

Garnets

Garnets are very abundant in Somaliland. A range of crystal sizes, colours and clarities has been seen in the collections of various traders. Crystals often show a perfect dodecahedral form (*Figure 12*), and these may be more valuable sold as mineral specimens than as potential gemstones. Colours range from light orange, through pink, cherry red and dark red, to purple and almost black. Garnet compositions were determined by electron probe microanalysis (EPMA), and the data in *Table III* of three average compositions from 41 analyses illustrate their compositional range. In *Table III*, GI is the average of 14 analyses of a deep orange-red stone which is a grossular (*Figure 13*); G2 (average of 18 analyses), is a pyrope of a deep red colour characteristic of this variety (*Figure 14*); whilst G3 (average of 9 analyses), is a scarlet red stone compositionally intermediate between pyrope and almandine (*Figure 15*). Specimens G2 and G3 showed iron

Figure 12: *Rough grossular garnet and fragment of dodecahedron, 5-6 mm in diameter.*

Figure 13 (below): *Orange-red grossular garnet (sample G1), 1.15 ct.*

Figure 14 (right, top): *Deep red pyrope garnet (sample G2) 0.77 ct.*

Figure 15 (right, bottom): *Bright red pyrope almandine garnet (sample G3), 1.01 ct.*

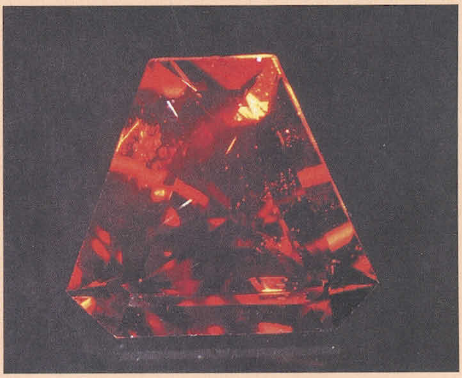


Figure 16: A cluster of parallel tubular, partially liquid-filled inclusions in sample G1.

absorption spectra characteristic of almandine; the intensity of the spectrum increasing with increasing iron content.

Elongate tubular inclusions that are partially filled with liquid are confined to one orientation (*Figure 16*), while exsolved rutile or boehmite are oriented parallel to the dodecahedral faces.

Green garnets have also been reported and tiny green glassy garnets were observed in the field in a calc-silicate body to the NE of Hargeisa. These occurred as bright green crystals, up to 4 mm across, in a variegated matrix of diopside and calcite; they have been identified by X-ray diffraction analysis as grossular.

This grossular is similar to the tsavorite garnets from Kenya which suggests that there is gem potential for this garnet if larger pieces exist.

The wide-range of garnet compositions indicates that they are not all from pegmatitic rocks. Pyrope may have been derived from ultramafic intrusions, or high-grade metamorphic basement rocks, whilst some of the almandine may also have been derived from amphibolite-grade metamorphic terrain.

Opal

Examples of both common opal and precious opal have been seen in Hargeisa.

Table III: *Composition of Somaliland garnets.*

	G1	*G2*	*G3*
SiO_2	38.78	41.79	40.19
TiO_2	0.71	0.06	0.03
Al_2O_3	19.97	23.28	22.56
Cr_2O_3	0.01	0.09	0.04
Fe_2O_3	3.42	0.35	0.32
FeO	1.21	9.54	20.07
MnO	0.12	0.27	0.54
MgO	0.12	17.95	12.68
CaO	35.49	6.30	3.80
Total	99.82	99.63	100.22
Formula based on 24 Oxygens			
Si^{4+}	5.92	6.00	5.99
Ti^{4+}	0.08	0.01	0.00
Al^{3+}	3.59	3.94	3.97
Cr^{3+}	0.00	0.01	0.01
Fe^{3+}	0.39	0.04	0.04
Fe^{2+}	0.15	1.15	2.50
Mn^{2+}	0.02	0.03	0.07
Mg^{2+}	0.03	0.85	2.82
Ca^{2+}	5.81	0.97	0.61
Sum: cations	16.00	15.99	16.00
End member proportions			
Pyrope	0.44	64.16	47.01
Almandine	2.57	19.13	41.74
Spessartine	0.27	0.54	1.13
Andradite	9.86	0.92	0.90
Uvarovite	0.01	0.27	0.13
Grossular	86.85	14.98	9.08

N.B. G1 is the mean of 14 analyses, G2 of 18 analyses and G3 of 9 analyses. Microprobe analyses were carried out by Dr P. Hill of the Department of Geology, University of Edinburgh.

The opal nodules range from 1-5 cm in diameter - like golf-balls, and vary from white to yellow, orange or red fire opal. Although the opals were not seen *in situ*, they are known to originate from a locality which lies between Borama and the coast. The opals display a small amount of play of colours (*Figure 17*) and would make fine cabochon gems. However, some of this

Figure 17 (above): *Two opals, 25 mm and 42 mm across. The orange piece shows a little green fire in the top left.*

Figure 18 (right): *Opal nodule, 6 mm across, with crust.*

material which was cobbed for cutting, developed fractures within a short time.

The Somali opals bear a remarkable similarity to opal from Shewa Province in Ethiopia, some 300 km to the west (Johnson *et al.*, 1996) which range in colour from near colourless or white, to yellow, orange, grey or brown and are typically 10 cm in diameter. Both Ethiopian and Somali opals are nodular with a 1-5 mm crust (*Figure 18*). Qualitative EDXRF on Somali samples showed the presence of calcium, iron, strontium, zirconium, potassium, niobium and sulphur as trace elements. These data are almost identical to the trace elements reported from the Ethiopian material (Johnson *et al.*, 1996) and suggest a related paragenesis.

The Ethiopian opals occur as nodules in acid volcanic rocks in a layer of welded tuff (approaching obsidian in character) about 3 m thick, between sub-horizontal rhyolite layers. The volcanic pile is 300-400 m thick and believed to be of Miocene age (8-27 Ma). Similar Miocene volcanic rocks occur in Somaliland west of Cabdulqaadir near the border with Djibouti (Abbate *et al.*, 1993). Within extensive basalt flows there are rare intercalated rhyolites, but whether these are the source of the Somali opals is not known. A full review of the stability and durability of the opal will be required before serious development can be initiated on proven reserves but nevertheless, the Somali material is likely to drift onto the market as a result of small scale mining.

Amethyst

Amethyst occurs in the quartz core of numerous pegmatites. Often it is somewhat banded in colour, or the deep purple coloration is patchy. In general, the mineral is rather pale and of low value as a gemstone, although it would make excellent beads. However, intensely purple amethyst of exceptionally fine quality has been shown, and was said to come from the Molis area just north of Hargeisa.

Chrome diopside

Chrome diopside occurs in fragments which may exceed 3 cm. Larger masses tend to be bottle green to greenish black. Smaller fragments are transparent and may be a lovely emerald green colour. This is known from other localities in East Africa as well, although the African deposits are until now quite small compared to those in Russia which is the major source.

Epidote

Epidote occurs as dark green or brown crystals in a number of localities. They are always confused for tourmaline. The identification of one transparent brown crystal as epidote was confirmed by FTIR.

Figure 19: *Four titanite fragments, the largest crystal is 9 mm across.*

Figure 20: *Vesuvianite with colour-banding.*

Spinel

Spinel occurs quite widely. Deep wine-red spinels, often mistaken for garnet or ruby by the locals, seem moderately abundant although not all will have come from the pegmatites. A bag of small sapphire crystals contained a few black spinel and augite fragments. On examination by EDXRF and FTIR the spinels proved to be 'pleonaste' with an SG of 3.82.

Titanite

Four yellowish-green crystals up to 10 mm were reported to have come from a pegmatite; these had good clarity and were thick enough to cut stones 3-5 mm in depth (*Figure* 19).

Topaz

Large colourless transparent crystals of topaz up to 10 cm in length have been shown by several traders although they were not observed *in situ* by the authors.

Tourmaline

Although tourmaline has been described as an accessory in pegmatites in old Survey reports, it did not appear in the collections shown, nor was it observed in any of the pegmatites visited in the field. Epidote or chrome diopside were always identified as tourmaline by the locals.

Vesuvianite

Vesuvianite occurs as abundant aggregates of coarse grey-purple to greenish-yellow elongate crystals in the same calcareous body which hosts the green grossular garnet. The vesuvianite crystals are mainly translucent although parts of the crystals are transparent and of gem quality. The largest single crystal examined was 40 x 15 mm and showed strong colour zoning in apple green and pale lavender (*Figure 20*). Parti-coloured gem-quality material could be particularly desirable, but the group that work this deposit are completely unaware of the potential of this mineral.

Zircon

Zircon appears to be quite widespread in occurrence in Somaliland. It varies from colourless to pale orange brown to deep red.

The development of the Mozambique orogenic belt

The deformation of Proterozoic rocks in Somaliland between 800 and 500 Ma ago, was part of a wider sequence of tectono-thermal events which has also been recognised on other continents. In relatively simple terms, rifting of a large continental mass (Rodinia) 900-850 Ma ago led to the formation of the 'Mozambique Ocean' (Abdelsalam and Stern, 1996) which then began to close again around 800 Ma. Crustal shortening led to NNW-trending continental folding on a regional scale which was linked to a high temperature metamorphic event (amphibolite to granulite facies), during the collision of West Gondwana (Africa and South America) and East Gondwana (India, Antarctica etc.) to form what is now known as the *Mozambique orogenic belt* (*Figure 21*). This belt forms the suture zone along which the final amalgamation of various continental fragments took place as a result of subduction of the 'Mozambique Ocean' floor. The timing of the tectono-thermal event varies. In the northern part of the belt in Somaliland, the event has been dated around 800 Ma (Dal Piaz *et al.*, 1987), with similar dates of 808 ± 6 provided by Stern (1994), and 828 ± 170 by Abbate *et al.* (1985). In Tanzania zircon age dates for the event are somewhat younger (720 and 640 Ma; Kröner *et al.*, 1997), whilst the culmination of metamorphism in Mozambique has been dated as 615 Ma and in Malawi at 550-575 Ma (Kröner *et al.*, 1997).

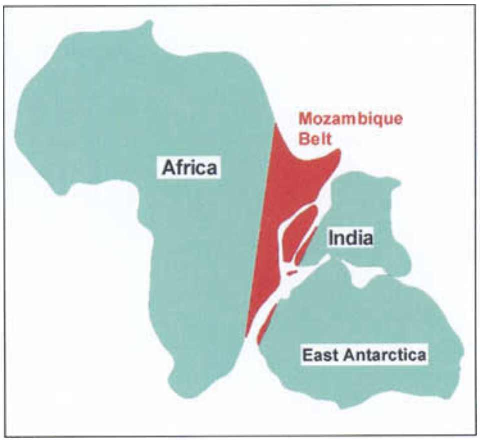


Figure 21: *Extension of the Mozambique orogenic belt from Mozambique through Tanzania and Kenya and extending into Somaliland. Note how the reconstruction includes Madagascar, part of India, Sri Lanka and East Antarctica within the Mozambique belt. Reconstruction based on Dalziel (1991) and Shackleton (1996).*

The belt averages between 250 and 325 km in width and extends from Mozambique and Tanzania, northwards to Ethiopia, Somaliland and into Saudi Arabia. It also includes rocks within Madagascar (Malisa and Muhongo, 1990), Eastern Antarctica (Dalziel, 1991; Shackleton, 1996), India (Choudhary *et al.*, 1992) and Sri Lanka (Harris *et al.*, 1996).

Although igneous activity has occurred in the Mozambique belt, both during periods of extension and compression, it is the emplacement of late stage granites, intruded after continental collision which are important for the genesis of gem-bearing pegmatites in eastern Africa. The most intense period of potassic granite intrusions occurred between 585 and 540 Ma (Küster and Harms, 1998), largely coinciding with the peak of temperature metamorphism in Madagascar and with regression to lower temperature amphibolite facies in northeastern Africa (Somaliland and Sudan). According to Küster and Harms (1998), the high temperature metamorphism and late-stage granitic magmatism are probably both related to post-collisional lithosperic thinning, magmatic underplating and crustal relaxation. However, the emplacement of potassic granites continued until 470 Ma and implies several magmatic episodes associated with different phases of post-orogenic crustal uplift after collision. Rb-Sr and K-Ar cooling ages for micas from granites in southern India (Soman *et al.*, 1982, Unnikrishnan-Warrier *et al.*, 1995) and Sri Lanka (Burton and O'Nions, 1990) which vary between 490 and 450 suggest that post-collisional uplift and cooling occurred much earlier in the northwest of the orogenic belt.

Comparison with other African gem occurrences within the Mozambique belt

Keller (1992), defined four categories of gem deposits within the Mozambique Belt in Kenya and Tanzania, according to their paragenesis:

1. Desilicification of granitic pegmatites or gneisses by ultramafic rocks resulting in the formation of ruby, sapphire, spinel, emerald, alexandrite and tourmaline.
2. Medium- to high-grade metamorphism of carbonates closely associated with graphite gneisses that provide the chemistry for the formation of tsavorite garnet, tanzanite and other gemstones.
3. Emplacement of lithium and beryllium-rich granite pegmatites with tourmalines, beryl, quartz, phenakite and euclase.
4. Hydrothermal alteration of serpentinites and other ultramafic rocks resulting in the formation of peridot, chrysoprase, prase-opal and rhodonite at much lower temperatures.

The first three of Keller's categories have definite equivalents in Somaliland. The majority of the emerald/aquamarine-bearing pegmatites in Somaliland would correlate with category 3 of Keller (1992), although no lithium-bearing minerals have been noted so far. The granitic pegmatites intruded into ultramafic rocks of the Bawn area would equate with category 1 of Keller (1992). These emerald-bearing pegmatites cut exceptionally biotite-rich rocks, which are interpreted to be ultramafic in origin. Limestones to the north of Bawn and NW of Hargeisa, which have undergone medium to high grade metamorphism, have a paragenesis similar to category 2 of Keller (1992). Although, no 'tsavorite' garnets, have been located, tiny crystals of green grossular have been identified from a thin calc-silicate horizon NE of Hargeisa. Purple vesuvianite, green diopside, scapolite and other minerals have also been identified in the same area so there is potential for 'tanzanite' and similar minerals. As yet no equivalents of Keller's category 4 are known, although the Abdul Qadr Complex has been identified as an ophiolite fragment (Berhe, 1990) and so typical source rocks for category 4 occurrences do exist within the area.

Conclusions

The gem deposits of the Mozambique belt in Kenya and Tanzania have been well documented by Keller (1992). Malisa and Muhongo (1990) have noted the extent of the Mozambique belt in eastern Gondwana and highlight the gem occurrences within Sri Lanka, India and Madagascar. The recognition of the extension of the Mozambique belt into Somaliland is therefore of considerable interest as it means that there is a potential for the production of a wide range of gemstones. This has important implications for the Somaliland economy, although the Somali producers need external help to maximize the potential. They need help to recognize the importance of geological factors, such as controls on emerald formation, to identify minerals using simple physical tests and to appreciate the value of different gem minerals. In particular, they need support with the marketing of gemstones as this will help to provide the funding they need to buy equipment to develop their prospects.

Acknowledgements

JK is indebted to Gerry McCarthy and staff of the EC Somalia Unit in Nairobi, for making the visit to Somaliland possible. Thanks go to all the mineral groups who allowed visits to their prospects, gave of their time and knowledge and generously donated material for study. Particular thanks go to the Minister, Director General and geologists at the Ministry of Minerals and Water, Yassim Kahen Booh ('Mr Fixit'), Hassan Younis, John Drysdale and particularly my driver Hassan Ibrahim who got me to all the remote places - and more importantly back again! The staff at Oxfam provided background information on historical aspects of the country and Barry Clarke at the EU office in Berbera gave great support. Both authors are indebted to the National Museums of Scotland Charitable Trust for a grant to enable selected gemstones to be faceted and to Paul Nex for the production of the maps and geological discussions on the Mozambique belt.

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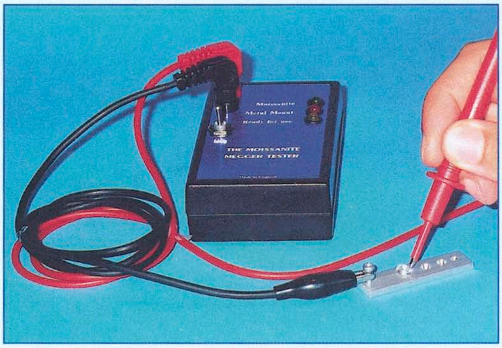

The Hanneman Refractometer

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ABSTRACT: The description of a very simple and very inexpensive refractometer of unlimited range for faceted stones is described. This instrument and the Hanneman specific gravity balance provide the basic tools for the student wishing to master gemstone identification.

Introduction

The two most useful physical properties for gemstone identification are specific gravity and refractive index. It is imperative that every gemmological student fully understands these principles and the means by which they can be determined.

For many years, the measurement of specific gravity was hampered by the lack of an inexpensive balance having the required sensitivity to handle small gems. Additionally, there were mathematical calculations involved. These problems were solved by the development of the Hanneman Balance (Anderson, 1980; Hanneman, 1998, pp. 50-64).

Refractive index measurements are frequently performed by rote by students using a critical angle refractometer which has an upper range limit of 1.81. An alternative, the inexpensive Hanneman-Hodgkinson refractometer (Hodgkinson, 1995, pp. 25-32; Hanneman, 1998, pp. 70-83), presented the student with a visual demonstration of the optical properties of transparent gemstones. This included the determination of refractive index, birefringence and dispersion. It also extended the RI range to about 2.37.

The basic principles of this technique were first expounded in a discussion of a pinhole refractometer (Hanneman, 1982). This present paper describes a logical extension of that concept which has culminated in a new unlimited range refractometer. Surprisingly, it can be constructed by any student at a cost of only a few pennies. Because of the educational features offered by this instrument, the author believes a treatment of the concept should be incorporated into the basic programme of every gemmological student.

Background

While visiting Alan Hodgkinson in May 1999, I witnessed a demonstration of a modified version of Dr Jamie Nelson's Pavilion Facet Fingerprinter (Hodgkinson, 1999). This incorporated a liquid immersion cell and was used to demonstrate the high refractive index and dispersion of synthetic moissanite.

I immediately recognized that this was essentially a pinhole refractometer. The immersion liquid allowed for an effective reduction of the refractive index of the test zone so that the 2.37 limit for round brilliant-cut gems which was imposed by air could be raised considerably and cover all gemstones.

The limit can be raised by a value equal to the difference between the refractive index of the liquid and that of air (n_D=1.000). Use of water n_D=1.333 could raise the limit by 0.333 to a value of 2.70, or use of baby oil (n_D=1.465) could raise the limit to above 2.8. Use of methylene iodide (n_D=1.74) could raise the limit above 3.00.

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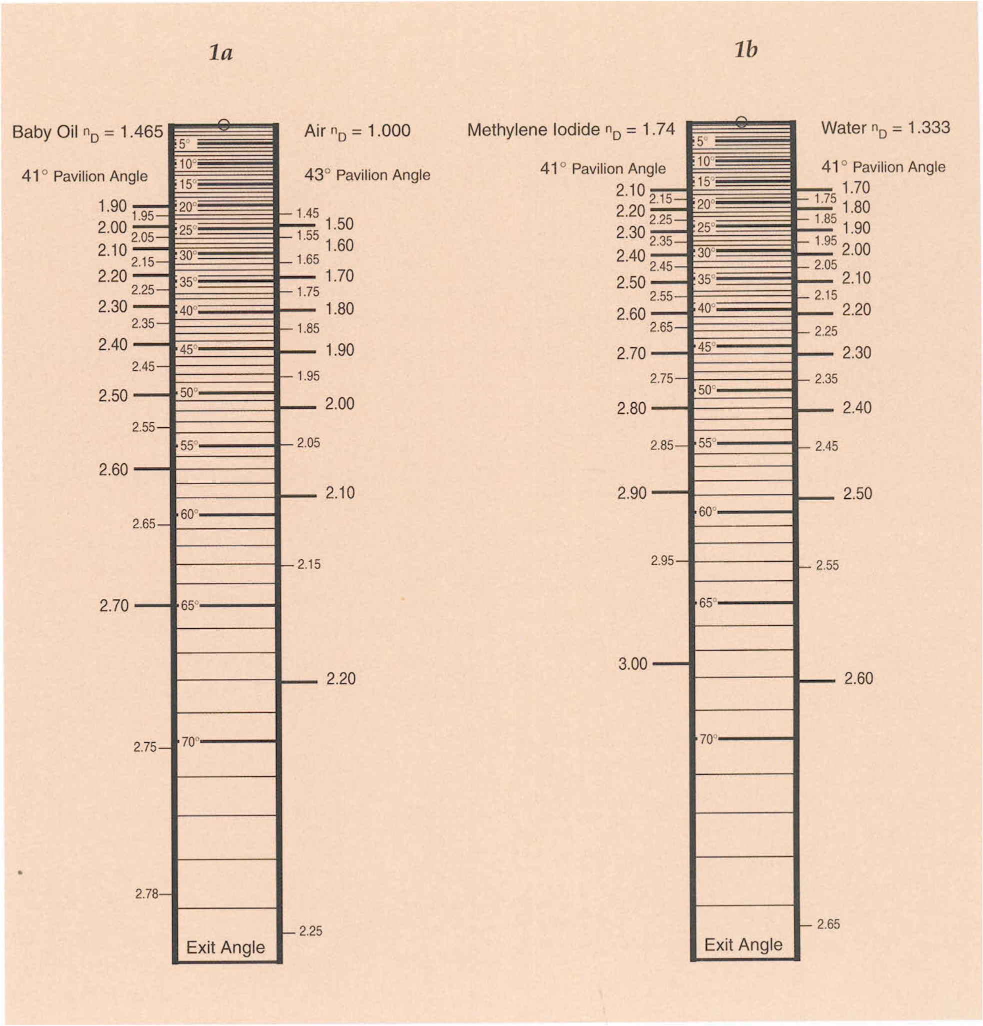


***Figure 1:** Hanneman Refractometer scales **(a)** for baby oil and air for specified pavilion angles **and (b)** for methylene iodide and water for a 41° pavilion angle.*

Using the Hanneman Refractometer Conversion Tables which had been calculated from the equation in Hanneman (1982) to relate exit angle to refractive index, the refractometer scales shown in *Figures 1(a)* and *(b)* were constructed. A schematic diagram of the refractometer is shown in *Figure 2* and an example in *Figure 3*. The scales can be enlarged to any size for the purpose of improving accuracy or readability. It is important that the height of the stone above the scale exactly matches the distance between the origin and the 45 degree line on the scale.

The refractive index (n_D) is determined from the position of the yellow region of the spectral image. A monochromatic filter can be employed if desired. Birefringence is determined as the difference in refractive index value (n_D) of the two images exhibited by doubly refractive gems.

It should be noted that the scales are calibrated in terms of index of refraction (n)

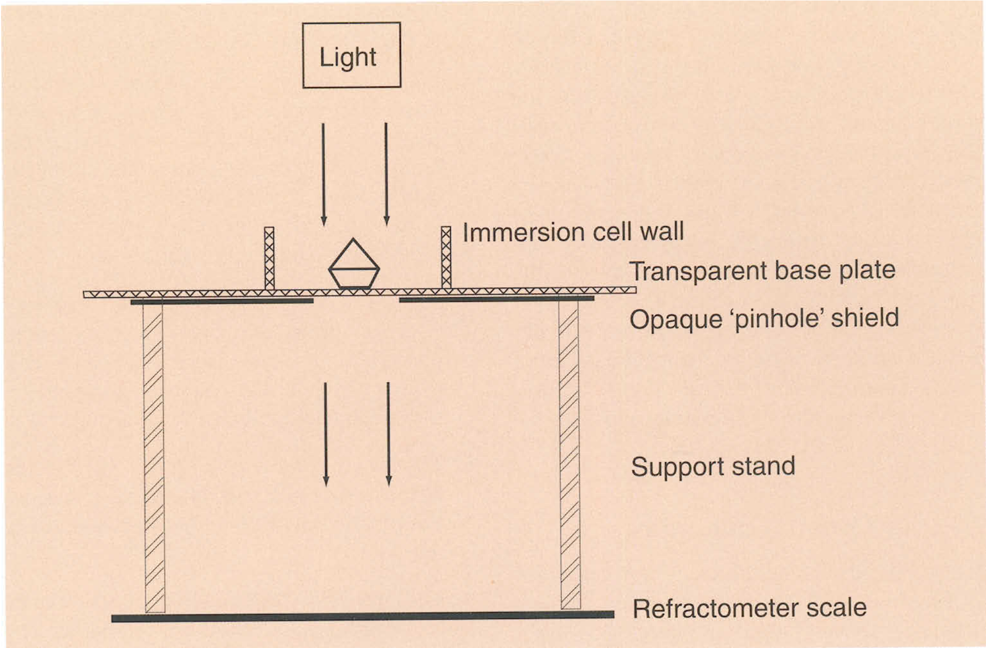


Figure 2: *Cross section diagram of Hanneman Refractometer at scale origin.*

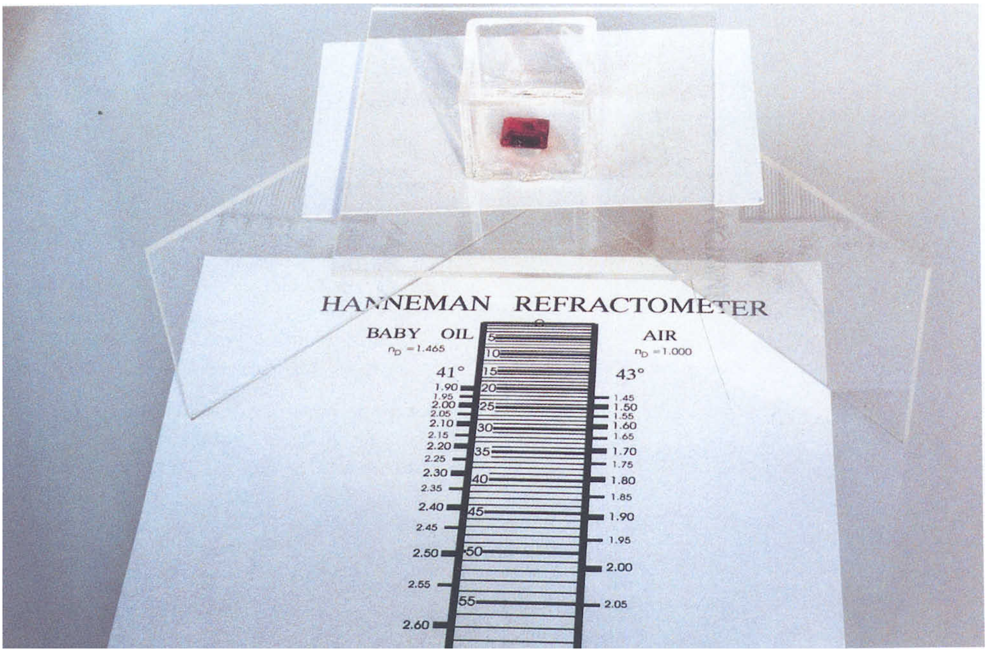


Figure 3: *Hanneman Refractometer stone holder and scale. Exit angle measurements are converted to values of ‘n’ by means of the Hanneman Refractometer Conversion Tables according to the pavilion angle of the sample.*

and not refractive index (n_D), as in the case of the critical angle refractometer. Consequently, one can determine the index of refraction for any colour of light that one might desire. This allows one to determine the gemmologist's value of dispersion. To do this, determine the difference between the extreme values (n) for the red and violet which can be observed. Then, multiply that value by 0.71. The extremes of the visible spectrum which are measured here extend from 760 to 397 nm (Fraunhofer lines A to H), while dispersion is defined over the range of B to G, i.e. from 687 to 431 nm. The 0.71 factor is derived from the relationship (687 - 381) / (760 - 397) = 256 / 363 = 0.705.

Construction notes

1. Any light source will do. A bare bulb and filament will produce sharper images than a frosted bulb or fibre-optic light pipe. A penlight torch is perfectly adequate.
2. Depending on the intensity of the light source, it may be necessary to shield the refractometer scale from extraneous light. A darkened room is ideal.
3. For general purposes, the hole should be large enough to allow a ring of light to form a halo around the shadow of the gem which is centered over the O on the origin line. A piece of white cardboard with a hole punched in its centre serves as a perfectly adequate opaque plate.
4. A sheet of polarizing material can be placed over the gem and rotated in order to observe or measure birefringence. A lens from a pair of broken polarizing sunglasses is perfectly adequate for this purpose.
5. The transparent plate and the walls of the liquid container can be fabricated from the plastic cover of a 'compact recording disc'.
6. The support for the transparent plate can be constructed from anything available. The only important feature is that its height must be such that the bottom of the gem (top of the plate) is exactly the height above the scale as the distance between the origin and the 45 degree line on the scale.

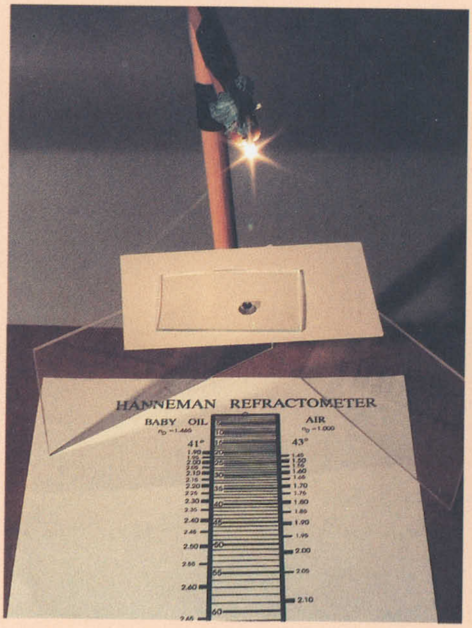
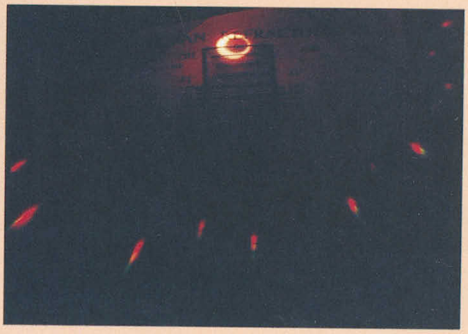
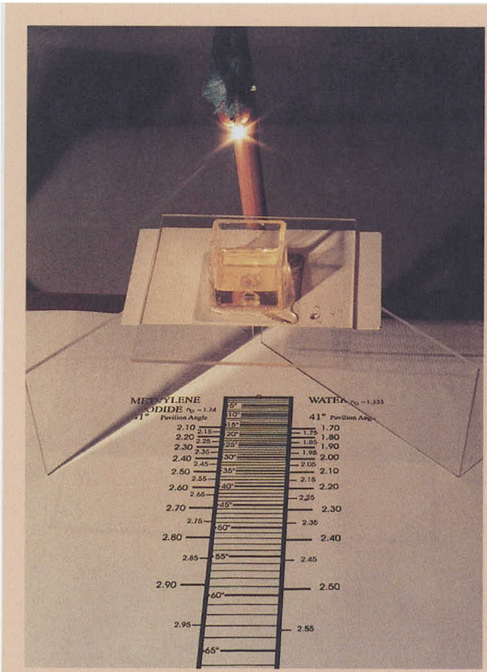


Figure 4a: Hanneman Refractometer set up to examine a round brilliant-cut CZ in air (no immersion liquid). Illuminated by a SIC (Standard Image Candle of 1 candle-power).

Figure 4b: Appearance of refracted images of CZ in a darkened room with the SIC light shielded. Photographic limitations prevent the long blue and violet portions of the spectrum from appearing. They are readily visible by eye.





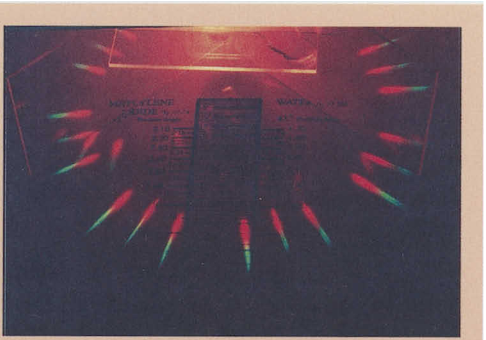


Figure 5a: *Hanneman Refractometer set up to examine a round brilliant-cut synthetic rutile immersed in methylene iodide. Illuminated by a SIC (Standard Image Candle of 1 candle power).*

Figure 5b: *Appearance of refracted images from synthetic rutile in a darkened room with the SIC light shielded. Note the extreme dispersion exhibited by the synthetic rutile. Each image consists of two overlapping images which must be separated by means of the polarizing filter in order to measure the dispersion.*

Figure 5c: *Appearance of refracted images from a diamond in a darkened room with the SIC light shielded. Photographic limitations prevent the long blue and violet portions of the spectrum from appearing. They are readily visible by eye.*

Operation notes

1. Set up the refractometer as shown in *Figures 2* and 3. While it is obvious that the most precise and accurate results can only be obtained by carefully aligning and rigidly securing all the component parts and the light source, results adequate for most confirmatory purposes and for teaching demonstrations can be obtained by merely assembling the components and using a hand-held penlight (torch).

2. Place a round brilliant cut-gem on the transparent plate and adjust the plate, the light, and the opaque plate with the pinhole, so that the light shines directly down onto the gem, through the hole, and produces a small bright halo around the shadow of the gem which is centered over the O on the origin line of the scale (*Figure 4a*). A symmetrical circle or circles of spectral images should appear concentric to the O (*Figure 4b*). If a different shaped gem is used, the images will correspond to the design of its pavilion facets. The arrangement and results from synthetic rutile and diamond are shown in *Figure 5*.

3. Adjust the gem so that the image you wish to examine falls along an imaginary centre line of the scale.

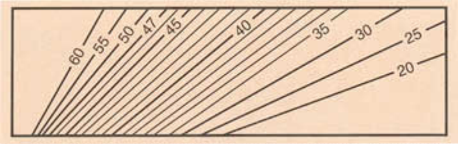


***Figure 6:** Protractor for estimating crown and pavilion angles.*

4. Read the scale. Almost all faceted gems have at least one set of pavilions facets cut at angles between 41 and 43 degrees. For general purposes, two calibrations have been provided. The one on the right of *Figure 1a* is for use with no liquid and assumes a 43 degree pavilion angle. This is a common angle used for lower refractive index gems. The scale on the left requires immersion in baby oil and assumes a pavilion angle of 41 degrees which is common for round brilliant cuts of higher refractive index gems. Higher index gems can be immersed in di-iodomethane (methylene iodide) and measured on the scale in *Figure 1b*.

5. The most accurate results can be obtained by (i) accurately measuring the angle of the facet producing the image by means of a protractor like that shown in *Figure 6*, (ii) using an enlarged scale for a more precise reading of the exit angle, and (iii) converting the measured exit angle to the refractive index using the Hanneman Refractometer Conversion Tables. However, none of these refinements are necessary to impart the basic principles to a student.

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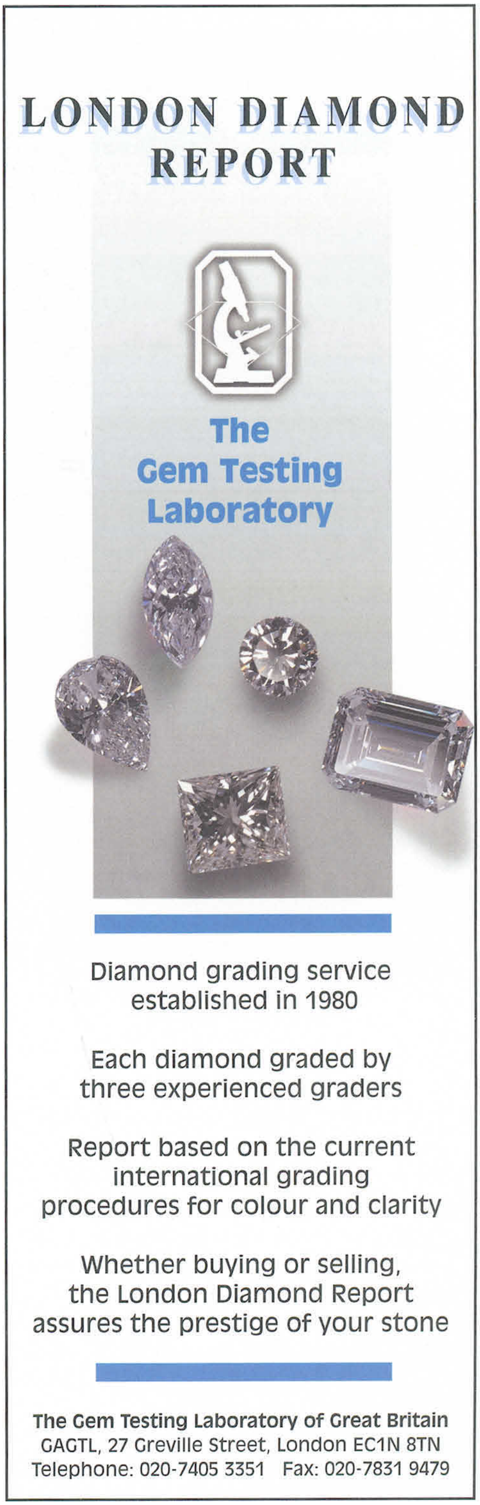

The cause of colour of the blue alexandrites from Malacacheta, Minas Gerais, Brazil

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ABSTRACT: A rare and very attractive variety of chrysoberyl, a blue alexandrite from Malacacheta, Minas Gerais (Brazil), commercially called 'peacock-blue' alexandrite, was investigated by electron paramagnetic resonance (EPR), optical absorption, photoluminescence and X-ray photoelectron spectroscopy (XPS). The peacock-blue alexandrite is known for its strong pleochroism ranging from blue to green or greenish-yellow, as well as its strong colour-changing effect showing blue or greenish-blue in daylight and reddish-purple in incandescent light. The results show that the rare bluish colours of the peacock-blue alexandrite are related to a critical balance between Fe^{3+} and Cr^{3+} substituting for Al^{3+} in the sites with mirror symmetry, while the concentration of Cr^{3+} in the sites with inversion symmetry is negligible.

Introduction

Most gemstones owe their colours to transition metal ions dispersed in the crystalline matrix. Such ions give rise to, in the presence of a strong ligand field, absorption bands in the visible spectral range. A classical example is the Cr^{3+} impurity in an octahedron formed by six oxygen atoms that, depending on the strength of the ligand field, causes both the deep red colour of ruby (Al_2O_3) and the vivid grass-green of emerald ($Be_3Al_2Si_6O_{18}$) (Nassau, 1983).

When the octahedral ligand field is intermediate in strength between that in ruby and that in emerald, a very interesting phenomenon occurs. That is the case of the very rare and highly prized alexandrite. This gemstone can have both the green colour of emerald and the red colour of ruby depending on the illumination conditions (daylight or incandescent light, respectively). Alexandrite is a variety of chrysoberyl, a beryllium aluminate gem mineral structurally isomorphous with the olivine family and with an ideal chemical composition $BeAl_2O_4$ (Bragg and Brown, 1926). Unlike the more common iron-bearing yellow chrysoberyl, alexandrite also contains Cr^{3+} that substitutes for $A1^{3+}$ (*Figure 1*).

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Figure 1: *Chrysoberyl crystals from Malacacheta photographed in incandescent light.*

The colour-changing effect, or the 'alexandrite-effect' (White *et al.*, 1967) as it is referred to nowadays, is attributed to two broad absorption bands belonging to Cr^{3+} substituting Al^{3+}. Their maxima are at approximately 400 nm (violet-blue) and 600 nm (yellow-orange) with a transmission window in between (White *et al.*, 1967, Farrell and Newnham, 1965). According to Poole (Poole, 1964), the alexandrite-like colour changes, which appear in various chromium-bearing compounds, occur due to the much higher spectral response of the human eye and brain to the green and yellow colours that fall near the 600 nm absorption band (Nassau, 1983). In green-rich natural light, the crystal is vivid green, while in the red-rich incandescent light the alexandrite shows a red colour with a violet hue. The same absorption bands, together with the orthorhombic symmetry of the crystal structure, render alexandrite strongly pleochroic (Farrell and Newnham, 1965). This pleochroism is also observed as a change in the colour, but only when looking at the crystal with light propagating along different orientations. Another important optical fingerprint of alexandrite is its characteristic emission spectrum. The Cr^{3+} in alexandrite, as in ruby and emerald, is responsible for an intense red fluorescence, with two sharp lines (called R_{1m} and R_{2m}) near 1.83 eV (or 679 nm) (Walling *et al.*, 1995).

Although the origin of natural alexandrite is still a controversial subject, it is accepted by many that alexandrite is formed when solutions rich in beryllium, originating from granites, percolate through ultramafic rocks (which are the source of chromium) and crystallise in a medium saturated by aluminium (Martin-Izard *et al.*, 1995).

For more than 20 years, alexandrite from Malacacheta has been recovered from alluvial deposits located along four streams named Córrego do Fogo, Ribeirão Setubinha, Ribeirão Santana and Ribeirão Soturno (Guimarães and Grossi Sad, 1977, Proctor, 1988, Basílio, 1999). Nowadays very few alexandrites of gem quality are found. The size of the crystals ranges from 1 mm up to 1 cm.

The main purpose of this paper is to present an optical and a structural characterization of this alexandrite from Malacacheta, with the focus on the peacock-blue variety. Electron microprobe, electron paramagnetic resonance (EPR), X-ray photoelectron spectroscopy (XPS), optical absorption and emission methods were used to provide reliable information on the colour and its correlation with the impurity-related point defects present in the material.

Structural details

$BeAl_2O_4$ is an orthorhombic crystal with space group $D_{2h}{}^{16}$ (p_{nma}) (Bragg and Brown, 1926). The unit cell has the following lattice parameters: a = 9.404 Å, b = 5.476 Å and c = 4.472 Å, and is composed of four $BeAl_2O_4$ molecules (Swanson *et al.*, 1960). The oxygen atoms are arranged in an approximately hexagonal close-packed array perpendicular to the c axis. The aluminium cations (Al^{3+}) occupy half of the interstitial octahedral sites, while the beryllium (Be^{2+}) ions are found in one eighth of interstitial tetrahedral sites. Both the octahedral and the tetrahedral sites are distorted in shape.

A refinement of the chrysoberyl structure showed that the eight distorted octahedral sites occupied by Al cations in the unit cell can have two distinct symmetries (Farrell

Glossary

X-ray photo-electron spectroscopy (XPS): A non-destructive technique generally used for chemical analysis of surfaces. In a vacuum chamber, the sample is irradiated by X-rays and the energy of the emitted electrons is measured. It is the opposite of the electron microprobe technique in which a sample is irradiated with electrons and the characteristic X-rays of each element are collected. With XPS, it is possible e.g. to obtain the relative concentrations of the chemical elements present at the surface.

Electron paramagnetic resonance (EPR): Used for chemical identification, site symmetry and valence states of point defects and impurities. In general, the samples are placed into a microwave resonance cavity. The resonance lines are detected with a fixed microwave frequency perpendicular to a variable static magnetic field. The sensitivity for paramagnetic impurities in solid state samples is from ppb to ppm.

Crystal field: The inhomogeneous electrical field of the neighbourhood ions of an impurity is called the crystal field. The crystal field around Cr^{3+} differs in intensity in different structures, e.g. in ruby, emerald or alexandrite structures. It can also have different symmetries due to the coordination number, resulting in different colours.

Crystal field transitions: Are transitions that involve redistribution of electrons in the partially filled 3d shells of transition metal impurities embedded in a crystal field. The crystal field transitions are optical transitions between ground and excited states. They result from the splitting of the 3d energy level of the free ion, induced by the crystal field. Normally these transitions are related to absorption bands in the visible spectrum and are the cause of colour.

Site symmetry: The site symmetry, which is directly associated with the coordination number, has a strong influence on the colour of some gems due to the symmetry of the crystal field. For example, in beryl, iron can enter either in an interstitial position in structural channels, or substitute for Al ions. In the substitutional site, Fe^{2+} produces a blue colour while in the interstitial site it causes no colour.

et al., 1963). The first four sites lie on a mirror plane (C_S) with only one Be^{2+} neighbour, while the other four have inversion symmetry (C_I), due to the symmetrical location of two neighbouring Be^{2+} ions. These sites differ not only in symmetry but also in volume, with the C_S site being larger than the C_I sites. While the C_S sites have an average nearest-neighbour distance (Al-O) of about 1.934 Å, the same distance for the C_I sites is only 1.890 Å (Farrell *et al.*, 1963). This volume difference strongly determines the distribution of substitutional Cr^{3+} between the two types of sites. For lower chromium and iron concentrations, the larger C_S sites are preferentially occupied. As the concentration of Cr increases, the C_I sites can also be occupied (Newnham *et al.*, 1964). In synthetic alexandrite, the relative site occupancy of the mirror-symmetry (C_S) sites is well known to be between 60 and 74% for the highest Cr concentrations (Newnham *et al.*, 1964). For lower chromium contents, EPR experiments yield more accurate data concerning site occupancy than X-ray powder diffraction data. In synthetic laser-quality alexandrite crystals with chromium contents ranging from 0.1% up to 0.3%, the relative site occupancy of the mirror sites has been estimated as 78% ± 3% (Forbes, 1983). There are basically two transition ion impurities in alexandrite and chrysoberyl, Fe^{3+} and Cr^{3+} that substitute for the Al^{3+}. With electronic spins $S = 5/2$ and $S = 3/2$ respectively, those impurities are paramagnetic, being thus detectable by means of electron paramagnetic resonance (EPR). While the substitutional C_S sites are magnetically equivalent in pairs, the four inversion sites (C_I) are magnetically inequivalent (Forbes, 1983). The EPR parameters for Cr^{3+} and Fe^{3+} on the C_S sites were first determined by Barry and Troup in 1969 and 1970. Later, the Cr^{3+} EPR

Experimental details

The microprobe analysis had the following operational conditions: 15 kV accelerating voltage, 20 mA current and 10 s counting time. The results in *Table I* are givenin per cent of weight. The spectrometer used for the chemical analyses was a Cameca model Camebax 5X-50. The analytical standards were Ian Steele and the lower limit of detection of 0.01 per cent of weight, with errors of the same order. It is important to note that the BeO level was not directly measured with the microprobe, being estimated from the stoichiometric concentrations of other oxides. The Be contents were confirmed with X-ray photo-electron spectroscopy (XPS). For the optical characterization, optical absorption and photoluminescence were used. The optical absorption spectra were collected with a Hitachi U-3510 spectrophotometer. The photoluminescence was measured with a Dilor Micro-Raman spectrometer with the green line of an Ar-ion laser (514.5 nm) as excitation. The EPR study was done with a conventional EPR spectrometer working at the X-Band (9 - 10 GHz). X-ray photoelectron spectroscopy (XPS) spectra were recorded by a VG-escalab 2201-XL spectrometer using Al Kα excitation (hυ = 1486.6 eV) operating at 10 mA and 15 kV. The vacuum during data acquisition was always near 10^{-9} torr. The analyser was operated at a constant pass energy of 40 eV and in 'small area mode' (~ 0.2 mm^2), in order to focus on different sample positions. When necessary, the gemstone was bombarded with Ar ions to eliminate surface contamination. Most experiments were made at room temperature.

parameters were refined for both the mirror and the inversion sites and the relative site occupancy was defined (Forbes, 1983).

Results and discussion

The peacock-blue alexandrite samples selected for this investigation were the rough crystals with highest purity and transparency, and with both the most intense and homogeneous pleochroism and alexandrite effect (*Figure 1*). The results of the electron probe microanalysis (WDS-EPMA) for two of the samples are shown in *Table I*.

From the group a single crystal was carefully chosen as the most representative sample. It was cut in the shape of a parallelepiped with dimensions of about 4 x 2.5 x 2 mm and faces oriented along the rhombic axes *a*, *b* and *c*.

Unpolarized optical absorption spectra were measured at 300 K for light propagating along the *a* and *b* axis as shown in *Figure 2*. Three strong bands at 570 nm (Cr1 or Y-band), 410 nm (Cr2 or U-band) and 300 nm (Cr3) are caused by Cr^{3+} in an octahedral site (*Table II*). These three bands belong to the spin-allowed crystal field transitions of the Cr^{3+} ion, i.e.$^4A_2 \rightarrow {}^4T_2(F)$, $^4A_2 \rightarrow {}^4T_1(P)$ respectively (Farrell and Newnham, 1965). Phonon structure can also be barely seen at 300 K as sharp and less intense peaks at 620

Table I: *Electron probe microanalyses of two representative rough samples of the blue alexandrite from Malacacheta.*

Wt.%	*No.1*	*No.2*
Al_2O_3	80.55	80.90
BeO	17.91	17.61
Na_2O	0.01	0.01
MgO	0.02	<0.01
SiO_2	<0.01	0.02
K_2O	<0.01	<0.01
CaO	<0.01	<0.01
TiO_2	0.29	0.33
Cr_2O_3	0.65	0.59
MnO	0.02	0.02
FeO	0.53	0.51
Total	99.98	99.99

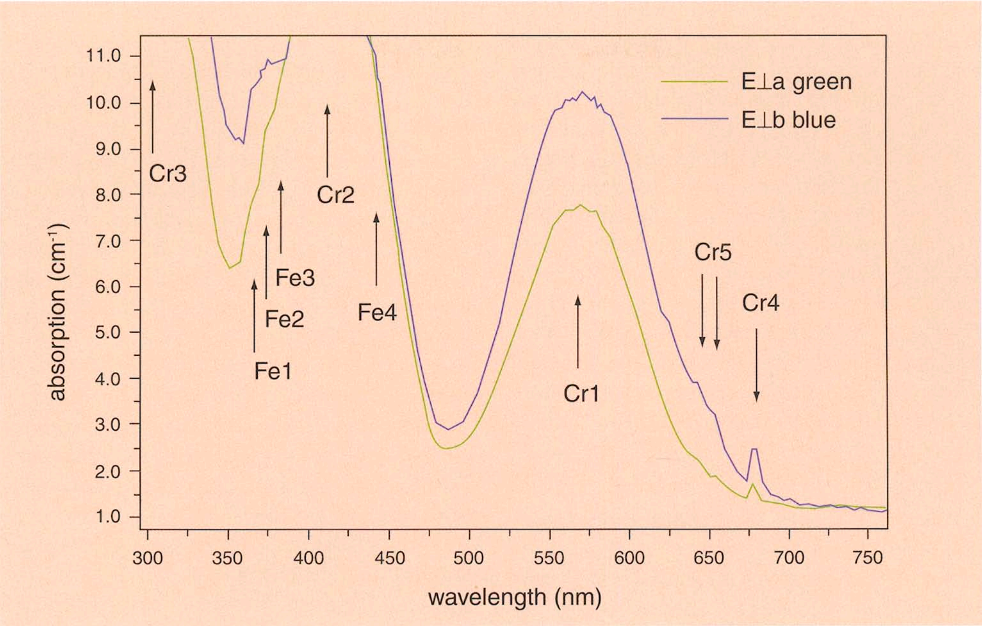

***Figure 2:** Unpolarized optical absorption spectra of the peacock-blue alexandrite measured at room temperature for light propogating along the crystal axis a and b with the marked positions in Table II.*

nm (Cr4) and 640 nm (Cr5). Other weak absorption peaks at 679 nm belong to the spin-forbidden transitions of Cr^{3+}, i.e. $^4A_2 \rightarrow {}^2E$ (Cr6), $^4A_2 \rightarrow {}^2T_1$ and $^4A_2 \rightarrow {}^2T_2$ (not marked).

As in most natural alexandrites, Fe^{3+} substituting for Al^{3+} was also detected in the blue alexandrites from Malacacheta. Four iron-related weak absorption lines were observed at 368 nm (Fe1), 378 nm (Fe2), 385 nm (Fe3) and 440 nm (Fe4), as marked in *Figure 2*. All four lines are due to spin-forbidden transitions from the ^6A ground state to the $^4A_1(G)$, $^4E(G)$, $^4T_2(D)$ and $^4E(D)$ excited states, respectively. Without Cr^{3+}, these four Fe^{3+} related lines in the violet and blue spectral range result in the yellow colour of chrysoberyl (Farrell and Newnham, 1965). The origin of the absorption transitions and their average positions are summarised in *Table II*. For samples with high Fe^{3+} content, the transmission window between the Fe and the Cr related absorption bands at about 480 nm shifts toward the green, resulting in a green alexandrite without blue hues.

***Table II:** Average positions and origin of the absorption bands of the peacock-blue alexandrite.*

Absorption band	*Position (nm)*	*Transition*
Cr1 (Y-band)	570	$^4A_2 \rightarrow {}^4T_2\,(F)$
Cr2 (U-band)	410	$^4A_2 \rightarrow {}^4T_1\,(F)$
Cr3	300	$^4A_2 \rightarrow {}^4T_2\,(F)$
Cr4	620	phonon structure of Cr1
Cr5	640	phonon structure of Cr1
Cr6 (R_{1m} and R_{2m} lines)	~679	$^4A_2 \rightarrow {}^2E$
Fe1	368	$^6A \rightarrow {}^4A_1\,(G)$
Fe2	378	$^6A \rightarrow {}^4E\,(G)$
Fe3	385	$^6A \rightarrow {}^4T_2\,(D)$
Fe4	440	$^6A \rightarrow {}^4E\,(D)$

The visually observed colours of the peacock-blue alexandrite, for natural light propagating with polarization perpendicular to the a and b axes are green and blue, respectively. Even though the transmission for the blue wavelengths is slightly higher for E ⊥ *a* (i.e. less absorption), as can be seen in the spectrum of *Figure 2*, the strength of the absorption bands between 550 nm and 600 nm is greater by far for E ⊥ *b*. Since the human eye is more sensitive to green-yellow (Nassau, 1983), the final result is green for E ⊥ *a* and blue for E ⊥ *b*, which is consistent with recent results obtained for certain synthetic alexandrite grown from a melt of stoichiometric composition by the Czochralski method (Liu *et al.*, 1995).

Figure 3 shows the photoluminescence spectrum of the same peacock-blue alexandrite sample measured at room temperature. The line observed in the absorption spectrum at about 679 nm (Cr6) (*Figure 1*) is in fact a doublet (678.5 nm and 680.3 nm at 300 K) that was better resolved in the photoluminescence spectrum (along with the phonon vibronic structure). This doublet, known as the R_{1m} and R_{2m} lines appears to be due to the deviation from octahedral symmetry of the Cr^{3+} ion on the mirror-symmetry sites, which lifts the degeneracy of the 2E level into two states A′ and A″ (Walling *et al.*, 1979; Hori et al., 1989). The inversion sites do not contribute to the photoluminescence spectrum.

The EPR spectrum for the magnetic field (B) approximately parallel to the crystal axis b measured at 300 K and a microwave frequency of 9.45 GHz is shown in *Figure 4*. In the spectrum, the two lines from Cr^{3+} in the mirror symmetry sites (C_S) can clearly be seen at about 1364 Gauss and 7845 Gauss. They belong to the Zeeman transitions -3/2 → 3/2 and -1/2 → 1/2, respectively, as observed in synthetic alexandrite (Forbes, 1983). The other EPR lines belong to Fe^{3+} in the mirror site (Barry and Troup, 1970).

In the peacock-blue alexandrite it was very difficult to detect the EPR lines from Cr^{3+} in the inversion sites (C_I). From the (C_I) four lines expected at 1638 Gauss, 1872 Gauss, 5704 Gauss and 9003 Gauss for B ∥ *b* (Forbes 1983), we could only detect a broad and weak line at 5700 Gauss. While the 9003 Gauss line was outside the range of our magnetic field, the other low-field lines were masked by the stronger Fe^{3+} lines and the low-field Cr^{3+} (C_S) line. The EPR line of the inversion site can, in principle, be associated with the very weak and broad line at about 5700 Gauss shown in *Figure 4*. This line, together with other weak and broad lines at lower fields could, however, belong to other defects like, for example, Cr-pairs. Assuming that the line observed at 5700 Gauss belongs in fact to the - 1/2 → +1/2 transition from the Cr^{3+} (C_I) (Forbes, 1983), we could roughly estimate its intensity ratio to be about 1/12 with respect to the - 1/2 → +1/2 line of Cr^{3+} (C_S) at 7845 Gauss. This value is slightly smaller than the ratio of ~ 1/10 one can estimate from the synthetic alexandrite EPR spectrum (Forbes, 1983). For synthetic alexandrites, a relative site occupancy of 78 ± 3% was found (Forbes, 1983). By comparing the intensity ratios of the two lines estimated for the peacock-blue alexandrite with the ratio obtained for the synthetic alexandrite, and scaling them with site occupancy, we conclude that the relative site occupancy for substitutional Cr^{3+} should be higher than 90% on C_S sites. This is also consistent with the strong luminescence of Cr^{3+} in the C_S sites (R_{1m} and R_{2m}), since the luminescence-active site is the C_S site.

Another aspect of the EPR spectrum that is important to mention is the large halfwidth of the EPR lines, that for most lines either from Cr^{3+} and Fe^{3+} exceeds 50 Gauss, and that in some cases even reaches 100 Gauss. For synthetic alexandrites it stays in the range between 10 and 30 Gauss (Forbes, 1983). This difference in the EPR linewidth of transition ion impurities in natural and synthetic alexandrites occurs mainly due to the disorder of the lattice that is expected to be higher for a natural crystal than for its synthetic counterpart.

The XPS spectrum of the same alexandrite sample studied by EPR is shown in *Figure 5*. From relative peak areas and sensitivity

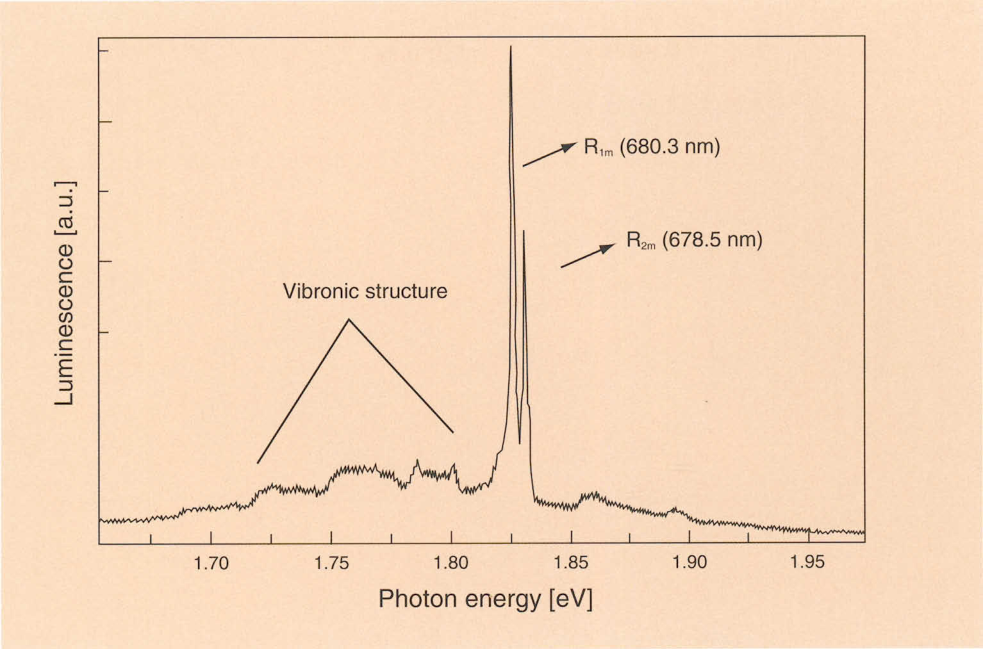

Figure 3: Photoluminescence spectrum measured at room temperature with the green line (514.5 nm) of an Ar-ion laser as excitation.

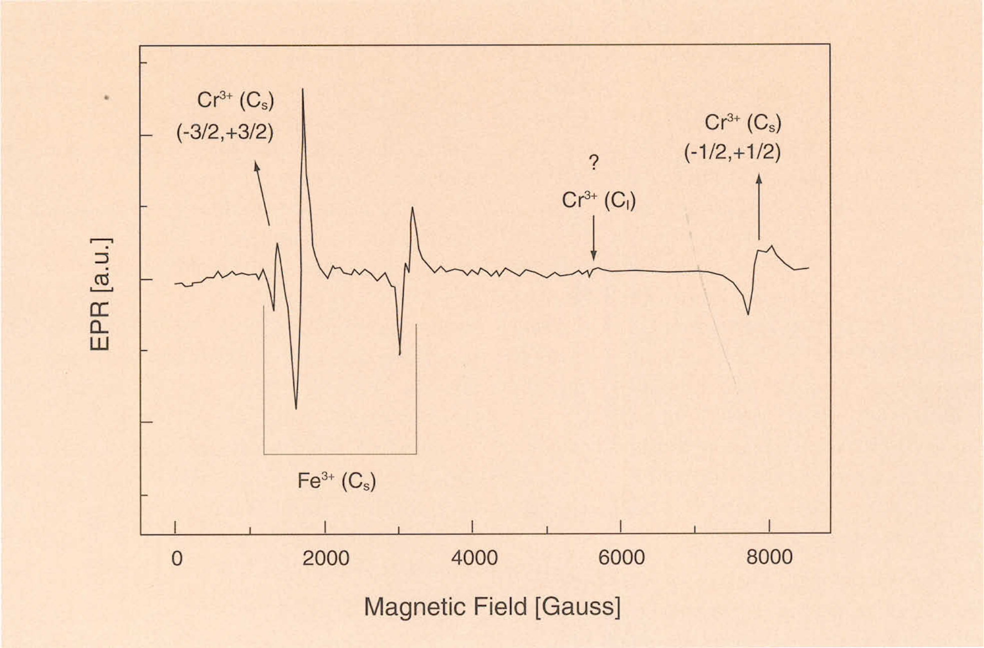

Figure 4: EPR spectrum measured at room temperature and with microwave frequency of 9.45 GHz and for B || b.

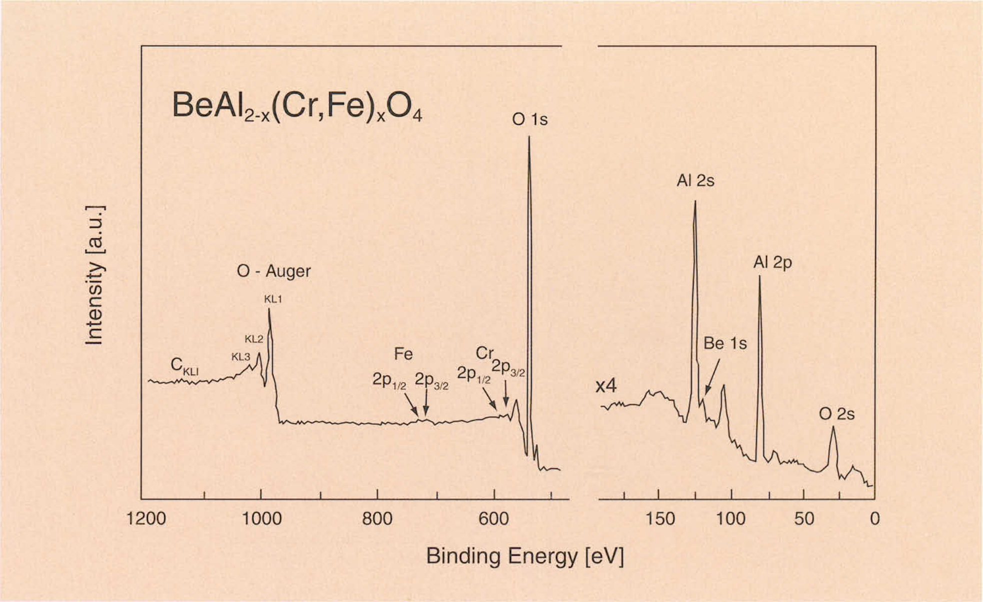

***Figure 5:** XPS spectrum of the peacock-blue alexandrite measured with Al Kα radiation in the binding energy ranges of 1200-500 eV, as collected (left side), and 200-0 eV, multiplied by 4 (right side).*

factors of the photo-emission lines, the molar fractional content in the alexandrite formula $BeAl_{2-x}$ (Cr, Fe)$_x$ O_4 was calculated, where $x = x_{Fe} + x_{Cr}$. Spectra were collected at different sample positions and the results averaged Al/O = 0.51 ± 0.06, and Al/Be = 1.87 ± 0.22, which gives 2 - x = 1.96 ± 0.23. From the $2p_{1/2}$, $2p_{3/2}$ of the Fe and Cr and the O-1s transitions $x = x_{Fe} \pm x_{Cr} = 0.022 \pm 0.015$. The Cr/Fe molar ratio x Cr/x Fe was calculated as 0.8 ± 0.4, consistent with the WDS-EPMA analysis. From the EPR and optical absorption experiments, it is clear that the Cr^{3+} and Fe^{3+} are the main cations in the peacock-blue alexandrite which affect the colour of this gemstone. EPR and photoluminescence results showed that Cr^{3+} occupies preferentially the mirror sites, i.e. more than 90% with respect to the inversion sites.

The pleochroic colours of the peacock-blue alexandrite, and the strong alexandrite effect of a change from greenish-blue in daylight to reddish-purple under incandescent light, are consequences of a specific balance in the concentrations of Cr^{3+} and Fe^{3+} substituting for Al^{3+} in the C^S sites in an otherwise colourless chrysoberyl crystal. While it is known that the iron-related absorption bands, in the absence of Cr, gives the typical yellow colour of the chrysoberyl, for samples with Fe and Cr, green or blue-green alexandrite is expected depending on the relative concentrations of Fe and Cr. For samples with high Fe content, the Fe-related broad absorption bands in the blue are intense and, as a result, the transmission window shifts slightly from 480 nm (blue-green) to the green 500 nm. *Figure 6* shows clearly that by changing the concentration ratio of Fe^{3+} and Cr^{3+}, the overlap of the two absorption bands and therefore the position of the absorption minimum at about 500 nm is influenced. As a consequence, the amount of transmitted blue wavelengths will depend heavily on the balance between Cr^{3+} and Fe^{3+}.

XPS enables determination of the specific range in the Cr/Fe molar ratio which gives the most attractive colours and the best

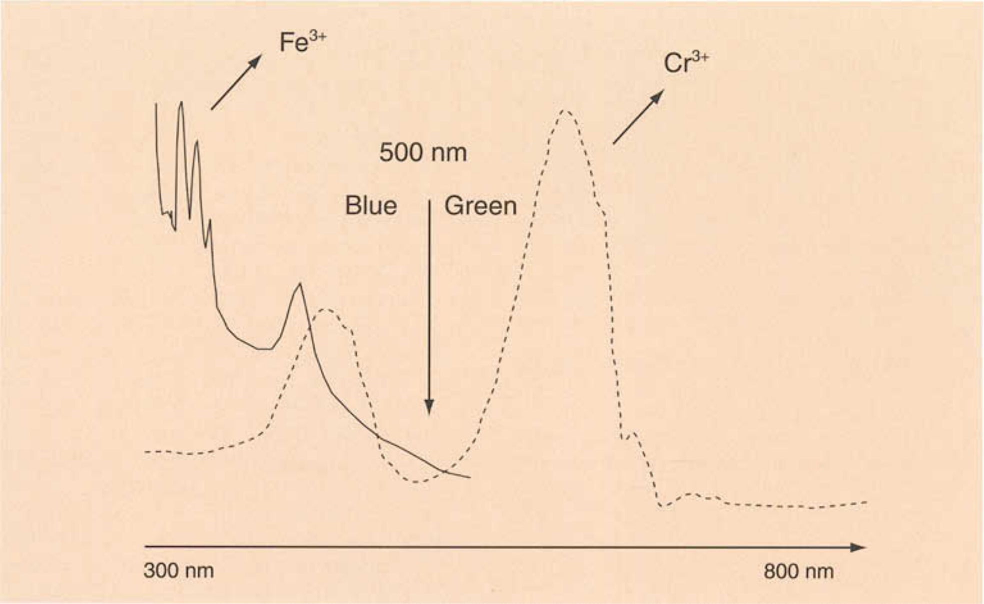

Figure 6: *The shape of the absorption bands of Cr^{3+} in synthetic alexandrite and of Fe^{3+} in chrysoberyl (after Farrell and Newnham, 1965). Both spectra were measured for light polarized along b.*

colour change in the peacock-blue alexandrite. The result was $0.4 < x_{Cr}/x_{Fe} < 1.2$. Finally, this model is also consistent with the existence of green alexandrites without blue tints because of the higher iron and/or lower chromium content, compared to the peacock-blue alexandrite. The results are consistent with the WDS-EPMA analysis. However, it is interesting to note the relatively high titanium content (*Table I*). Whether or not optical transitions belonging to charge transfer Fe^{2+} - Ti^{4+}, well known in so many oxygen-based minerals, influence the optical absorption spectrum has not yet been resolved.

Conclusions

The origin of colour of the peacock-blue variety of alexandrite from Malacacheta (Minas Gerais, Brazil) is explained by the presence of Fe^{3+} and Cr^{3+} substituting for Al^{3+} in the mirror sites. For intermediate Fe/Cr ratios ($0.4 < x_{Cr}/x_{Fe} < 1.2$), and with both Fe^{3+} and Cr^{3+} in the mirror sites, the minimum in the absorption spectrum lies at about 480 nm, giving rise to the blue tones of this variety of alexandrite. For higher Fe and intermediate Cr contents, the minimum in the spectrum shifts to the green ($\lambda > 500$ nm), and the alexandrite loses the bluish colours when viewed along *b*. For very low Cr concentrations, absorption is strong in the violet-blue region and the chrysoberyl cannot be considered to be alexandrite because it becomes yellow, losing its strong pleochroism in the green range and the 'alexandrite-effect'.

Acknowledgements

This work has been supported by the Brazilian foundation FAPEMIIG (CEX 245197 and CEX 172495). We are grateful to M.P. Ferreira and to V.C. Costa (CDTN), for help with the optical absorption spectrometer. We are also grateful to H.D Pfannes for motivating discussions and to F.S. Lameiras for his critical review of the manuscript.

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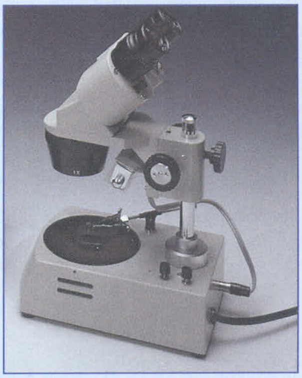

Abstracts

Diamonds

Gems and Minerals

Synthetics and Simulants

Diamonds

Diamonds in volcaniclastic komatiite from French Guiana.

R. Capdevila, N. Arndt, J. Letendre and J-F. Sauvage. *Nature*, **399**(6735), 1999, pp 456-8.

Analyses are presented of diamondiferous volcaniclastic komatiites from the Dachine deposit in the 2210 ± 900 m.y. old greenstone belt of the Guiana Shield, French Guiana. The ultramafic host of the deposit is ≥ 5 km x ≤ 1000 m wide. Bulk samples contain < 1-77 (mainly) microdiamonds/kg rock. Larger diamonds (>1 mm) (≤ 4 carats/m^3 rock) occur in poorly sorted alluvium overlying mineralised bedrock. Cubo-octahedral diamonds and low $\delta^{13}C$ ratios (-23 to 27‰) indicate eclogitic sources. Nine analyses are listed of komatiites for major and trace elements. The diamonds are probably xenocrysts sampled at depths of > 150 km and transferred rapidly to the surface. Primary, anhydrous komatiite magma formed by deep melting, penetrated hydrated lithosphere beneath the Dachine island arc, accumulated H_2O and diamonds and was propelled to the surface. R.K.H.

Layered mantle lithosphere in the Lac de Gras area, Slave Craton: composition, structure and origin.

W.L. Griffin, B.J. Doyle, C.G. Ryan, N.J. Pearson, S.Y. O'Reilly, R. Davies, K. Kivi, E. van Achterbergh and L.M. Natapov. *Journal of Petrology*, **40**(5), 1999, pp 705-27.

Garnet and chromite concentrates and lherzolite, harzburgite, dunite, websterite and eclogite xenoliths from 21 Cretaceous-Tertiary kimberlite intrusions have been used to map the Archaean lithosphere mantle beneath the central Slave Province, Canada. Ni (for garnet) and Zn (for chromite) - derived *T* enable estimates of the depth of crystallization and show a sharp discontinuity in mantle composition at 900°C. The lithospheric mantle < 145 km is extremely depleted in LILE and HFSE compared to other known Archaean mantle. It has a higher harzburgite/lherzolite ratio and may have a higher olivine/orthoproxene ratio. It is an ancient oceanic or sub-arc mantle. The deep mantle (145-200 km) is similar to the Kaapvaal lithosphere sampled by Group I kimberlites but the harzburgite/lherzolite ratio decreases with depth. Eclogites come from this deeper layer which contains abundant diamonds, was derived from the lower mantle (ferropericlase-perovskite inclusions) and is a fossil plume head. Some representative partial major and trace element analyses of garnets are given. B.E.L.

Changes and new developments in Africa.

J.J. Gurney. *Gems & Gemology*, **35**(3), 1999, 34-6.

Africa currently produces 51.8 million carats of rough diamonds annually (46% of the world total by weight, or 72% by value). It is forecast that African diamond production will increase to > 60 million ct/yr in the foreseeable future. It is reasonable to expect further discoveries in the Kalahari craton and in Mauretania.
R.A.H.

Diamonds from Australia.

A.J.A. Janse. *Gems & Gemology*, **35**(3), 1999, 37-9.

The Argyle lamproite pipe has been mined since 1985 and produces mainly small brown diamonds of irregular shape; only 5% are of gem quality, but now ~ 40% of the non-gem Argyle diamonds are cut economically in India into inexpensive low-quality stones. The only other producing diamond mine is Merlin, in the Northern Territory, which came into production in 1999; it draws from 4-7 small kimberlite pipes and produces diamonds of very good quality.

Created Diamonds'; avariety of colours are being produced as well as near-colourless material. It is noted with some amusement that synthetic moissanite is more expensive than synthetic diamond. R.A.H.

Gem news.

M.L. Johnson, J.I. Koivula, S.F. McClure and D. DeGhionno (eds). *Gems & Gemology*, **35**(2), 1999, 142-55.

Abstractors

J. Flinders	J.F.	B.E. Leake.	B.E.L	A.H. Rankin	A.H.R.
R.K. Harrison	R.K.H.	P.B. Leavens	P.B.L.	I. Sunagawa	I.S.
R.A. Howie	R.A.H.	M. O'Donoghue	M.O'D.		

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

ISSN: 1355–4565

The first diamonds from Merlin project in the North Territory, Australia, included a 14.76 ct 'white' octahedron from the Scaramore pipe. R.A.H.

Genesis of diamonds in the lower mantle.

L. LIU. *Contributions to Mineralogy and Petrology*, **134**(2-3), 1999, 170-3.

The occurrence of the ('forbidden') assemblage ferropericlase + enstatite as inclusions in diamonds implies formation and that of their host diamonds in the lower mantle. Magnesite is probably the only stable carbonate at > ~ 220 km depth. The reaction boundary for magnesite decarbonation has a positive dT/dP slope at lower P which becomes negative at higher P if no other phase intervenes, and probably intersects the geotherm at ~ 900 - 1100 km, below which magnesite decomposes into assemblages periclase + diamond + O. Hence, the most likely inclusion to form in diamond in the lower mantle is ferropericlase, the occurrence of only this type of inclusion in diamonds from Sao Luiz, Brazil, substantiating this view. J.F.

Observations of GE-processed diamonds: a photographic record.

T.M. MOSES, J.E. SHIGLEY, S.F. MCCLURE, J.I. KOIVULA AND M. VAN DAELE. *Gems & Gemology*, **35**(3), 1999, 14-22.

Natural high-purity diamonds are being processed at high T and high P by the General Electric Co. to improve their colour, i.e. to make them more nearly colourless. Agreement has been reached with Pegasus Overseas Ltd (POL) and GE to inscribe the girdle surface of all their processed stones with the letters POL. The GIA has now established a database of information after examining 858 GE POL diamonds; 99% of them are type IIa. Most of the stones examined were 1-2 ct generally cut in one of several 'fancy' shapes. Photographs are presented showing some of the unusual internal features such as graining and 'partially healed' cleavages; they often show a slightly hazy appearance. Examples are reported of stones in which the GE POL inscription has been partially or completely removed, but the database built up on these stones allowed their detection. R.A.H.

Canadian diamond production: a Government perspective.

D. PAGET. *Gems & Gemology*, **35**(3), 1999, 40-42.

The main cluster of economically viable diamond-bearing kimberlite pipes occur in the Lac de Gras area in the Slave Province of the Northwest Territories. Here the Ekati mine has a resource of 66 million tonnes at 1.07 ct/t, with an average value of US$100 per carat. Other diamond projects in the evaluation stage include that at Jericho in Nunavat [a new territory in the East Arctic, on the east side of Hudson Bay, formally created in 1999]. R.A.H.

Russian diamond sources.

N.V. SOBOLEV. *Gems & Gemology*, **35**(3), 1999, 43.

More than 800 kimberlite bodies have so far been identified in the Siberian craton of the Republic of Sakha (formerly Yakutia) and produce ~ 98% of all diamonds mined in Russia, the remaining 2% being recovered from placers in the Ural Mts. Within Saakha, 10% of the production is from the Anabar placers on the Ebelyakh River; several pipes in the Muna field are being prepared for mining. The Arkhangelsk diamondiferous province in the East European craton has several high-grade kimberlite pipes, of which the Lomonossov may be the first to be developed. R.A.H.

Gems and Minerals

Il 'demantoide' della Val Maleno

F. BEDOGNÈ, E. SCIESA AND P. VIGNOLA. *Rivista mineralogica italiana*. **23**, 208-17, 1999, illus. in colour.

Yellow-green andradite is found in the Val Malenco area of northern Italy. The name demantoid has frequently been used for this material and some small crystals do achieve a deep emerald-green. Crystals occur in serpentinites as rhombic dodecahedra with faces modified by trapezohedra: the composition of a number of specimens is given in tabular form. The finest green crystals appear to be limited to the two areas Campo Francisca and Alpa Acquanegra M.O'D.

[The quantitative appraisal of the green of jadeite.]

(Chinese with English abstract)

Y. CHAN, F. PAN AND J. REN. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 412-15.

A new standard is proposed for the naming and classification of the green colour of natural jadeite, based on photometry. Green jadeite is classed as one of six 'species' pure green, very slightly yellowish-green, very slightly bluish-green, slightly bluish-green, yellowish-green and bluish-green. The colour is evaluated according to saturation and brightness, these two indices then being united to establish the new standard. R.A.H.

[Mineralogical characteristics of chatoyant quartz in Luodian County, Guizhou.]

(Chinese with English abstract)

M. DENG. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 416-7.

The Luodian chatoyant quartz may have originated in quartz veins in blue asbestos; it is brown-green, light green and bluish-green in colour. It contains parallel fibres of tremolite. In bright sunshine or under a tungsten light it reflects a dazzling slit of light from the interior of the stone. R.A.H.

The separation of natural from synthetic colourless sapphire.

S. ELEN and E. FRITSCH. *Gems & Gemology*, **35**(1), 1999, 30-41.

Increasing amounts of colourless sapphire, promoted mainly as diamond substitutes but also as natural gemstones, have been seen in the gem market during the past decade. Natural colourless sapphires can be distinguished from their synthetic counterparts by their trace-element composition and short-wave UV transparency. EDXRF shows higher Fe, Ti, Ca and Ga in natural sapphires; these impurities cause a reduction in the SWUV transparency that can be detected by UV-visible spectrophotometry, i.e. a total absorption in the UV region below 280-300 nm, which is not seen in synthetic stones. A SWUV transparency tester that can rapidly identify parcels of colourless sapphires is described.

R.A.H.

The identification of Zachery-treated turquoise.

E. Fritsch, S.F. McClure, M. Ostrooumov, Y., Andres, T. Moses, J.I. Koivula and R.C. Kammerling. *Gems & Gemology*, **35**(1), 1999, 4-16.

Over the last ten years, millions of carats of turquoise have been enhanced by a proprietary process called the Zachery treatment. This process effectively improves a stone's ability to take a good polish and may or may not improve the colour. It also decreases the material's porosity limiting its tendency to absorb discolouring agents such as skin oils. Examination shows that the process does not alter the gemmological properties of the turquoise; it does not involve impregnation with a polymer. Most Zachery-treated turquoise can be identified only through chemical analysis (most efficiently by EDXRF or EPMA techniques) as it contains significantly more K than its untreated counterpart.

R.A.H.

Guatemala jadeites and albites were formed by deuterium-rich serpentinizing fluids deep within a subduction zone.

C.A. Johnson and G.E. Harlow. *Geology*, **27**(7), 1999, pp 629-32.

Jadeites and albitites from the Motagua Valley, Gutemala, are high-*P*-low-*T* metasomatic rocks that occur as tectonic inclusions in a serpentinite-matrix mélange. Metasomatism was driven by a fluid with a $\delta^{18}OH_2O$ value of 6‰ and a δDH_2O value that is high in comparison with metamorphic fluids at the other high-*P*-low-*T* localities of similar grade. It is inferred that the fluid was originally sea-water that was entrained during subduction either as mineral-bound H_2O, or as free pore waters. The fluid drove serpentinization reactions in ultramafic rocks, possibly leading to deuterium enrichment of H_2O, prior to forming the jadeites and albitites at a depth of 29 ± 11 km. There are isotopic and fluid-inclusion similarities to rodingites, which are Ca-rich metasomatites found at other serpentinite localities. The results suggest that the serpentinization process, whether it occurs within subduction zones or on the flanks of oceanic spreading ridges, may produce residual fluids that are H_2O rich, have 1-8 wt.% eq. NaCl, and have high, perhaps sea-water-like δD values. P.B.L.

On the identification of various emerald filling substances.

M.L. Johnson, S. Elen and S. Muhlmeister. *Gems & Gemology*, **35**(2), 1999, 82-107.

Criteria for distinguishing emerald filling materials have been investigated, 39 fillers being divided into six substance categories ~ three 'presumed natural' (essential oils, including cedar wood oil, other oils and waxes) and three 'artificial resin' (epoxy and other prepolymers, including UV-setting adhesive, and polymers). Regardless of their composition, fillers with RI > 1.54 show flash effects in emeralds. On the basis of Raman and IR spectroscopy, the fillers can be separated into five spectral groups A-E. Most, but not all, commonly used artificial resins have spectra distinct from that of cedar wood oil. However, the detection of one substance in a fissure does not imply that all others are absent. R.A.H.

Gem news.

M.L. Johnson and J.I. Koivula (eds). *Gems & Gemology*, **35**(1), 1999, 47-60.

Items described include a 2 cm prism of Colombian emerald with a large moveable gas bubble and a twelve-rayed star quartz from Sri Lanka (sillimanite being responsible for the asterism). R.A.H.

Gem news.

M.L. Johnson, J.I. Koivula, S.F. McClure and D. DeGhionno (eds). *Gems & Gemology*, **35**(2), 1999, 142-55.

A new source for tsavorite is recorded ~ 15 km from Ruangwa in Lindi Province, Tanzania. R.A.H.

[The colorimetry and chromaticity study of Xinjiang Hetian jade.] (Chinese with English abstract)

W. Li and R. Wu. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **19**(4), 1999, 418-22.

Analysis of the visible spectrum of Hetian jade indicates that the green colour is due to the total iron content. The absorption peak at 450 nm is produced by the *d~d* transition of Fe^{3+}, and the broad, weak bands at 640 nm can be attributed to the $Fe^{2+} \rightarrow Fe^{3+}$ charge transfer. The colour indices of Hetian jade are calculated from the reflectivit and transmission ratio; this jade has low saturation and low brightness. EPMA results and cell parameters are given for tremolite in the Hetian jade.

R.A.H.

Exotic origin of the ruby deposits of the Mangari area in SE Kenya.

A. Mercier, P. Debat and J.H. Saul. *Ore Geology Reviews*, **14**, 1999, 83-104

The Mangari gem-quality ruby deposits occur as lenses and veins associated with ultrabasic bodies of the Proterozoic Mozambique belt. Representative chemical compositions are presented for the following minerals associated with corundum (ruby): sapphirine, chlorite, spinel, zoisite and plagioclase. Data are also presented for the following minerals from the sillimanite gneiss, country rocks: biotite, garnet at plagioclase. The *P-T* conditions for the gneisses, based on mineral thermobarometric methods, are within the ranges 5.4 to

6.7 kbar and 605 to 670°C. Comparable *P-T* estimates for corundum-bearing rocks are within the ranges, 8 to 10.5 kbar and 700 to 750°C. The Mangari deposits are fragments of a deeper crust brought up to their present-day level by ultrabasic bodies during emplacement as thrust sheets. It is suggested that the rubies were formed under granulite conditions but were tectonically emplaced into country rocks of lower metamorphic grade and *P-T* conditions. A.H.R.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure (eds). *Gems & Gemology*, **35**(1), 1999, 42-6.

Items noted include green faceted ovals purporting to be chinese peridotite which were found to be glass, and a cat's-eye taaffeite in which the chatoyancy was due to the presence of parallel reflective planar inclusions with striations. R.A.H.

Achat in Osterreich.

G. Niedermayr. *Mineralien Welt*, **10**(6), 1999, 52-6.

Fine ornamental-quality specimens of agate are found at several locations in Austria. A number of formations are described, notably the Bohemian Massif where the agate is found in serpentinites. Agate is also found in volcanic rocks. M.O.D.

Sapphire and garnet from Kalalani, Tanga Province, Tanzania.

A.V. Seifert and J. Hyrsl. *Gems & Gemology*, **35**(2), 1999, 108-20.

Reddish-orange gem-quality sapphire, pyrope-almandine and tsavorite occur in desilicated pegmatites cutting serpentinite massifs surrounded by amphibolite-facies rocks in the Kalani area (~ 3 km S of the Umba area). Gemmologically, the sapphires are virtually identical to those from Umba, but the garnets are different. The dark red to brownish-red pyrope-almandine from Kalalani is distinct from the pink-purple rhodolite found at Umba, and tsavorite is not known from the Umba area. Optical and physical properties are reported together with EPMA values for pyrope-almandine. R.A.H.

Texture formation and element partitioning in trapiche ruby.

I. Sunagawa, H.-J. Bernhardt and K. Schmetzer. *Journal of Crystal Growth*. **206**, 1999, 322-30, 5 figs., 1 table.

Based on textural and compositional investigations on ruby single crystals which show textures with six arms and six growth sectors (trapiche ruby from Mong Hsu, Myanmar), the mode of formation of the unique texture has been determined, and the element partitioning was related to the growth mechanism. The arms and the branches were formed earlier by dendritic growth on rough interfaces, and the growth sectors by lateral growth on smooth interfaces. The arm and branch portions consist of plural mineral phases but show a low and almost uniform Cr content in corundum throughout the extension, whereas the growth sectors consist of a single ruby phase and show Cr zoning parallel to the growth surfaces. Element partitioning in the earlier dendritic growth is governed by thermodynamic parameters, whereas that of the latter layer-by-layer growth by kinetics. The present size of trapiche ruby crystals was attained in a very short duration, i.e. that required to complete the skeleton by dendritic growth. I.S.

[The identification of a filled ruby.] (Chinese with English abstract)

H. Wan. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 410-11.

An EPMA examination of a secondary inclusion in a faceted ruby showed that its main component is a silica glass. R.A.H.

[The enhancement and treatment of pearl's colour.] (Chinese with English abstract)

J. Wang, J. Liang and M. Peng. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 407-9.

It is argued that since the colour of neither natural nor cultured pearl can meet people's demands, the colour needs enhancing. After being bleached, dyed and irradiated the colour of pearls is more satisfactory. R.A.H.

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.

[Discussion on character of the rough jadeite crust.] (Chinese with English abstract)

E. Zhang, X. Yin and M. Peng. Kwangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 400-2.

The natural rough jadeite crust can be distinguished from man-made crust by EPMA, XRD and IR techniques. Chemical analyses (9) and IR spectra of three different depth zones in the sample are presented. R.A.H.

[Rossmanite, olenite, elbaite and the 50% rule as a basis for distinguishing between mineral species in Li-Al tourmalines.] (Russian with English abstract)

A.A. Zolotarev and A.G. Bulakh. *Proceedings of the Russian Mineralogical Society*, **128**(2), 1999, 32-8.

New structural formulae for liddicoatite, rossmanite and olenite have been calculated using a uniform approach. The compositions of the Li-Al tourmalines are plotted on vector diagrams; on these the composition of rossmanite plots in the olenite field, and there seems no difference between properties and XRD data for rossmanite and olenite. This work indicates that, for the Li-Al tourmalines, new mineral species cannot be distinguished only on the basis of atomic occupancy at a particular structural site; all interdependent substitutions for atoms in the various structural positions must be considered. R.A.H.

Synthetics and Simulants

Russian synthetic ametrine.

V.S. Balitsky, T. Lu, G.R. Rossman, I.B. Makhina, A.A. Mar'in, J.E. Shigley, S. Elen and B.A. Dorogovin. *Gems & Gemology*, **35**(2), 1999, 122-34.

Gem-quality synthetic ametrine has been produced commercially in Russia by hydrothermal growth in alkaline solutions. The faceted material mostly resembles the Bolivian natural ametrine, but colour zoning and twinning are distinctive in the synthetic stones. XRF showed higher K, Mn, Fe and Zn than in natural ametrine. IR spectra of the synthetic citrine portions showed more intense absorption in the 3700-2500 cm^{-1} range and the synthetic amethyst zones showed a weak diagnostic peak at 3543 cm^{-1}. R.A.H.

Controlled crystallization of emerald from the flux melt .

S.N Barilo, G.L. Bychkov, L.A. Kurnevich, N.I. Leonuk, V.P. Mikhailov, S.V. Shiryaev, V.T. Koyava and T.V. Smirnova. *Journal of crystal growth*, **198/199**, 1999, 716-22, 3 figs., 3 tables.

Gem-quality emerald single crystals, with small dichroism, uniform distribution of colour throughout, and weighing as much as 150 ct, were synthesized from flux melt, using seed plates cut parallel to $(10\bar{1}0)$ and $(11\bar{2}0)$. The optimal concentration ratio of the solute near the crystallization front was maintained through adequate stirring by a platinum crystal holder rotated at a rate of 30 rpm and seed positioning. Laser experiments and threshold measurements were made to examine the emerald quality. Lasing was achieved at an absorbed pump energy threshold of less than 0.6 mJ. I.S.

Diamond formation during reduction of oxide and silicate-carbon systems at high *P-T* conditions.

A.I. Chepurov, I.I. Fedorov, V.M. Sonin, D.G. Bagryantsev and N. Yu. Osorgin. *European Journal of Mineralogy*, **11**(2), 1999, 355-62.

Diamonds have been synthesized in fayalite + graphite and magnetite + graphite mixtures by partial reduction of the samples with hydrogen and metallic titanium at 1300-1400°C and 45-55 kbar. Hydrogen provided local reduction of the samples with separation of metallic iron, which catalysed the transformation of graphite into diamond. Iron reacted with other elements and was not found in the free state in the experimental products. These experiments can be regarded as a simplified model for the formation of some types of natural diamond during the interaction of reduced fluids with carbon-bearing mantle rocks. R.A.H.

[Study on inclusion in synthetic diamond.]

(Chinese with English abstract)

B. Lin, H. Wan and M. Peng. Kuangwu Yanshi (*Bulletin of Mineralogy, Petrology and Geochemistry*), **18**(4), 1999, 308-9.

An inclusion in a synthetic diamond was shown by EPMA and XRD to be 'melnikovite' (greigite, $A^{2+} B_2^{3+} S_4$). It is suggested that the growth conditions in a specific oxidation-reduction environment allowing the coexistence of Fe^{2+} and Fe^{3+}. R.A.H.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure (eds). *Gems & Gemology*, **35**(2), 1999, 136-41.

Items noted include a 19.64 ct faceted orange-brown bastnäsite, a 0.29 ct black synthetic diamond, and cobalt-doped synthetic forsterite whose strong pleochroism makes it a convincing tanzanite imitation. R.A.H.

Some diagnostic features of Russian hydrothermal synthetic rubies and sapphires.

K. Schmetzer and A. Peretti. *Gems & Gemology*, **35**(1), 1999, 17-28.

Most Russian hydrothermal synthetic rubies, and pink, orange, green, blue and violet sapphires (coloured by Cr and/or Ni), reveal diagnostic zigzag or mosaic-like growth structures associated with colour zoning. After proper orientation, these internal patterns are easily recognized using a standard gemmological microscope in conjunction with immersion or fibre-optic illumination; pleochroism is also useful for separating Cr-free blue-to-green synthetic sapphires from their natural counterparts, but this requires the determination of orientation of the optic axis in a faceted sample. Samples coloured by a combination of Cr, Ni and Fe are also described. R.A.H.

Epitaxial diamond growth on sapphire in an oxidizing environment.

M. Yoshimoto, K. Yoshida, H. Maruta, Y. Hishitani, H. Koinuma, S. Nishio, M. Kakihana and T. Tachibana. *Nature*, **399**(6734), 1999, 340-2.

The nucleation and growth of diamond by vapour deposition in a hydrogen-free, pure-O_2 environment to form hetero-epitaxially aligned crystallites on single-crystal synthetic (0001) sapphire wafers, are reported. The growth of the diamond occurs where the oxidative etching of C must compete with its formation. By choosing a *T*-range that results in preferential oxidation of graphite to that of diamond, accumulation of the latter occurs. Diamond crystals grew at ~ 600°C under O_2 *P* of 0.1-0.2 torr. An SEM photograph shows diamond crystals on the sapphire substrate. R.K.H

BOOK REVIEWS

The diamond formula

A.S. BARNARD, 2000. Butterworth Heinemann, Oxford. pp x, 166. Illus. in black-and-white. Softcover. ISBN 0 7506 4244 0. £24.99.

Useful and brisk round-up of the present position in the synthesis of gem-quality diamond with the first chapters giving an account of how the different processes developed. Some of the early pioneers are introduced and a large section of the text is devoted to developments in gemmological testing. For all sections references are made to a list at the end of the book and a number of photographs show persons and apparatus of diamond synthesis history. A good deal of useful information is given on De Beers synthetic industrial diamond and a chapter discusses the possible use of chemical vapour deposition (CVD). Details of gemmological laboratory testing are well-written and easy to read.

In compiling such a book the author accepts that most of the text should be 'stop press', so fast is the development of gem diamond synthesis! Details of the high pressure/high temperature altered diamonds and the story of GE POL must wait for the next edition of an excellent, readable and affordable book which is very suitable for diamond course students as well as the general reader. M.O'D.

Glossary of obsolete mineral names

P. BAYLISS, 2000. The Mineralogical Record, Tucson. pp viii, 235 + extra leaves for additional notes. Hardcover. ISBN 0 930259 04 1. US$32.00 plus $3 postage and packing.

With two columns per page and a small though legible typeface, this book is a companion to *Fleischer's glossary of mineral species* (Mandarino, eighth and latest edition 1999) and to *Hey's mineral index* (Clark, 1993). It is also something of a successor to the now rare *Dictionary of the names of minerals* (Chester, 1896) and *A catalogue of minerals and synonyms* (Egleston, 1892). The present work aims at the inclusion of all names used for mineral substances throughout history, which are not now considered valid or current [author's preface]. Varietal names of the gem minerals (e.g. ruby, sapphire) are not included. Further details on group, supergroup, subgroup, family, superfamily and subfamily are defined by Smith *et al.* in *Advances in X-ray analysis* **41** (1998) and notes on structural formulae can be found in Smith *et al. American Mineralogist*, **83**(126), 1998.

The entries in this book are brief, consisting of name, present equivalent, if any, source and author of information, thus Alumina hydrate = diaspore, Egleston 8 (1892): taprobanite = red Cr-rich taaffeite-*8H*, *American Mineralogist*, **69** (215), 1984. I have noted a few typos but on the whole the entries have been carefully transcribed. I have not attempted to check the Linnean-style names proposed for minerals in the earlier editions of Dana's *System of mineralogy* but on a read-through some of them have shown up; cuprum lazureum (azurite), oculus mundi (opal) are examples. Many names appearing unfamiliar at first sight are later seen to consist of non-English forms and on the whole the author has traversed this minefield successfully. Gemmologists with an interest in minerals should buy this very reasonably-priced book. M.O'D.

Minerals of Broken Hill

W.D. BIRCH (Ed.), 1999. Broken Hill City Council, Broken Hill. pp xii, 289. ISBN 0 9599486 9 4. Price on application.

This is the second large, full coloured survey on the minerals of Broken Hill to appear in the last 17 years: in 1982 Australian Mining and Smelting Ltd published a good quality survey under the same title. Considerable work has taken place on the site since that time and all serious mineral collectors will want to be able to consult a copy of the present book, if not to buy it. The text begins with a geological and historical survey of the area, including a close study of the main ore-body, and then continues with the main descriptive section in which mineral species are arranged alphabetically. The text includes notes on species no longer validated: this type of information is always necessary and should never be discarded even when the species is discredited. Future workers may have lost sight of type specimens, thus making work cited in earlier reports uncertain so it is well worth knowing why a particular theory is advanced. References are given to significant papers where the occurrence of a particular species is especially noteworthy.

The descriptive section is followed by a complete list of recognized minerals from the Broken Hill deposit, by a first-class bibliography of 25 pages and by a glossary. The editor and publishers are to be congratulated for producing so fine a book: the photographs are for the most part of outstanding quality though I found the odd one slightly (but only slightly) out of focus. Several of the species could have been taken as having ornamental potential and more would make collectors' gemstones. M.O'D.

Symmetrielehre der Kristallographie

R. BORCHARDT AND S. TUROWSKI, 1999. Oldenbourg Verlag, München. pp viii, 108, pl 32, softcover. ISBN 3 486 24648 8. DM 63.00.

Clear and useful guide to mineral crystals with 32 cut-out models of the simpler examples, the book is unusual as it is arranged in descending orders of symmetry, the text relating specifically to the models at the end but also providing crystallographic descriptions and examples of mineral species whose crystals take, or can take, the particular forms depicted. M.O'D.

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The Desmond Sacco collection: focus on southern Africa

B. Cairncross, 2000. The author, Marshalltown, Johannesburg. pp 408, illus. in colour. Hardcover. ISBN 0 620 24340 6. Price on application.

This magnificent book catalogues a part of the Desmond Sacco mineral collection, covering southern Africa. Though many of the specimens depicted would have gemstone potential, faceted stones, though forming part of the complete collection, are specifically excluded from the book. The countries covered apart from South Africa, are Zimbabwe, Mozambique, Namibia and the Democratic Republic of the Congo. Introductory material gives a brief biography of Desmond Sacco and the development, housing and growth of the collection. Sacco trained as a field geologist and the various positions he has held have greatly assisted both the collection and the public awareness of the beauty and importance of fine African minerals. Perhaps the greatest highlight in a fascinating career was Sacco's discovery of rhodochrosite at his own company's mine, N'Chwaning 1 in the south African Kalahari manganese field. This material is, of course, well-known to gemmologists.

Tributes to the collection and its founder follow and many of the displays are illustrated before the section on Namibia begins: as with the other countries covered the text opens with a map before examining the major mineral deposits in detail. The mineral photographs are so arranged that there are never more than six in a single opening and may occupy a whole page: dimensions of the specimens are given and, even better, each location has its own bibliography. From the gemmological point of view some of the finest specimens in the Namibian section are translucent yellow smithsonite (from Berg Aukas), amethyst (Brandberg), blue and yellow-green tourmaline (the Karibib-Usakos pegmatites), topaz (Klein Spitzkoppe), cerussite and nambulite (the Kombat mine), fluorite (Okorusu), cuprite (Onganja) and yellow transparent mimetite (Tsumeb - naturally the location with the most species). From South Africa are the rhodochrosites from the Kalahari and prismatic purple sugilite (Wessels mine): gold deposits and diamond crystals are not included. From Mozambique are manganotantalites and very large topaz crystals from the Alto Ligonha pegmatites, transparent yellow-green beryl and red tourmaline from Nampula. Gemmy specimens from Zimbabwe include a fine heliodor from the Green Walking Stick mine, Miami, gemmy aquamarine from Karoi and both ruby and blue sapphire crystals from the south of the country. Cuprite and cobaltian calcite crystals feature in the Democratic Republic of the Congo.

Reading through the book the reader will come across several examples of minerals large and clear enough to facet ~ but this would really be vandalism! Here are some of them, none the less: orange sturmanite, colourless thaumasite and bright yellow ettringite (N'Chwaning), wulfenite and orange cadmium-rich smithsonite (Tsumeb). The book is not cheap but try to see a copy somehow, somewhere! M.O'D.

Gemme: dati per l'identificazione

P. De Stefano, R. Marcon and S. Morabito, 1993. Finpreziosi Italia s.r.l., Milan, for the Istituto Gemmologico Italiano. pp xii, 99. Absorption spectra in colour. Softcover, ring-bound. ISBN 88 86279 00. price on application.

Large-format (34 × 24 cm) tabular guide to the major gemstones arranged by colour. All major constants are given and consolidated individual tables of refractive index and specific gravity are provided at the end of the main text. There is a short though useful bibliography and an index. Presentation is very clear and the whole production reflects credit on the compilers and publishers. M.O'D.

Gems: a lively guide for the casual collector

D.J. Dennis Jr, 1999. Harry N. Abrams Inc., New York. pp 192, illus. in colour. Hardcover. ISBN 0 8109 4126 0. £18.95.

This is a book like many other general enthusiastic introductions in that it does not aim to be gemmologically accurate, nor is it. This would only be of concern to the pedant, perhaps, as the book is quite attractive, with small colour photographs of gemstones placed in the text margins in place of larger ones in a separate central section, a commoner practice today. This may not be the happiest way of introducing gemstones when details of the text are a little vague on occasion. The reader new to the subject needs more illustrations - some of stones set in jewellery would be welcome - but on the whole the book succeeds quite well in its stated aims. There is some pleasing eccentricity which surfaces most prominently in the section on the care of jewellery: it is suggested that toothpaste is not an ideal cleaning medium - this instantly brings to my mind one way in which a piece of jewellery (never loose stones of course) might in ignorance of the book's strictures be cleaned in haste before a dinner party, with alarming consequences. It would be better not to dwell on this! M.O'D.

Einkaufsführer 1999

Sudwestdeutsche Verlagsanstalt, Mannheim, 1999. pp 748. ISBN 3 87804 276 0. Softcover, DM79 + DM17.50 post and packing.

Latest edition of an established guide to the watch, jewellery, precious stone and silver goods industries of Germany, this well-produced directory is invaluable with anyone wishing to get in touch with gemstone dealers and others who in many cases have included most attractive advertisements of their products. Entries are classified and cross-referenced. M.O'D.

Boron: mineralogy, petrology and geochemistry

E.S. GREW AND L.M. ANOVITZ, 1996. Mineralogical Society of America, Washington. pp xx, 862, softcover. ISBN 0 939950 41 3 (series ISSN 0275 0279) (*Reviews in Mineralogy*. **33**). Price on application.

Gemmologists as well as mineralogists and geologists will find a great deal of useful information in this large multi-author study of the role of boron in the earth sciences. From page 503 to page 623 attention is focused on tourmaline group minerals and this will be of particular interest to the student of the gem minerals and their geochemistry but there is also much to say about all boron-bearing species. Comprehensive bibliographies accompany all sections. M.O'D.

Naming gem garnets

W.W. HANNEMAN, 2000. The author, Poulsbo, WA, U.S.A. pp xii, 103. Includes colour charts. Ring-bound, softcover. ISBN 0 9669063 1 4. US$20.00.

Passing on a warning from the author that the print run will be short, try to get this excellent overview of garnet nomenclature before too long.

There has always been a problem over 'what to call the garnets?'. Hanneman gives a useful conspectus of previous work on garnet nomenclature and adds, to summarized papers by various authors, copies of letters to the editors of gemmological journals in which he comments upon the papers. Hanneman feels that some at least of the nomenclature schemes postulated by mineralogists are unhelpful and that some of the names (which may have arisen through trade sources) are both of equal validity through assumption and also help to promote the wider acceptance of the newer gem species and varieties among the general public. The use of such names would in no way detract from mineralogical precision since quite different ends are sought by gemmologist and mineralogist. Perhaps one analogy might be with coats-of-arms, some of which are so ancient that no documents record their granting: none the less they are accepted just because everyone has long recognized them. This is in fact what seems to be happening: if it is, a certain common sense would seem to be operating. Probably the two sides might never agree but why should they need to?

In pointing out the steps by which garnet classification and nomenclature have reached their present state, Hanneman has performed a useful service and the book deserves a wide readership. In his journey quite a number of other topics arise, all throwing light upon his main thesis: in addition he includes colour charts and tables listing properties taken from a number of different sources. A note describing the operation of the Hanneman Garnet Refractometer is included (it will measure refractive indices up to 1.90). Like all the author's instruments and this book, it works well and the cost is minimal. M.O'D.

Rubies (diamonds, emeralds, sapphires) are a girl's best friend

SUE HEADY with gemmological introduction by Michael O'Donoghue, 1999. Grange Books plc, Rochester. Series of four books, each with 96 pages, illus. in colour. Hardcover. ISBN 1 84013 259 0: 1 84013 258 2: 1 84013 261 2: 1 84013 260 4. £3.99 each.

Attractive tall-format presentations of four major gemstones set in major items of jewellery which have featured in Christie's sales catalogues of the past few years. A short gemmological introduction to each species is provided by the present reviewer. For the most part the jewels have reproduced well: the descriptive text is selected from the sales catalogue entries and the whole series, let alone each book, is amazingly cheap for what you get and would make a starter gift for anyone developing an interest in jewellery and gemstones. The dust covers are particularly attractive when seen in combination with the tall format. Each book is available separately. M.O'D.

Gems and gem industry of India

R.V. KARANTH, 2000. Geological Society of India, Bangalore. pp ix, 405. Illus. in colour. [*Memoirs of the Geological Society of India*, **45**.] Hardcover. ISBN 81 85867 41 0. US$75.00.

Despite history, India remains the sleeping giant of Asiatic gemstone production. Rumours abound of specimens of the highest quality turning up but there seems never to have been a consistent supply. This reviewer has spoken to a number of gem miners who have worked in India who bear out these possibilities. India has a varied geology which is well described in this standard text. The preface correctly remarks that there has been no book on Indian gemstones since the publication of Iyer's *Indian precious stones* (1946) [and this book has many weaknesses] so the appearance of this one is timely to say the least.

The reader may be surprised to find that the first 188 pages comprise in fact a treatise on gemmology with no particular reference to India. Details of specifically Indian stones and conditions begin almost apologetically during the section on diamond which appears as the first of the isotropic minerals (the descriptive text is arranged as isotropic, uniaxial and biaxial). While the descriptions of the materials are what the reader would expect, the real treasure (in that the details have never appeared in monograph form before) is the comparative wealth of locality information, much of which is referred to coordinates. It is here that we find some indication of the potential gem wealth of the country. Entries also describe the significant geology and mineralogy of the major deposits with some notes on mining practices; some historical references are also given and extracts from correspondence giving up-to-date information occur here and there. There are also notes on simulants in the appropriate places.

The descriptive section and the book close with a fairly extensive bibliography and a set of identification tables. While three maps are provided they are too small in scale to be much more than a rough guide to the whereabouts of the major sites. There could well have been more and better maps and their absence detracts from the general usefulness of the book. While thoroughly appreciating the difficulties that would be encountered if a long-term study of current deposits was undertaken it might have been better to have gone all-out for that, rather than trying to make a gemmological textbook out of at least one third of the text. Nevertheless, the book is of real value, but when I think what it could have been ...! M.O'D.

The MicroWorld of Diamonds

John I. Koivula, 2000. Gemworld International Inc., Northbrook, Ill., U.S.A. pp xxiii, 157, Illus. in colour. Hardcover. ISBN 0 964 17335 2. US$95.00.

The author (an internationally acclaimed gemstone inclusion photographer and researcher) hopes that this book will open 'a doorway providing an introductory look at the colourful, fascinating and highly educational microworld of nature's diamonds, and the microclues to diamond enhancement, synthesis and simulation.' It goes much deeper and could well serve as a reference text and laboratory manual for all gemmologists whether they be tiros or experienced researchers.

There are twelve chapters of varying length and importance. The first four describe the Virtues; the famous 4 C's; the tabulation of properties; and diamond notes ~ a mini textbook of general information. In Chapter 5 on inclusion identification the author suggests that his Level One may be seen as observing and mentally analysing; it requires considerable experience and is time consuming. Level Two as identifying with instruments, which may be highly sophisticated and expensive and Level Three as providing a complete chemical and structural analysis for serious research papers; it is seldom performed in most gemmological laboratories. Chapter 6 on microscopy describes all the standard techniques as well as many innovative procedures which the author himself has developed over the years. In Chapter 7 the micro-surfaces on nature's diamonds are explained as being largely due to etching and dissolution and are dealt with under the headings of surface graining, knots and naats, nuances of polishing, burn marks, radiation stains and etched dislocations and channels. The next 34 pages of text (Chapter 8) with over a hundred colour photographs are probably a very appropriate illustration of the author's real passion ~ inclusions in gemstones and in diamonds in particular. He explains how these inclusions tell us about their host's place of origin and its journey through the earth and how they are our only real window through the crust and into the mantle. Chapter 9 explains how evidence of the enhancement of natural diamonds can be detected by the study of micro-surfaces and interiors. In contrast Chapter 10 details the micro-features of gem-quality synthetic diamonds, whilst Chapter 11 describes the corresponding features of the various diamond simulants. In his short Chapter 12 the author concludes that from what he can determine this work is the largest single published compilation of photomicrographs on the subject of diamonds; he also comments that 'the book is as much a work of natural art as it is of natural science' (the reviewer agrees).

There are over 400 superb colour photographs and each is explained with a detailed and lucid caption. The whole text is very user-friendly for the beginner, but there is also much 'meat' for the specialist, who will find the excellent bibliographies at the end of each chapter particularly useful. The standard of production is commendably high. At US$95 the book is not cheap, but its cost could easily be retrieved by any jeweller or gemmologist who avoids an expensive mistake with an enhanced diamond or synthetic moissanite as a result of studying this admirable and artistic work. E.A.J.

De wondere Wereld van de Edelsteen

R.C. Litjens, 1998. Vakschool voor Edelsmeden en Fijne Techniek, Schoonhoven, The Netherlands. pp 153, hardcover. Dfl 49.50.

Attractively produced gemmological textbook for students with no colour pictures but quite good ones in black-and-white. The text follows an acceptable pattern, placing theory and instrumentation before discussing the gem species. Diagrams and photographs (I have not seen them before and a very interesting one of emerald mining in Zimbabwe caught my eye) are often arrestingly placed in the margins of the text and the various tables and notes on nomenclature seem to be accurate. There is a shortish bibliography whose entries for the most part refer to respectable literature. Altogether this would make a good introductory text for Dutch speaking students. M.O.D.

Miller's jewellery antiques checklist

Miller's, London, 1997. pp 192, illus. in colour. Hardcover. ISBN 1 85732 816 7. £9.99.

A pocket-sized guide in which all objects are shown in colour, this attractive book aims at helping first-time customers in the antique jewellery market. After an introduction in which the commoner gemstones are described, together with notes on stone measurement and the care of jewellery, the text is arranged by type of object: thus brooches, bracelets, cameos, mourning jewellery and stickpins all have their individual though small sections. In each section the descriptions are roughly chronological. There is a short bibliography and an equally short list of major designers and manufacturers. Read with care, this makes a good introduction to jewellery studies. M.O.D.

Pietre pretioase fine ornamentale, perle

A. Mircea-Dragomir and K. Heinz, 1997. Editura Ipunct Bucuresti. pp 146. Softcover. IISBN 973 99265 0 9. Price on application.

Pleasantly produced and well-illustrated guide to gemstones and pearls with general notes on a wide range of species, identification tables and a bibliography in which entries are arranged chronologically. The book is claimed to be the first professional book on gemstones to be published in Romania: readers with a classical background will find little language difficulty. A second edition might well incorporate colour photographs and a little more information on European and other localities but this book is a good start. M.O'D.

The triumph of love: jewellery 1530-1930

G.C. MUNN, 1993. Thames & Hudson, London. pp 104, illus. in colour. Hardcover. ISBN 0 500 23661 5. £18.95.

A beautifully-produced book in which the jewellery of romance, courtship, liaisons, marriage and fidelity are celebrated, as these qualities (or some of them) were celebrated in their time, which in the context of the book takes the reader to the middle of the 20th century. The arrangement of the text is chronological: there is a bibliography and the history of many of the artefacts described is noted, as are the biographies of many of the designers and owners. This is a book of scholarship lightly worn and of great charm. M.O'D.

Gold and platinum jewelry buying guide

R. NEWMAN, 2000. International Jewelry Publications, Los Angeles. pp 156, illus. in colour. Softcover. ISBN 0 929975 29 4. US$19.95.

Many gemmologists will be concerned professionally or more loosely with the use of gold and platinum in jewellery. This reviewer, with an interest in some aspects of gold and other precious metals, found the book set at exactly the right standard for both professional sales staff and for those who come across gold and precious metals less often, with chapters on terminology, manufacturing methods, mounting and setting techniques and their evaluations, chains (and how cheap or fake ones frequently kink), determination of fineness and of fakes, colours, coin jewellery and bullion coins, valuations and care of jewellery. As always the text is very easy to read and the pictures succeed very well, considering that most gold artefacts are of similar colour. There is a useful bibliography and the price is amazingly low, as always with this publisher. Both publisher and author must be highly commended once more. M.O'D.

Gold in der Schweiz 2 Auflage

P. PFANDER AND V. JANS, 1999. Ott Verlag, Thun. pp188, illus. in colour, hardcover. ISBN 3 7225 6300 3. DM43.80.

Revised edition of a guide to Swiss gold localities first published in 1996, this survey will be of considerable interest to those gemmologists with an interest in minerals and in gold itself. Types of occurrence, mineralogy and geology are generally described and the main body of the text, in which locations are given, is arranged on a geographical basis. Details of the different occurrences and illustrations of some notable specimens and mines go to make up an invaluable guide, in which up-to-date references are also given. Most sites are indicated on maps in the text and the quality of the illustrations is excellent. M.O'D.

The simpler? polyhedra. Part 3

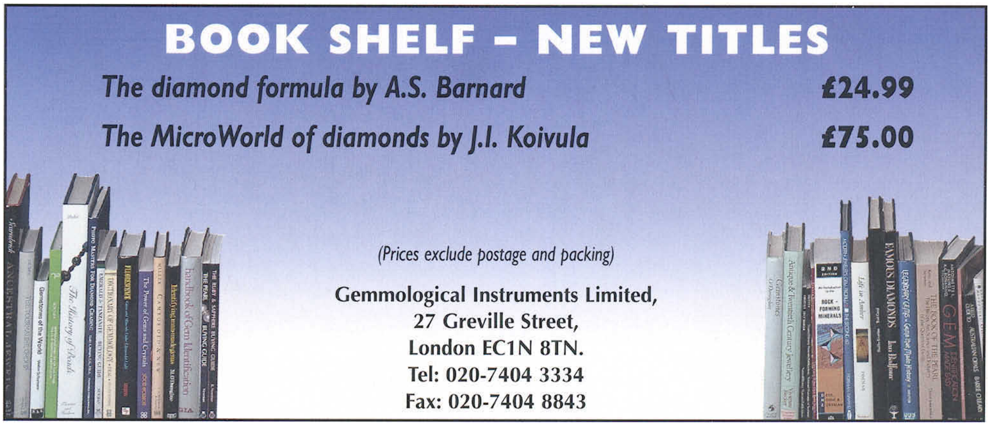
P. TAYLOR, 1999. Nattygrafix, Ipswich. pp 79, softcover ISBN 0 9516701. £6.00.

The third part of this interesting presentation of possible answers to the question 'What constitutes a uniform polyhedron?' deals with those polyhedra which are essentially assemblies of polygons, similar to tilings of the plane but with fewer or lesser valued polygons at each vertex. 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

Photographic Competition

The 2000 Photographic Competition on the theme ***The Light Fantastic: optical effects in gems*** drew a record number of entries of a very high standard.

First Prize

Dennis Durham, Kingston upon Hull

Rock crystal (15.86 ct) depicting twelve reflections of a single hexagonal crystal now transformed to secondary minerals (illustrated on front cover).

Second Prize

Anthony de Goutiere, Victoria, BC, Canada

Trigons on diamond crystal

Third Prize

Victoria James, Orem, Utah, USA.

Opal

ISSN: 1355–4565

OBITUARY

Dean Stirling Mark Field

Members of the Canadian Gemmological Association were saddened recently to learn of the sudden death of the founder of the CGA, Dean S.M. Field (D.1955). Dean was born in Cape D'Or, Nova Scotia, on 1 June 1917 and died in Toronto on 7 May 2000.

His interest in gemstones began at an early age when a local jeweller and watchmaker befriended him and gave him a small phial of stones consisting of a seed pearl, a small diamond, an emerald, a ruby, a sapphire and several other small gemstones. Later Dean and his mentor hunted for zeolites, amethyst crystals and agate pebbles which he sold to tourists.

Like many young men of his age Dean suffered as a result of the stock market crash in 1929 and a university degree was denied him. He moved back and forth between home and Montreal, Toronto and Vancouver seeking work wherever he could find it. A breakthrough for him came with the publication in 1941 of Robert Webster's *Practical Gemmology*. He read the whole book in not much more than one night and then went back to study it in detail. In 1947 he began his studies toward a Fellowship Diploma. As a result of continuing work with National Security Dean was not able to complete his studies until 1955. Had he been able to complete his theory and practical examinations the same year he would have passed with distinction.

Dean had begun to work in 1947 for the Toronto Gem Lab and when he completed his studies he prepared a series of twenty semi-formal lectures on gems and gemmology which he offered to 32 students from the Toronto area. The disadvantage of these private lectures was that his students did not have recognized documents of achievement so he began negotiations to coach the established course of the Gemmological Association of Great Britain. In 1958 Dean founded the Canadian Gemmological Association to, in his words, 'foster the friendship and camaraderie that was built up during the years of study and discovery' (see *The Canadian Gemmologist*, **10**(1), 8-12). Dean served as president from 1958 to 1960 and again from 1980 to 1981.

Dean Field, Founder of the Canadian Gemmological Association, at the CGA Gem conference, Toronto, in October 1993. Photo: Willow Wight.

Later Dean Field became the official gemmologist and gem buyer for the T. Eaton Company, a major Canadian department store featuring outlets from coast to coast as well as a mail order service. With his formidable knowledge, his wealth of anecdotes, his wonderful sense of humour and his enthusiasm, Dean was a welcome speaker at many of the CGA meetings which he continued to attend as recently as April of this year. In recent months he had begun a compilation to mark the discovery of deposits of gem diamonds in the North West Territories of Canada which he had predicted in an article he wrote for *The Canadian Mining Journal* in July of 1950.

Dean was able to bridge the generation gap and was a mentor to many of us in his later years. All at the CGA had hoped that he would be here to celebrate the 50th anniversary of the association that he founded.

* * *

Hugh B. Crawford (D.1978), Castle Douglas, Kirkcudbrightshire, died in January 2000.

Dr William G. Cross (D.1965), Christchurch, Dorset, died on 16 January 2000 after a long illness.

GIFTS TO THE ASSOCIATION

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

Arild Andersson, Oslo, Norway, for a 2.73 ct faceted oval peridot and two thulite cabochons, all from Norway.

Mrs Afzal Fatima Ali, South Norwood, for a collection of books and instruments presented in memory of her late husband, Syed Jafer Ali Abedi.

Professor Hermann Bank, Idar Oberstein, Germany, for 9 quartz soudés and 14 synthetic spinels imitating moonstone.

Friedrich August Becker, Idar Oberstein, Germany, for three tourmaline pieces each with one facet, cut during the GAGTL trip to Idar Oberstein, and ten posters.

K.C. Subhash Chandra of the Geological Society of India, Gavipuram, Bangalore, for Gems and gem industries in India by R.V. Karanth.

John R. Führbach, Amarillo, Texas, U.S.A., for two pieces of tumbled Brazilian amethyst and a faceted stone.

Eiko Ito for a blue-grey cultured pearl, a flower of cultured pearls, a packet of ground coffee containing ground-up cultured pearl and an article on 'Circle pearls' by Eiko.

Dr George Harrison Jones, Burnham, Buckinghamshire, for two blue chalcedony cabochons.

Ronald F. King, Maidenhead, Berkshire, for a box of miscellaneous stones and a set of slides.

Charles McShane for a stained quartzite.

Keith Palmer, Sphinx & Femina Ltd, Chiswick, London, for seven bead bracelets ~ imitation turquoise, hematite, calcite, tiger's-eye and three quartzite, two of which are stained.

Stephane Salerno, Edmonton, Alberta, Canada, for a 3.35 ct chatoyant agrellite cabochon.

Pierre Vuillet a Ciles, Villards d'Heria, France, for a 2.95 ct langasite, a yellow-green synthetic stone.

MEMBERS' MEETINGS

London

On 7 April a visit was arranged to the School of Geological Sciences, Kingston University. As well as learning about the current research on fluid inclusions in minerals from Professor Andy Rankin and his team, the group visited the the School's new laboratories which house equipment such as the Raman and electron microprobes.

On 19 April at the GAGTL Gem Tutorial Centre, Professor Alan Collins gave a lecture entitled *The colour of diamond and how it can be changed.*

On 27 April members visited De Beers, where they were given a talk on the diamond trade today and were able to view the displays in the Diamond Information Office.

On 4 May at the GAGTL Gem Tutorial Centre John Nels Hatleberg, visiting the UK from New York, gave a talk on the replicas of famous diamonds that he produced and also his conceptual jewels. Samples of his work had been displayed in a temporary exhibition at the Natural History Museum, South Kensington.

On 18 May at the GAGTL Gem Tutorial Centre Corinna Pike gave an illustrated talk entitled *The Rose - nature's jewel as a decorative emblem.*

On 14 June a visit was arranged to the *Treasures of the 20th Century*, the Millennium Exhibition at Goldsmiths' Hall.

Midlands Branch

On 31 March at the Earth Sciences Building, University of Birmingham, Edgbaston, Dr Rob Ixer gave a talk entitled *All that glitters is not gold.*

On 28 April at the Earth Sciences Building, silversmith Martyn Pugh gave a review of 20 years in the art of design and manufacture of jewellery, official pieces and objets d'art. The talk was followed by the Branch Annual General Meeting at which David Larcher, Gwyn Green, Elizabeth Gosling and Stephen Alabaster were re-elected President, Chairman, Hon. Secretary and Hon. Treasurer respectively.

On 21 May at the Earth Sciences Building, jewellery designer Memory Stather talked about her choice of materials, sources of inspiration and displayed samples of her work.

FORTHCOMING EVENTS

13 September	**London.** *From geology to jewellery - the platinum millennium.* ***Dr Judith Kinnaird***
20 September	**North West Branch.** *History of English watches from verge to lever.* ***Peter McIvor***
29 September	**Midlands Branch.** *Gemmology and Gem Testing Quiz*
18 October	**North West Branch.** *Minerals and gems at the Great Exhibition of 1851.* ***David Lancaster***
27 October	**Midlands Branch.** *The works of Peter Carl Fabergé.* ***Stephen Dale***

GAGTL ANNUAL CONFERENCE

Sunday 29 October - Barbican Conference Centre, London

Keynote speaker: Professor Al Levinson, Calgary, Alberta, Canada
Diamonds in Canada - geology to gemmology

Paul Spear, DTC Research Centre, Maidenhead
Synthetic and treated diamonds

Dr Judith Kinnaird, University of Witwatersrand, South Africa
The sparkle in Somaliland

Robert Fawcett, The Cultured Pearl Company Ltd.
South Sea cultured pearls - their place in the market

Harry Levy, President of the CIBJO Diamond Commission
What's in a name?

CONFERENCE VISITS

27 October: **De Beers**
30 October: **The Gilbert Collection at Somerset House**

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

30 October	*Presentation of Awards*
15 November	**North West Branch.** *AGM* followed by *Gem collection and anecdotes.* ***John Pyke Snr***
23 November	**London.** *Amber - has the bubble burst?* ***Helen Fraquet***
24 November	**Midlands Branch.** *The minerals of Pakistan.* ***Michael O'Donoghue***
2 December	**Midlands Branch.** *Annual Branch Dinner*

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

North West Branch

On 21 June at Church House, Hanover Street, Liverpool 1, Memory Stather gave a talk entitled *Pocket sculptures - gemstone carving?*

Scottish Branch

On 27 March at the British Geological Survey, Edinburgh, Brian Jackson gave a talk entitled *The lore of gemstones*.

The Annual Conference of the Scottish Branch was held in Perth from 28 April to 1 May. A report was published in the June 2000 issue of *Gem and Jewellery News*.

MILLENNIUM TRADE DINNER

To celebrate the 75th anniversary of the founding of the Laboratory and to renew confidence and optimism in the jewellery trade at the start of the millennium, the GAGTL joined with the London Diamond Bourse and Club to hold a dinner at Goldsmiths' Hall in the City of London. The guest speaker was Gary Ralfe, Managing Director globally of De Beers.

Freddy Hager, President of the LDBC, welcomed those present and GAGTL Trade Liaison Committee Chairman, Jeffrey Monnickendam, introduced Gary Ralfe. The vote of thanks was given by Terry Davidson, immediate past Chairman of the Trade Liaison Committee. The event was generously sponsored by Malca-Amit (U.K.) Ltd.

A full report of the Dinner and Gary Ralfe's speech was published in the June 2000 issue of *Gem and Jewellery News*.

ANNUAL REPORT

The following is the report of the Council of Management of the Gemmological Association and Gem Testing Laboratory of Great Britain for 1999.

The Gemmological Association and Gem Testing Laboratory of Great Britain (GAGTL) is a company limited by guarantee and is governed by the Council of Management. The president, Professor R.A. Howie, and the Vice Presidents E. Bruton, A.E. Farn, D.G. Kent and R.K. Mitchell continued in office. C.R Cavey resigned from the Council of Management in January; J. Monnickendam and E. Stern joined the Council in April and I.F Mercer in June.

Dr G. Harrison Jones retired from the Board of Examiners and Miss C.M. Woodward was elected Chairman. The GAGTL is indebted to Dr Jones for his guidance and wisdom in examination matters for more than 24 years. At the AGM in June,

Millennium Trade Dinner held at Goldsmiths' Hall in the City of London. Centre, Gary Ralfe, Managing Director globally of De Beers, with Jeffrey Monnickendam, Chairman of the GAGTL Trade Liaison Committee and his wife (left) and Freddy Hager, President of the London Diamond Bourse and Club with his wife (right).

R.G. Fuller resigned from the Members' Council and J. Kessler and J. Monnickendam did not seek re-election; the Council continued to be chaired by C. Winter. J. Monnickendam was elected Chairman of the Trade Liaison Committee and the new Vice-chairman is J. Kessler.

At the Gem Tutorial Centre in Greville Street, the Gemmology and Gem Diamond courses were well subscribed with a good mix of students coming from home and overseas. Correspondence courses (or distance learning) have been made very much more effective with establishment of a gemstone library, regular gem practical tuition or refresher courses, and seminars on examination technique. New sections have been added to the Gemmology Diploma course to improve guidance and productive homework, and a new supplement with information on the latest treatments was added at the end of the year.

Gem Diamond course students now have the option of training in the evenings over eight months, training for one day a week over four months, or by correspondence. New options are being prepared for 2001.

New Allied Teaching Centres (ATCs) have been established in Montreal, the Caribbean, Singapore and Taiwan, and numbers of students overseas taking our courses now exceed those in the UK.

Comprehensive training in gems for the jewellery trade is available through a growing number of focused short courses and custom-made tutorials. Topics range from pearls to jade, synthetics, enhancements and diamond.

In addition to the Gem Tutorial Centre courses held in London, the education team has run courses in other major cities in the UK and in Finland, Ireland, Norway, Sweden and the USA (Chicago and Washington). In association with De Beers D. Garrod ran a series of tutorials entitled 'Diamond or not' to inform trade personnel on how to detect synthetic moissanite.

Practical handbooks have been written for nearly all of these courses, and one of them, the Gem observation guide, has been developed and produced for sale. Plans are in hand to develop other handbooks in a similar way.

Through study at the ATCs, students can train to take diplomas in gemmology or gem diamond. The Preliminary gemmology examination has recently been augmented with a practical element, and the Diploma can now be taken in nine languages in addition to English: Chinese, Dutch, Finnish, Greek, Japanese, Korean, Norwegian, Spanish and Swedish.

For all examinations, pass rates were better this year than for several recent years although no student quite reached the levels required for the Tully and Bruton medals. In the Diploma in Gemmology examinations, the Anderson-Bank prize was awarded to Miss Jie Yang of Wuhan, P.R of China, and the Diploma Trade prize was awarded to Miss Yurika Tachibana of Tokyo, Japan. The Anderson Medal for the best candidate of the year in the Preliminary examination went to Miss Liu Jiewen of Guilin, P.R of China, and the Preliminary Trade prize was awarded to Miss Yan Wei of Shanghai, P.R of China.

Once again, the Presentation of Awards was held at Goldsmiths' Hall; the President presided and the prizes and diplomas were presented by the Guest of Honour, Mr E. Alan Jobbins.

The laboratory continued to issue both London and CIBJO Diamond reports, origin of colour reports for coloured diamonds, identification and treatment reports for coloured stones and pearl reports. Growing numbers of treated gems and non-nucleated cultured pearls in the gem trade have meant that the balance of work in the laboratory has changed to respond. Staff have participated in developing guidelines for the best nomenclature in the CIBJO standard books, and S.J Kennedy represented GAGTL at the annual conference in Bern, Switzerland.

GAGTL again exhibited at the International Jewellery Fair at Earl's Court in September, and daily seminars run by D. Garrod and L. Stather attracted full houses. GAGTL also exhibited at the Las Vegas Jewellery Fair in June (M. Burland and D. Garrod), and at the Hong Kong Fair in September where B. Hunt, L. Stather and A.J. Clark promoted education, instruments and membership to Far Eastern visitors. I.F. Mercer visited Hong Kong, Wuhan and Shanghai in March to coordinate Allied Teaching Centre (ATC) activities, and in November R.R. Harding visited Wuhan to present an Honorary Fellowship to Professor Chen and to present a prize and diplomas to students successful in GAGTL exams. Diplomas were also presented to successful students in Hong Kong at the Annual Dinner of the Hong Kong Gemmological Association on 11 November.

In the UK, the GAGTL branches in Birmingham, the North West and Scotland continued with a variety of lectures, seminars and field trips.

The theme of the 1999 Members' Photographic Competition was 'Gems of the Century', the winner being R. Huddlestone of London. We are most grateful to Quadrant Offset Limited, who design and print both the calendar and the Journal of Gemmology, for sponsoring the prizes. A selection of entries was made for the 2000 calendar which is circulated free to members.

The Annual Conference was held at the Barbican Centre in London on the theme 'New developments in the gem world'. The keynote speaker was Dr James Shigley of the GIA who spoke on diamond identification. New African gemstones were comprehensively discussed by Campbell Bridges of Bridges Exploration Ltd., and a thought-provoking perspective on the retail gem trade was provided by Dr Jack Ogden, Chief Executive of the NAG and Secretary General of CIBJO. Over 130 participants from twelve different countries attended the lectures and demonstrations where synthetic moissanite, a GE POL treated diamond and the new Brewster Angle Meter could be examined.

In the *Journal of Gemmology* 22 papers were published in 1999 with topics ranging from trapiche rubies to colour changes in alexandrite and tourmaline, and from black jadeite to the diamond industry in India. A total of 171 abstracts and 81 book reviews were also published and the Council express their sincere thanks to the Assistant and Associate Editors for their invaluable help and advice during the year.

Gem and Jewellery News is published jointly with the *Society of Jewellery Historians* and in 1999 contained a wide range of comment on such topics as synthetic and treated diamonds, the new eternal cut diamond, Society lectures, the International Gemmological Conference in India, and Millennium marketing. The contributions of editors C. Johns, H. Levy, M. O'Donoghue and C. Pike are very much appreciated.

Gemmological Instruments is a wholly-owned subsidiary of GAGTL and in the last few years has pursued a policy of introducing a range of equipment which is simple, robust and effective. Developed over many years by P.G. Read, and latterly with the collaboration of N.W. Deeks, the Brewster Angle Meter was introduced to members at the Annual Conference. Work continues on refining the Megger tester for synthetic moissanite identification.

Whilst the GAGTL managed a slightly increased turnover in 1999, it finished the year with a deficit of £116,000, which is very disappointing for all concerned when one considers the hard work put in by the staff in an endeavour to achieve a better result. A large proportion of our business is now outside the UK and the strong pound has made it difficult to achieve realistic margins and remain competitive. However, a number of new projects have been formulated during the year, which should improve our prospects in 2000. Measures have since been taken to reduce costs.

Gemmological Instruments Ltd. achieved an increase in turnover, but only returned a small surplus on the year. During the year work proceeded with the development of some new and improved instruments, which should boost trade in 2000 as they become available.

During the year Miss J. Holness and Miss V. Adams resigned and Miss L. Halton and Miss E. Rolph joined the staff. Miss M. Keating joined under a European Union scheme and Miss Y. Yoshitake assists with various educational activities. To all staff, the Council of Management extend their thanks for the effort and dedication demonstrated in the success of many activities. The Council also pays tribute to the work of the committees and appreciates the expertise voluntarily offered in advising the GAGTL on its future course of action. Lastly the Council would like to thank all those individuals who have donated gems, books, instruments and other gemmological items; these are much appreciated and actively used in many of our courses.

The Council of Management, May 2000

1950 - 2000

CONGRATULATIONS

to the Norwegian Gemmological Association

on their 50th Anniversary

GEM DIAMOND EXAMINATIONS

In the Gem Diamond Examinations held in January 2000, 45 candidates sat the examination and 40 qualified, 5 with Distinction. The names of the successful candidates are listed below:

Qualified with Distinction
Rose, Neil R., Wetherby, North Yorkshire
Keating, Michelle, London
Li Peng He, Beijing, P.R. China
Lv Jie, Beijing, P.R. China
Song Huagiang, Beijing, P.R. China

Qualified
Chawla, Upkaran Singh, Wimbledon, London
Chen Shu-Chen, Kaohsiung, Taiwan, R.O. China
Chen Shu-Chuan, Taipei, Taiwan, R.O. China
Comar, Ankush, Bushey, Hertfordshire
Domercq, Sandrine, London
Du Juan, Beijing, P.R. China
Du Min, Beijing, P.R. China
Fengmei Lu, Wuhan, Hubei, P.R. China
Garbis, Nikolaos, Argostoli, Kefalonia, Greece
Gordon, Carole A.M., Richmond, Surrey
Guan Da Wei, Beijing, P.R. China
Hengyi Zheng, Wuhan, Hubei, P.R. China
Hsu Miao Chu Taipei, Taiwan, R.O. China
Jang, Yunsil, Staines, Middlesex
Kamil, Ruzwan, Colombo, Sri Lanka
Katada, Mitsuru, Ivanhoe, Victoria, Australia
Katz, Joslynne, F., Johannesburg, South Africa
King, Kumi, London
Kote, Satomi, London
Langton, R., Marton, Lancashire
Lei Shi, Wuhan, Hubei, P.R. China
Li Lung Hsing Jerry, Taipei, Taiwan, R.O. China
Lin Yeong Leh, Taipei, Taiwan, R.O. China
Linjun Fu, Wuhan, Hubei, P.R. China
Nanda Sareen, Shaunali, London
Qi Chen, Wuhan, Hubei, P.R. China
Wang Cheng-An, Puli Town, Nan-tu County, Taiwan, R.O. China
Wu Rong, Beijing, P.R. China
Wu Sung-Mao, Taichung, Taiwan, R.O. China
Xie Hao, Wuhan, Hubei, P.R. China
Xunxiao Qian, Wuhan, Hubei, P.R. China
Yang Hui-Ning, Taipei, Taiwan, R.O. China
Yihua Wu, Wuhan, Hubei, P.R. China
Yuanfeng He, Wuhan, Hubei, P.R. China
Zhu Ming, Beijing, P.R. China

MEMBERSHIP

The following have been elected to membership during March, April and May 2000:

Fellowship and Diamond Membership (FGA DGA)

Walton, Brian, Oldham, Lancashire, 1972/1973

Fellowship (FGA)

Bawa, Mohammed Shah Riza, Harrow, Middlesex. 2000
Brown, Mary J., Yangon, Myanmar. 2000
Criado Friesch, Romina, Madrid, Spain. 2000
Dickson, Rebecca B., London. 2000
Dwane, Christine, Montreal, Quebec, Canada. 2000
Ehlenbach, Richard J., Carlisle, Massachusetts, U.S.A. 1984
Ellis, Nigel, Tasmania, Australia. 2000
Fukushima, Hideaki, Chiba City, Japan. 1991
Geung Wan Yin, Hong Kong. 2000
Jiang Wen, Jing Zhou, Hubei, P.R. China. 1999
Johnson, James P., Friern Barnet, London. 2000
Koers, Jessica M., Amsterdam, The Netherlands. 2000
Poon Wai Kong, Singapore. 2000
Rambukkange, Timothy P., Kandy, Sri Lanka. 1999
Sedore, John D., Richmond, British Columbia, Canada. 2000

Diamond Membership (DGA)

Chawla, Upkaran S., Wimbledon, London. 2000
Chen Li Li, Ashfield, Sydney, New South Wales, Australia. 1998
Nanda Sareen, Shaunali, London. 2000
Wang Cheng An, Nan-tou County, Taiwan, R.O. China. 2000
Wu Sung-mao, Taichung, Taiwan, R.O. China. 2000
Yu Kam Chi, Hong Kong. 1997

Ordinary Membership

Anderson, James I., Southampton, Hampshire
Apostolatos, Panos, Patras, Greece
Beattie, Alan P., Glenageary, Co. Dublin, Ireland
Black, Valerie, London
Boillat, Pierre-Yves, Geneva, Switzerland
Bond, Eileen, Braughing, Hertfordshire
Cedeno, Leonor, Sutton, Surrey
Cheng, Helen S.F., St John's Wood, London
Di Fonzo, Antonio, Ridgmont, Bedfordshire
Feely, Martin, Galway, Ireland
Fenton, Sarah, Battersea, London
Gammon, Linda, Cowes, Isle of Wight
Gravier, Denis M., Hauterive, France
Irwin, Cyan, Dublin, Ireland
Maher, John K., Celbridge, Co. Kildare, Ireland
Mathews, Fiona, Amersham, Buckinghamshire
Meaden, Phillip A., Pakefield, Suffolk
Mitchell, Deborah J., Goffs Oak, Hertfordshire

Mulligan, Ardythe, Dundee, Ohio, U.S.A.
Ram, Satyen, Richmond, Surrey
Smith, Susanna M., London
Tse, Jerry, Ilford, Essex
Whelan, Craig, Liverpool

Laboratory Membership

Elka SA, Athens, Greece

TRANSFERS

Fellowship (FGA) to Fellowship and Diamond Membership (FGA DGA)

Chen Shu-Chuan, Taipei, Taiwan, R.O. China. 2000
Domercq, Sandrine, London. 2000
Kamil, Ruzwan, Colombo, Sri Lanka. 2000
Rose, Neil, R., Wetherby, North Yorkshire. 2000
Yang Hui-Ning, Taipei, Taiwan, R.O. China. 2000

Diamond Membership (DGA) to Fellowship and Diamond Membership (FGA DGA)

Balzan, Cortney G., Fairfax, California, U.S.A. 2000
Ma Si Ji, Beijing, P.R. China. 2000
Simpson, Peter R., Richmond, Surrey. 2000

Ordinary Membership to Fellowship (FGA)

Ancemot, Alexandre, Nantes, France. 2000
Chambers, Sara L., Cardiff. 2000
Cheong-Ly Karine, London. 2000
Johnson, Janet M., Friern Barnet, London. 2000
Joyner, Louise, London. 2000
Pratt, Jonathan J., Guildford, Surrey. 2000
Sharples, James, Bolton, Lancs. 2000
Zini, Grazia, Ferrara, Italy. 2000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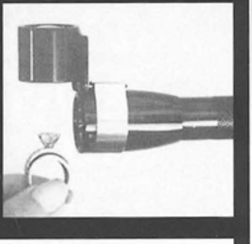

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Guide to the preparation of typescripts for publication in *The Journal of Gemmology*

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

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

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

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

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

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

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

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

A **This is a first level heading**

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

B *This is a second level heading*

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

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

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

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

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

Notes and References Authors may choose one of two systems:

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

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

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

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

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

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

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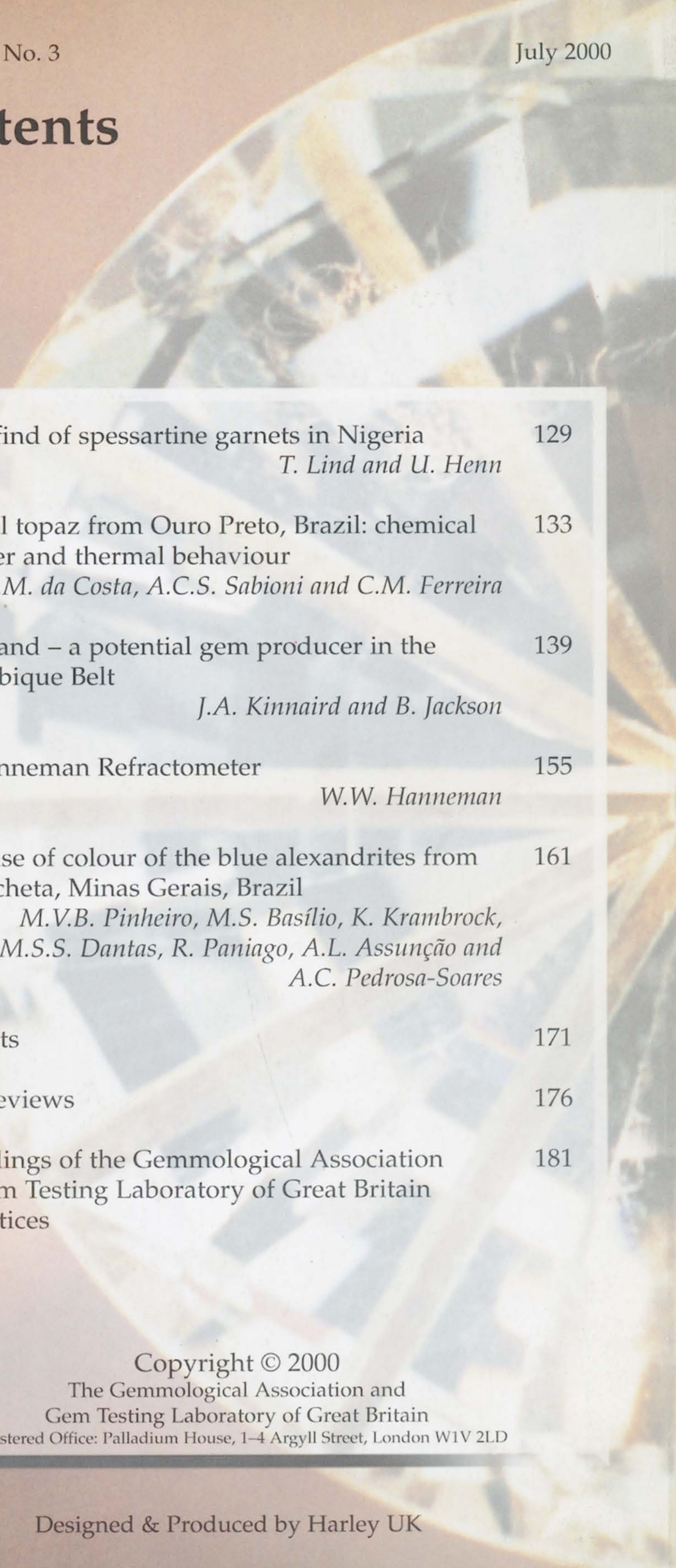

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