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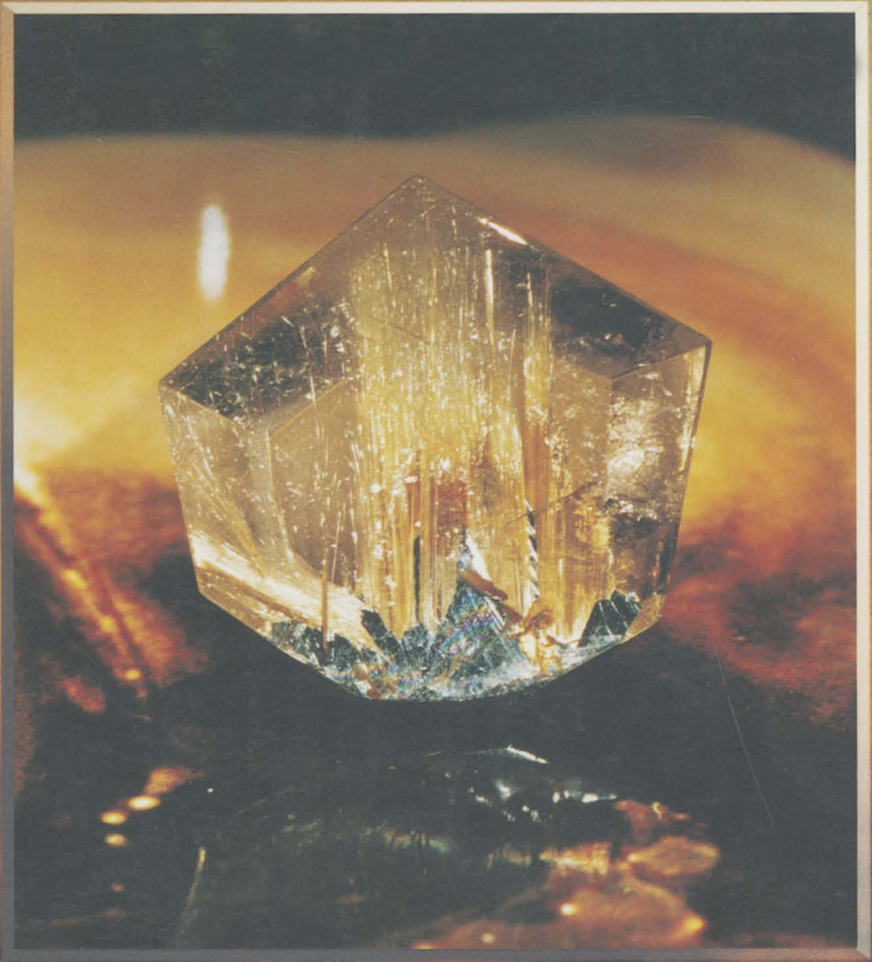

Madagascar gems • Type II diamonds • Describing gems

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New gemstone occurrences in the south-west of Madagascar

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ABSTRACT: In late 1998, spectacular gemstone occurrences were discovered in the south-western part of Madagascar. The secondary deposits extend from the south of the Isalo National Park near the town of Ranohira up to the town of Sakahara further west with major mining areas around Ilakaka and south of Ankazoabo. The occurrences produce pink, blue, violet, yellow, orange, green, pale brown and colourless corundum varieties, spinels, chrysoberyls, garnets, aquamarines, tourmalines and other gems. Of particular importance are pink and blue sapphires which are found in large quantities. The gemmological properties of fancy-coloured sapphires correspond to those found in the Umba valley and Tunduru area in Tanzania whereas the blue sapphires are reminiscent of sapphires from Sri Lanka. In addition a number of pinkish-orange corundum varieties show colours and absorption spectra that correspond to Sri Lankan padparadschas. The geological environment of the new deposits in Madagascar is similar to the alluvial deposits of Sri Lanka and Tanzania and the three areas may have been part of single land mass before the break-up of Gondwana.

Keywords: gemmological properties, geology, internal characteristics, Madagascar, padparadscha, sapphire

Introduction

Madagascar has been well known for centuries for its formidable list of gemstones. Already in the 16th century Portuguese, Dutch, English and French sailors had travelled to the island adjoining the continental margin of East Africa and had returned to Europe with various gemstones. After becoming a French protectorate in 1885 and colony in 1896 a systematic exploration of Madagascar took place and Lacroix (1922) provided a detailed description of the minerals that were found. At the beginning of the 20th century Madagascar entered the gemstone supply scene with commercial quantities of aquamarine appearing from 1908, morganite, tourmaline and quartzes from 1911, and spodumene, feldspars, garnets and various other gemstones from 1922. After obtaining independence in 1960 the systematic mining and export of gemstones decreased. The political and economic development in the 1970s, however, resulted in a larger supply of gemstones to the western market. During the 1990s new gemstone occurrences of commercial significance were found, these include as the emerald occurrence of Mananjary on the east coast (Schwarz and Henn, 1992) and the sapphire fields of Andranondambo in the southeast of the island (Milisenda and Henn, 1996; Kiefert *et al.*, 1996). At present Madagascar produces

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***Figure 1:** Simplified geographical map of south-western Madagascar.*

more than 50 different varieties of gemstone (Henn *et al.*, 1999).

In late 1998, spectacular gemstone occurrences were discovered in the south-western part of Madagascar (Henn *et al.*, 1999) delivering significant quantities of blue and pink sapphires, and lesser amounts of spinels, chrysoberyls, garnets, tourmalines, zircons, topazes and aquamarines.

Locality and mining

The new gemstone occurrences occupy extensive areas east of Ihosy and north of Ejeda in the south-western part of Madagascar (*Figure 1*). When the first finds were made in late 1998 and news of the discovery spread, people from the whole region rushed to the area seeking their fortune in gemstones.

Since summer 1999 mining has been concentrated in three main areas. The first region includes a 90 x 20 km wide belt between Ranohira and Sakahara. Intensive mining takes place around the village of Ilakaka, which is now well known for the production of blue sapphires. A second important mining area covers a 30 x 20 km wide zone around Fotiyola and Andranolava, south of Ankazoabo with interesting occurrences of pink sapphires. Thirdly, the area around Murarano has rich deposits of blue and pink sapphires as well as alexandrites.

Mining is controlled by the Ministry of Mines and hundreds of claims have been conferred, each measuring approximately 2.4 x 4 km. The gem gravels are excavated by using simple hand tools from numerous pits

Figure 2: *Alluvial gemstone deposit at Ilakaka, south-western Madagascar.*

(*Figures 2 and 3*) and the gems are then separated from the earthy gravels by washing in nearby streams (*Figure 4*). Dealers from overseas may rent small huts and use them as buying offices (*Figure 5*). Local miners crowd round the booths to show the rough, most of which is sold to dealers from Sri Lanka and Thailand.

Geology

The Precambrian of Madagascar formed a segment of crust of Archaean to mid-Proterozoic age that experienced its main thermo-tectonic evolution during the Pan-African event (Andriamarofahatra *et al.*, 1990; Guerrot *et al.*, 1993; Paquette *et al.*, 1993), which is known to have affected large parts of Africa. In a reconstruction of the Gondwana supercontinent, the high-grade rocks of Madagascar formed the eastern part of the Mozambique belt, which is regarded as a collision structure resulting from collision of East Gondwana (India-Antarctica-Australia) and West Gondwana (Africa-South America) some 600 million years (Ma) ago.

The sedimentary Morandava basin of

Figure 3: *Miners working at the pits near Ilakaka.*

Figure 4: Washing the gravels in a nearby stream, Ilakaka.

western and south-western Madagascar form part of a larger basin which finds its continuation on the East African continent. The sediments in this basin were deposited continuously from Carboniferous times (approximately 345 Ma ago) to the Tertiary less than 60 Ma ago. The separation of the basin was due to the break-up of Gondwana and continental drifting some 165 million years ago.

The recently discovered secondary deposits containing gems are located within the Morandava basin. In Africa, the thick continental succession of rocks ranging in age from Upper Carboniferous to Lower Jurassic is commonly defined as Karroo (Schlüter, 1997), and attains a maximum thickness of approximately 9000 m in the southern part of the basin. This Karroo Supergroup can be subdivided into three units as follows:

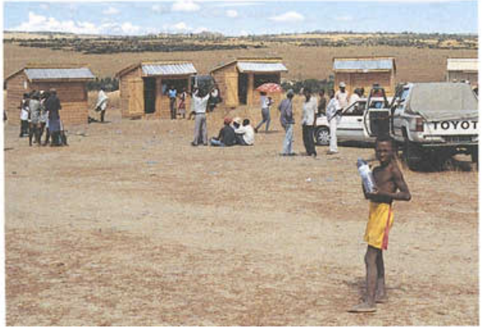

Figure 5: Dealers sit in booths and buy rough from local miners.

1. the 'Sakoa-Group' at the base, Carboniferous to Mid Triassic in age with predominantly sandstone and argillitic layers as well as coal beds;
2. the 'Sakamena-Group' of Upper Permian to Mid Triassic age with alternating argillitic and sandstone layers and
3. the 'Isalo-Group', Upper Triassic to Upper Liassic and consisting of alternating sandstone and red argillitic layers.

At Ilakaka the gems are recovered from sediments of the Isalo-Group which were deposited some 200 Ma ago (Andriamanantena, pers. comm, 1999) and originated from the Precambrian basement.

Characteristics of the gemstones

A number of representative samples of gemstones from the new deposits in south-western Madagascar are shown in *Figure 6*.

Sapphires

The sapphires from the new finds show an interesting range of colours. Blue and pink stones are of particular commercial significance, but colourless, pale green, yellow, orange, pale brown, brownish-red and violet sapphires are also present (see *Figure 6*). The rough crystals of blue sapphires range in weight from 1 to 30 ct, faceted stones are known up to 15 ct. The rough pink sapphires are 1 to 15 ct in weight and faceted stones up to 6 ct were observed on the market. Fine quality sapphires of a natural blue colour are very rare. Most of the material is thermally enhanced to improve its colour and clarity. With respect to both colour and clarity the Madagascar blue sapphires are similar to material from Sri Lanka. Pinkish-orange varieties also strongly resemble Sri Lankan padparadschas. In contrast yellow, orange and brownish-red stones correspond to the colours of sapphires found in Tanzania (Umba valley and Tunduru). Madagascar has however yielded pink sapphires which vary from a light to fine deep pink in shades not found elsewhere.

The standard gemmological properties of the Madagascar sapphires are in the range known for the mineral species corundum: n_e= 1.760 - 1.762, n_o = 1.768 - 1.770 with Δn = -0.008 and SG = 3.98 - 4.00.

Interesting results were obtained by measuring the absorption spectra. Spectra of blue sapphires from the new occurrences in the south-west of Madagascar are comparable with those of specimens from Sri Lanka (Ceylon-sapphires) and consistent with sapphires derived from high-grade metasedimentary sources. The absorption spectrum is dominated by a broad pleochroic band between 500 and 800 nm with an absorption maximum at approximately 580 nm (*Figure 7*) which is caused by a Fe^{2+}/Ti^{4+} charge transfer. In the blue and violet spectral range absorption bands of Fe^{3+} are present, one at 450 nm and a doublet with maxima at 387 and 377 nm. Total absorption in the violet region starts at approximately 300 nm. In contrast to this specific absorption pattern the blue sapphires from the Andranondambo gem fields in the south east of Madagascar (Milisenda and Henn, 1996) possess spectra with a total absorption starting at about 320 - 330 nm (see *Figure 7*), similar to the spectra of sapphires from Tanzania and Malawi. A third type of blue

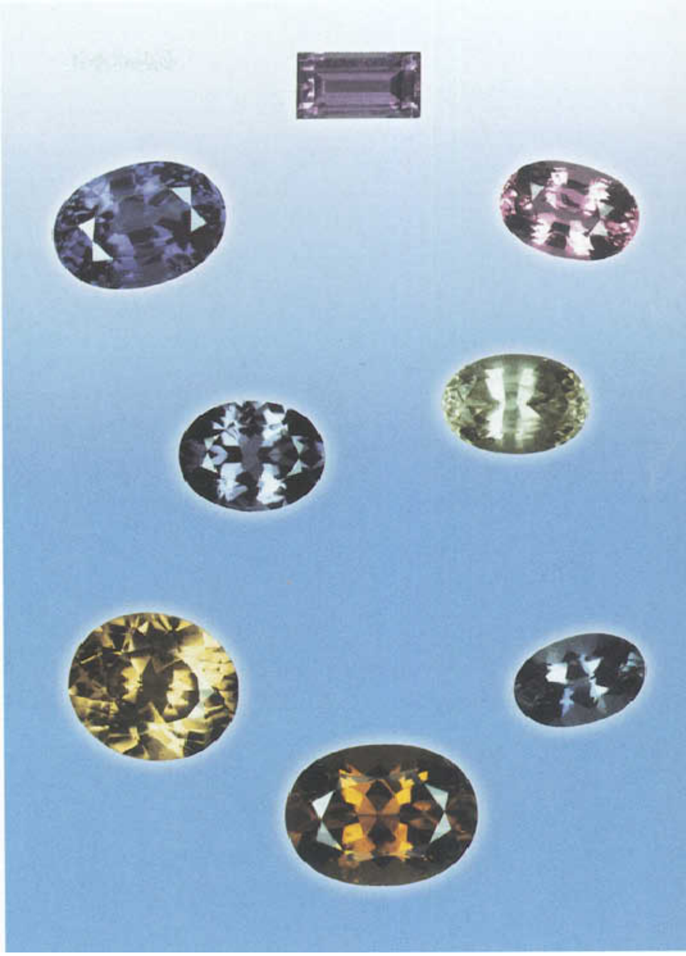

Figure 6: *Gemstones from the new finds in south-western Madagascar. Upper row from left to right: sapphire (5.12 ct), violet sapphire (1.12 ct), pink sapphire (2.30 ct). Middle row: spinel (2.37 ct) yellow-green sapphire (2.16 ct). Lower row: chrysoberyl (5.03 ct), tourmaline (6.02 ct), aquamarine (1.51 ct).*

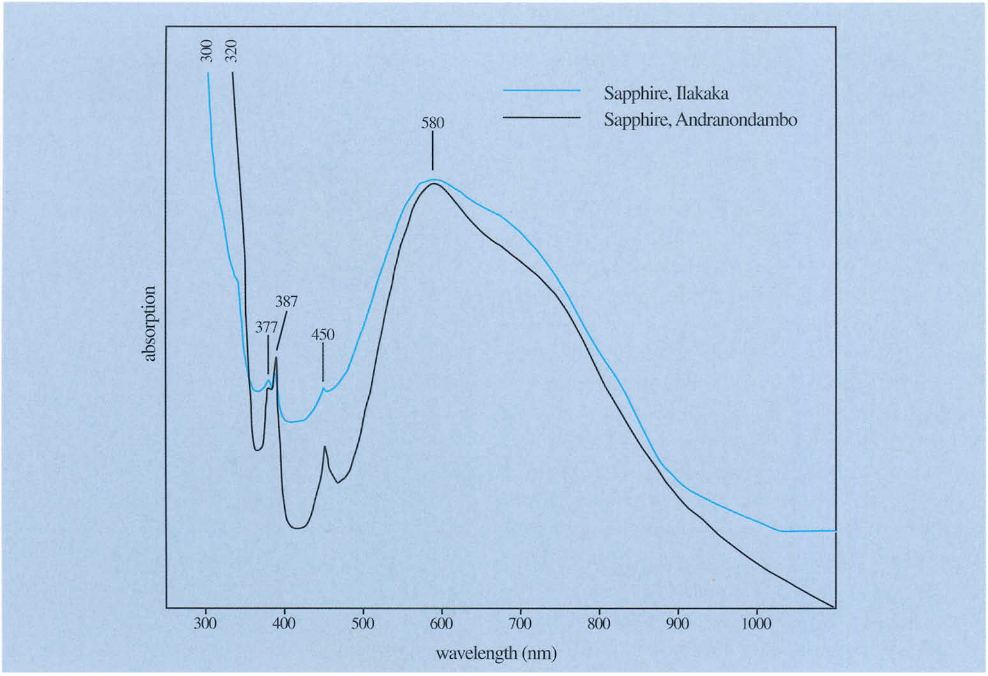

Figure 7: *Non-polarized UV/VIS/NIR - spectra of natural coloured sapphires from the new occurrence near Ilakaka and the known deposit at Andranondambo in south-eastern Madagascar.*

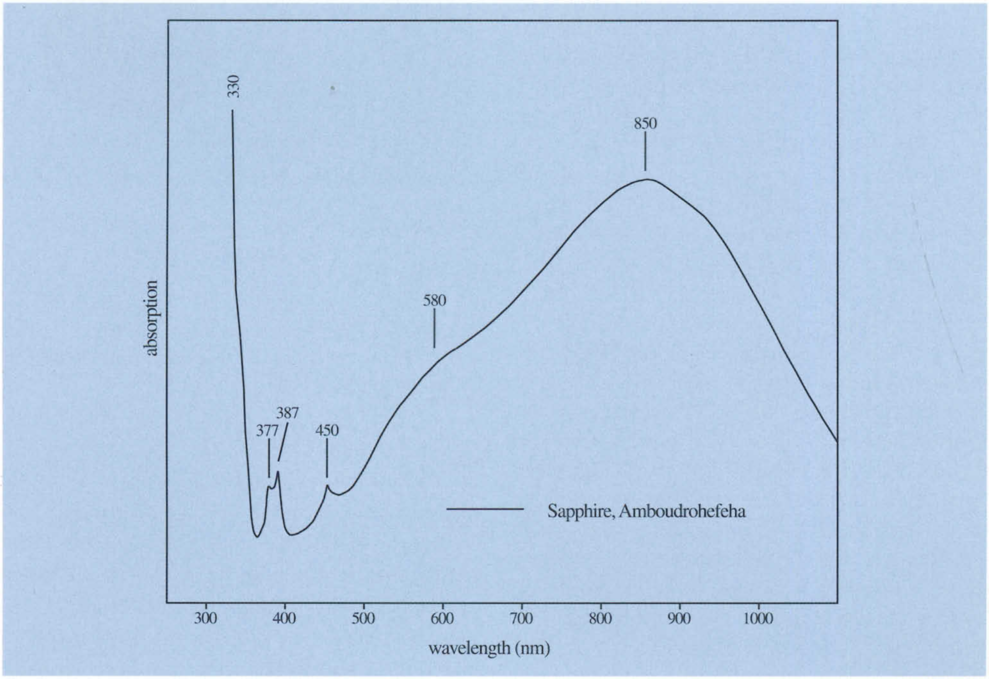

Figure 8: *Non-polarized UV/VIS/NIR - spectrum of a natural coloured, basaltic-type sapphire from Amboudrohefeha in northern Madagascar.*

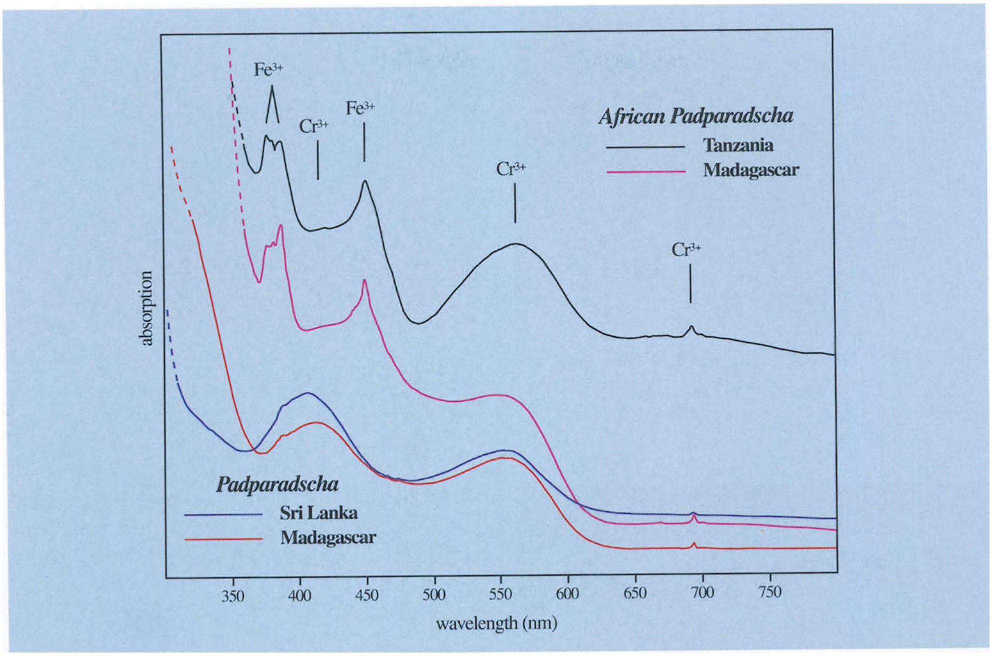

***Figure 9:** Non-polarized UV/VIS/NIR - spectra of representative samples of orange to brownish-orange and pinkish-orange corundums from Madagascar, compared with a padparadscha from Sri Lanka and an 'African padparadscha' from Tanzania.*

sapphire originates in the north of Madagascar near Amboudrohefeha. These specimens are recovered from basaltic rocks and show a typical broad absorption band in the near infrared with a maximum at 850 nm due to a Fe^{2+}/Ti^{3+} charge transfer process (*Figure 8*). In a recently examined parcel of Madagascar sapphires all three types were present.

The yellow, orange and brownish-red sapphires from Madagascar possess absorption patterns comparable with those of sapphires from the Umba-valley and the Tunduru/Songea area in Tanzania. The yellow sapphires show the typical Fe^{3+}-spectrum with absorption maxima at 450 nm, 387 and 377 nm. The orange sapphires are coloured by iron and chromium. In addition to the Fe^{3+} bands producing the yellow colour, additional broad pleochroic bands of Cr^{3+} are visible and produce the red component. The absorption maxima are at 555 and 410 nm and the typical Cr-line is situated at 693 nm (*Figure 9*). Increased iron contents change the colour to a brownish tone which is characteristic for orange sapphires from East Africa (Schmetzer *et al.*, 1982; Henn *et al.*, 1989). This range of orange to brownish-orange sapphires is known in the trade as 'African padparadscha'. However, a number of the Madagascar specimens showed a pinkish-orange reminiscent of padparadschas from Sri Lanka. The absorption spectrum measured on a representative specimen is dominated by colour centres and trivalent chromium (± Fe^{3+}) and corresponds to similar spectra obtained from Sri Lankan material (see *Figure 9*).

The inclusion pattern of the blue sapphires from the new gemfields was also compared to that of blue sapphires from Sri Lanka and found to be similar, whereas the internal features of the fancy-coloured sapphires more resemble the East-African type. Typical inclusions in the blue sapphires from Ilakaka include oriented rutile needles (*Figure 10*), zircons with tension cracks, healed-cracks and distinct growth and colour zoning (*Figure 11*). The yellow and orange to

Figure 10: *Oriented rutile needles in a sapphire from the new deposit in south-western Madagascar. Immersion, transmitted light, magnified 20x.*

Figure 11: *Distinct growth and colour zoning and healed crack in a sapphire from the new deposit in south-western Madagascar. Immersion, transmitted light, magnified 20x.*

Figure 12: *Lamellar twinning in a fancy-coloured sapphire from the new deposit in south-western Madagascar. Immersion, transmitted light, crossed polars, magnified 20x.*

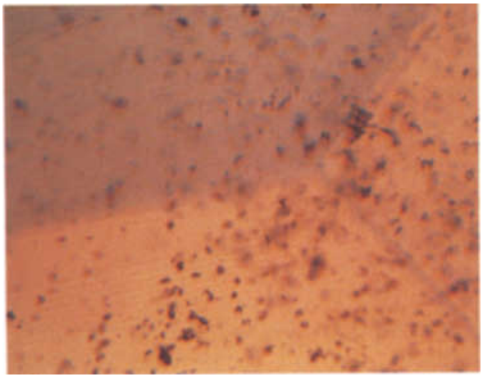

Figure 13: *Numerous small zircons form a typical inclusion pattern in the fancy-coloured sapphires from the new deposit in south-western Madagascar. Immersion, transmitted light, magnified 40x.*

brownish-orange sapphires showed lamellar twinning (*Figure* 12), partly with boehmite tubes, and numerous small zircon grains (*Figure* 13).

Spinel

Corundum of metamorphic origin is commonly accompanied by spinel and this is the situation in the gemstone occurrences of south-west Madagascar. Blue and violet colours (see *Figure 6)* predominate and are caused by divalent iron. The refractive indices measured ranged from 1.716 to 1.720 and the specific gravity varied between 3.54 and 3.63. Black hercynite octahedra are characteristic inclusions and crystallographically oriented rutile needles (*Figure 14*) were observed with the microscope.

Chrysoberyl

This mineral species is present as chrysoberyl, chrysoberyl cat's-eye and alexandrite. The chrysoberyls possess yellow to yellowish-green and yellowish-brown colours (see *Figure* 6) caused by trivalent iron. The following refractive indices, birefringences and specific gravities were determined: n_x = 1.744 - 1.749, n_y = 1.747 - 1.752, n_z = 1.752 - 1.758, with Δn = 0.008 - 0.009 and SG = 3.70 - 3.72. Typical internal features are step-like growth structures, healed-cracks and isolated two-phase inclusions as well as hollow tubes. The presence of numerous oriented hollow tubes may produce a cat's-eye effect. The alexandrites examined showed a distinct colour-change from bluish-green in daylight to violet-red in artificial light.

Garnets

Specimens of the garnet family are frequently found in the gemfields of south-western Madagascar, especially rhodolites, colour-change garnets and hessonites. The rhodolite garnets possess the typical violet-red to reddish-violet colours caused by divalent iron. Refractive index and specific gravity measurements are in the known range for solid solutions of the pyrope - almandine series: n = 1.764 - 1.772 and SG = 3.75 - 3.81. Oriented rutile needles as well as a distinct tabby extinction under crossed polars were observed with the microscope.

The colour-change garnets are bluish-green in daylight and red to reddish-violet in artificial light. These garnets belong to the binary series pyrope-spessartine and have a refractive index between 1.760 and 1.763 and specific gravity between 3.76 and 3.87. The change of colour is caused by a broad absorption band in the yellow spectral range due to minor contents of trivalent vanadium and/or trivalent chromium.

The hessonite garnets from the new finds are typically brownish-yellow with refractive indices between 1.744 and 1.749 and specific gravities between 3.60 and 3.69.

Beryl

Historically beryl is one of the most important gemstones recovered in Madagascar, but the presence of this species in the new finds is sparse. The standard gemmological properties of some intense blue aquamarines (see *Figure* 6) purportedly from the new deposits were n_e = 1.580 - 1.589, n_o = 1.587 - 1.598 with Δn = 0.007 - 0.009 and SG = 2.72 - 2.74. Fine growth structures and fluid inclusions formed a typical inclusion pattern.

Tourmaline

Another important gemstone group of Madagascar is tourmaline. Occurrences in the new gemfields include pale brown to yellow-brown dravites and uvites (see *Figure* 6) as well as pink elbaites. The following refractive indices, birefringence and specific gravity were determined: n_e = 1.619 - 1.621, n_o = 1.639 - 1.641, Δn = 0.020 and SG = 3.05 - 3.07.

Figure 14: *Crystallographically oriented rutile needles in a spinel from the new deposit in south-western Madagascar. Immersion, transmitted light, magnified 20x.*

Other gems

In addition to the stones mentioned above reddish-brown zircons, pale blue and colourless topazes, kunzites and iolites from the new deposits were examined.

Conclusions

The new finds in south-western Madagascar have significantly increased the commercial importance of blue and fancy-coloured sapphires from Madagascar. However, as was also the case in the Tunduru area in southern Tanzania, the situtation has been complicated both by gems brought in and sold as local produce and by Madagascan stones taken out and sold as Sri Lankan.

Because Sri Lanka and Madagascar once formed a single landmass it is very likely that these sapphires were formed in the same geological environment, namely high-grade metamorphic sediments. The presence of Sri Lankan-type blue and padparadscha sapphires in Madagascar is consistent with this interpretation. Consequently, our contribution to the current debate in the trade about whether the term 'padparadscha' should be confined only to Sri Lankan specimens is that it should not because the pinkish-orange stones from both Sri Lanka and Madagascar have essentially the same colours, properties and geological source.

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Colour-change garnets from Madagascar: comparison of colorimetric with chemical data

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ABSTRACT: In this study 24 colour-change garnets from Madagascar have been studied to gain data for a correlation between chemical composition and colorimetric calculations. All samples belong to the pyrope-spessartine solid solution series. They contain some traces of vanadium (0.27 to 1.61 wt% V_2O_3), which is responsible for the colour-change in these garnets. Based on visual observations, the investigated samples were separated into five groups of different colour-change behaviour when examined under daylight and incandescent light. Generally, most garnets changed from bluish-green in daylight to purple in incandescent light, although some changed from yellowish-green to pink and brownish-green to brownish-red. Two samples remained almost unchanged, i.e. blue and brown respectively. The visual separation in five groups is consistent with differences obtained by colorimetric calculations. The colorimetric calculations are presented in the CIELab colour space. Comparing colour behaviour with chemical analyses results in a correlation with several intrinsic chemical factors, mainly vanadium, chromium, manganese, magnesium and iron.

Keywords: chemistry, CIELab colour space, colorimetry, colour-change garnet, Madagascar, vanadium

Introduction

The colour-change effect is well known by gemmologists and highly appreciated in the gem trade. The term was originally used for alexandrite, a variety of chrysoberyl, changing its colour appearance distinctly under different 'white' illuminations, e.g. daylight and incandescent light. Gem-quality garnets displaying colour change were first mentioned from East Africa (Crowningshield, 1970; Jobbins *et al.*, 1975). In the following years similar garnets were further reported from Umba valley and Tunduru in Tanzania (Schmetzer and Ottemann, 1979; Schmetzer and Gübelin, 1980; Stockton, 1982; Hänni, 1983; Manson and Stockton, 1984; Stockton, 1985; Koivula and Kammerling, 1988) and from Athiliwewa and Embilipitiya in Sri Lanka (Johnson and Koivula, 1996b; Johnson and Koivula 1998a). However, commercial quantities of colour-changing garnets have entered the gem trade only recently due to the discovery of new gem deposits in south west Madagascar (area of Ilakaka and Bekily; Johnson and Koivula, 1998b); most faceted stones are less than 1 ct.

Generally, colour-change garnets are greenish-blue to almost blue in daylight and purplish to purple in incandescent light (Johnson and Koivula, 1998a). Some change

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Materials and methods

For this study, 24 colour-changing garnets (21 faceted and 3 rough specimens labelled A-D, F-J and L-Z) ranging from 0.25 ct to 2.38 ct have been investigated. They were chosen to represent the largest possible range of colour (*Figure 1*). For comparison we also included a spessartine garnet (K) of light orange colour. All samples, including the spessartine, originate from the recently discovered secondary gem deposit near the town of Bekily in southern Madagascar (W. Spaltenstein, L. Aubert, A. Leuenberger, D. Bontempi, all pers. comm., 1999 and 2000).

Apart from standard gemmological testing for internal strain (polariscope), refractive index, specific gravity and fluorescence to long and short-wave ultraviolet radiation, the colour of each sample was determined using daylight and tungsten light (incandescent light). For tungsten light observations, a calibrated light source of 2800 K (similar to CIE illuminant A) was chosen.

Figure 1: *Some of the investigated colour-change garnets from Madagascar under tungsten illumination. Photo by M.S. Krzemnicki, © SSEF*

In the standard visual observation routine, all samples were placed about 50 cm from the observer and colour was observed when looking straight through the table facet. For daylight measurements, the samples were shielded from direct sunlight and only exposed to diffuse daylight. For colour determination in tungsten light, the light source was slightly inclined to the table facet, as this is the customary way to examine gemstones in the trade.

UV-VIS spectrometric data (800-350 nm) of all specimens were taken with a Varian Cary 500 spectrophotometer, using a scan rate of 60 nm/min in the transmission mode. Based on these absorption spectra, the colorimetric data (CIELab coordinates) were calculated using Mathematica® (calculations kindly provided by G. di Pietro, Institute for Scientific Photography, University of Basel) and our own CIELab calculation program.

The chemical compositions of 18 samples were obtained using a Cameca SX-50 electron microprobe and a JEOL-JXA 8600 electron microprobe with an acceleration voltage of 15 kV and a beam current of 10 nA (Geochemical Laboratories, ETH Zürich and MPI University of Basel); well-characterized oxides and silicates of Al, Si, Ca, Mn, Fe, V, Cr, Ti, Mg were used for standardization. The chromium content in weight percent oxide was corrected for peak overlaps by interfering vanadium-Kβ using the formula:

$$Cr_2O_3(\text{corrected}) = Cr_2O_3(\text{initial}) - 0.1 \times V_2O_3$$

All quantitative chemical data were further corrected for matrix effects by ZAF-type on-line procedure.

Table I: Gemmological properties of the studied colour-change garnets

Samples:	24 colour-change garnets
Weight:	0.25 to 2.38 ct
SG:	3.748 to 4.104
RI:	1.745 to negative reading (> 1.785)
Polariscope:	anomalous double refraction
UV LW:	inert
UV SW:	inert
Colour in light:	daylight: blue, greenish-blue, brownish-green, yellowish-green incandescent: purple, brownish-red, pink
Colour-change:	very slight to distinct
Saturation:	medium to strong
Transparency:	transparent
Lustre:	bright vitreous

their colour from yellowish-green to pink or pale brown (Johnson and Koivula, 1998b).

In the first detailed gemmological study of colour-change garnets from Madagascar, Schmetzer and Bernhardt (1999) separate colour-change garnets into two groups according to their chemistry. Most colour-change garnets are intermediate members of the pyrope-spessartine solid solution series containing minor amounts of vanadium and/or chromium (Jobbins *et al.*, 1975; Stockton, 1982; Manson and Stockton, 1984; Stockton and Manson, 1985; Koivula and Kammerling, 1988; Johnson and Koivula, 1996b; Johnson and Koivula, 1998b; Schmetzer and Bernhardt, 1999). All studied colour-change garnets from Madagascar belong to this group (Johnson and Koivula, 1998b; Schmetzer and Bernhardt, 1999). Only a few colour-change garnets were found to be chromium-rich (Schmetzer *et al.*, 1980).

The colour-change effect has been studied for decades (see references in Bosshart et al., 1982; Liu et al., 1999), mainly concentrating on alexandrite. A comprehensive description of colour-change materials (minerals and artificial products) is given by Liu et al. (1999). They compared colorimetric calculations with standard gemmological observation techniques for colour description. Previously Schmetzer et al. (1980) had studied the relationship between the colour change of different materials and the chemistry and/or crystal structure of a mineral.

In this study, the authors would like to integrate these two research approaches by presenting data on colour-change garnets from Madagascar, with emphasis on the correlation of chemical data with colorimetric calculations and colour observation.

Physical properties

The gemmological properties of the colour-change garnets (sample K, spessartine, excluded) are summarized in *Table I*. The distinct variations in RI (from 1.745 to > 1.785) and SG (3.748 – 4.104) are due to extensive exchange of magnesium by manganese in the samples (members of the pyrope-spessartine solid solution). Chemical analyses revealed a close correlation of RI (and SG) with the chemistry of colour-change garnets (*Figure 2*). Previous studies on colour-change garnets (Jobbins *et al.*, 1975; Stockton, 1985; Johnson and Koivula, 1996a, 1996b; Johnson and Koivula, 1998b; Koivula and Kammerling, 1988; Schmetzer and Bernhardt, 1999) reported RI values between 1.757 and 1.770, a distinctly smaller range than that in the present sample selection.

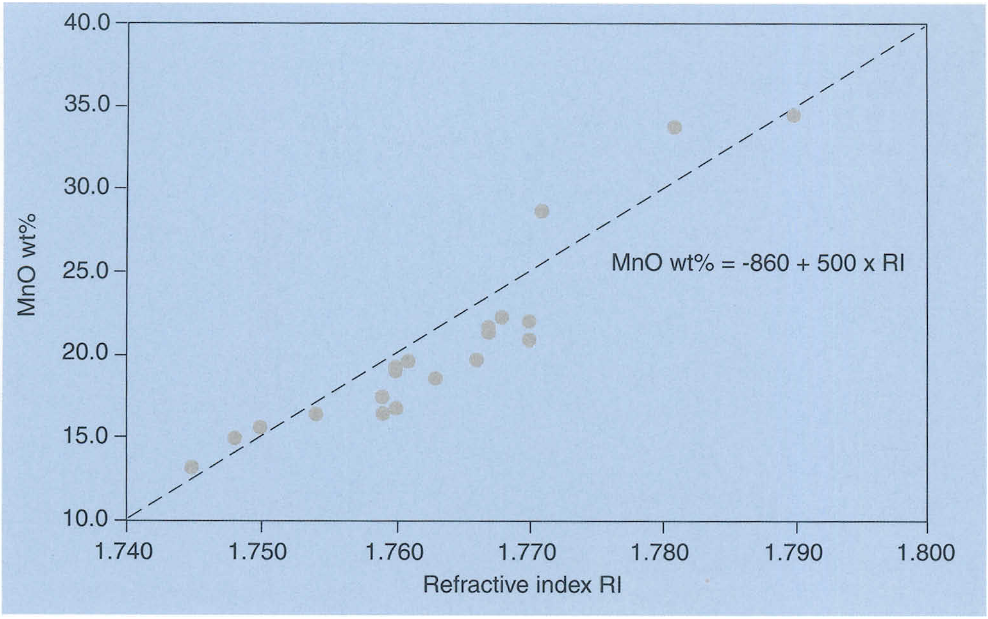

Figure 2: Correlation of manganese content (MnO wt%) versus refractive index of colour-change garnets from Madagascar. A qualitative correlation line has been drawn to show the direct relationship between main component content (i.e. manganese) and optical property (RI). A similar diagram can be obtained by plotting Mn content against SG.

All samples remained inert when exposed to long and short-wave ultraviolet radiation. Under the polariscope they showed slight to moderate anomalous extinction, resulting from internal strain within the garnet structure. Regularly oriented long prismatic crystal inclusions, often in a three-dimensional lattice array were found to be rutile.

Visual colour determination

The colour of all samples was determined by a consistent observation technique (see section 'Materials and methods'), similar to that in common practice in gemmological laboratories and in the trade. Nevertheless, visual colour determination of a faceted

***Table II:** The colour-change behaviour of the studied garnets from Madagascar*

Group	*Samples*	*Daylight*	*Tungsten light*	*Colour change*	*References*
Group I	J	blue	blue with purplish hue	very slight hue change	9, 11
Group II	A, B, D, F-I, L-N, Q, T-W, Y, Z	blue-greenish blue	purplish-blue – purple	moderate – distinct	1, 2, 4, 6, 7, 11, 12
Group III	P, R. S	yellowish-green	pink – light purple	slight – moderate	3, 5, 6, 7, 11, 12, 13
Group IV	C, X	brownish-green	brownish-red	moderate	6
Group V	O	brown	reddish-brown	very slight	

References:

1. Jobbins *et al.*, 1975
2. Johnson and Koivula, 1996a
3. Johnson and Koivula, 1996b
4. Johnson and Koivula, 1998a
5. Johnson and Koivula, 1998b
6. Koivula and Kammerling, 1988
7. Liu *et al.*, 1999
8. Manson and Stockton, 1984
9. Schmetzer and Ottemann, 1979
10. Schmetzer *et al.*, 1980
11. Schmetzer and Bernhardt, 1999
12. Stockton, 1982
13. Stockton and Manson, 1985

gemstone still remains a challenge, as several aspects contribute to its overall colour appearance (Liu *et al.*, 1999). Usually, the body colour is the most important factor. However, reflections on pavilion facets often display quite different colour hues (Stockton, 1982). The cut of the specimen may enhance or reduce these reflected colours. For this study, each specimen was attributed to its dominating spectral colour (e.g. blue in daylight) under daylight and tungsten illumination, just adding hues (e.g. purplish-blue). Additionally the colour saturation (medium, medium strong, strong) and the strength of colour change (very slight, slight, moderate, distinct) were estimated. Based on this the 24 specimens were separated into five groups of different colour-change behaviour (see *Table II* and *Figures 3 and 4*).

- *Group I* garnets remain blue under both illuminations; only a slight change of colour hue is observed (sample J, *Figure 5*). The colour saturation is strong (Schmetzer and Ottemann, 1979).
- *Group II* garnets change their colour moderately to distinctly from bluish to purplish (daylight/tungsten light). Their colour saturation ranges from medium to strong. In the gem trade, these colour-change garnets are commercially the most important (Schmetzer and Bernhardt, 1999). Samples A, B, D, F-I, L-N, Q, T-W, Y, and Z (a total of 17) belong to this group.

Figures 3 and 4: *Colour-change garnets from Madagascar under daylight illumination (Figure 3, top) and under tungsten light (Figure 4, bottom). Colours slightly adjusted by AdobePhotoshop®. Photos by M.S. Krzemnicki, © SSEF.*

- *Group III* garnets change their colour from yellowish-green to pink (Koivula and Kammerling, 1988; Schmetzer and Bernhardt, 1999). The colour saturation is medium to medium strong, the colour-change slight to moderate (samples P, R, S).
- *Group IV* garnets change their colour moderately from brownish-green to brownish-red. The colour saturation is strong (samples C, X).

Figure 5: *Almost blue garnet from Madagascar (sample J, group I) in daylight. This sample displays only a very slight change of colour hue when examined under tungsten light. Photo by M.S. Krzemnicki, © SSEF.*

Figure 6: *Brown garnet from Madagascar (sample O, group V) in daylight. This sample displays only a slight change of colour hue towards reddish-brown when examined under tungsten light. Photo by M.S. Krzemnicki, © SSEF.*

- *Group V* garnets change their hue slightly from brown (daylight) to reddish-brown (tungsten) (sample O, *Figure 6*). The colour saturation is strong.

The following results and interpretations of colorimetric and chemical data are discussed in relation to the visual separation in groups I-V.

Chemical data

Quantitative chemical analyses (WD-XRF) and calculated end member mol% (Deer *et al.*, 1992) of some of the colour-change garnets from each group are given in *Table III*. All samples (except sample K, a nearly pure spessartine) are intermediate members of the pyrope-spessartine solid solution series. Apart from the major MgO and MnO components, they are characterized by a significant grossular component (CaO up to 7.31 wt%, i.e. 13.8 mol% grossular), and a rather smaller iron content from 0.52 up to 3.10 wt% FeO). In the analyses, all iron is presented as FeO (i.e. Fe^{2+}, almandine component). Due to the low iron concentrations an estimation of Fe^{3+} based on Droop (1987) is not reliable, although small amounts of Fe^{3+} might be present (andradite component).

All samples (except spessartine, sample K) contain distinct amounts of vanadium (from 0.27 in sample R to 1.61wt% V_2O_3 in sample J) and chromium (from 0.11 in sample R to 0.95 wt% Cr_2O_3 in sample M). Only in sample M (group II) is the uvarovite component (Cr_2O_3) slightly higher than the goldmanite component (V_2O_3). In all other samples vanadium content exceeds that of chromium by a factor of 2 to 5.

Table III: *Electron microprobe analyses of some colour-change garnets from Madagascar*

	Group I	*Group II*	*Group II*	*Group III*	*Group IV*	*Group V*	*Spessartine*
	Sample J	*Sample M*	*Sample A*	*Sample R*	*Sample C*	*Sample O*	*Sample K*
RI	1.763	1.767	1.748	1.760	1.781	neg.	neg.
SG	3.832	3.893	3.748	3.871	4.068	4.104	4.168
Oxide weight%							
MgO	10.45	11.78	15.25	10.49	4.21	0.87	b.d.
MnO	18.49	21.31	14.75	18.89	33.69	34.41	42.27
CaO	7.31	3.01	4.65	5.09	1.73	3.11	0.21
FeO	0.65	2.84	0.96	2.29	0.52	3.10	b.d.
Cr_2O_3	0.38	0.95	0.17	0.11	0.24	0.26	b.d.
V_2O_3	1.61	0.91	0.43	0.27	1.30	0.44	0.01
TiO_2	0.06	0.03	0.04	0.11	0.25	0.51	b.d.
Al_2O_3	21.12	20.48	22.70	21.67	19.99	20.06	20.88
SiO_2	38.63	38.81	41.47	40.22	37.22	37.65	36.65
Total	98.70	100.12	100.42	99.14	99.15	100.41	100.02
Endmember mol%							
Pyrope	39.3	42.6	55.4	40.1	16.9	3.6	0.0
Spessartine	39.5	43.8	30.5	41.0	76.9	80.1	99.4
Almandine	1.4	5.8	2.0	4.9	1.2	7.1	0.0
Uvarovite	1.1	2.9	0.5	0.3	0.8	0.8	0.0
Goldmanite	4.9	2.8	1.3	0.8	4.2	1.4	0.0
Grossular	13.8	2.1	10.4	12.8	0.1	6.9	0.6

For this table, only representative analyses of the studied colour-change garnets from Madagascar were chosen.

Cr_2O_3 was corrected for interference with vanadium – Kß, see section 'Materials and methods'.

b.d. – below detection limit. Endmember calculation after Deer *et al.*, 1992

neg. – negative RI, i.e. above upper limit of the TIR-refractometer at 1.785

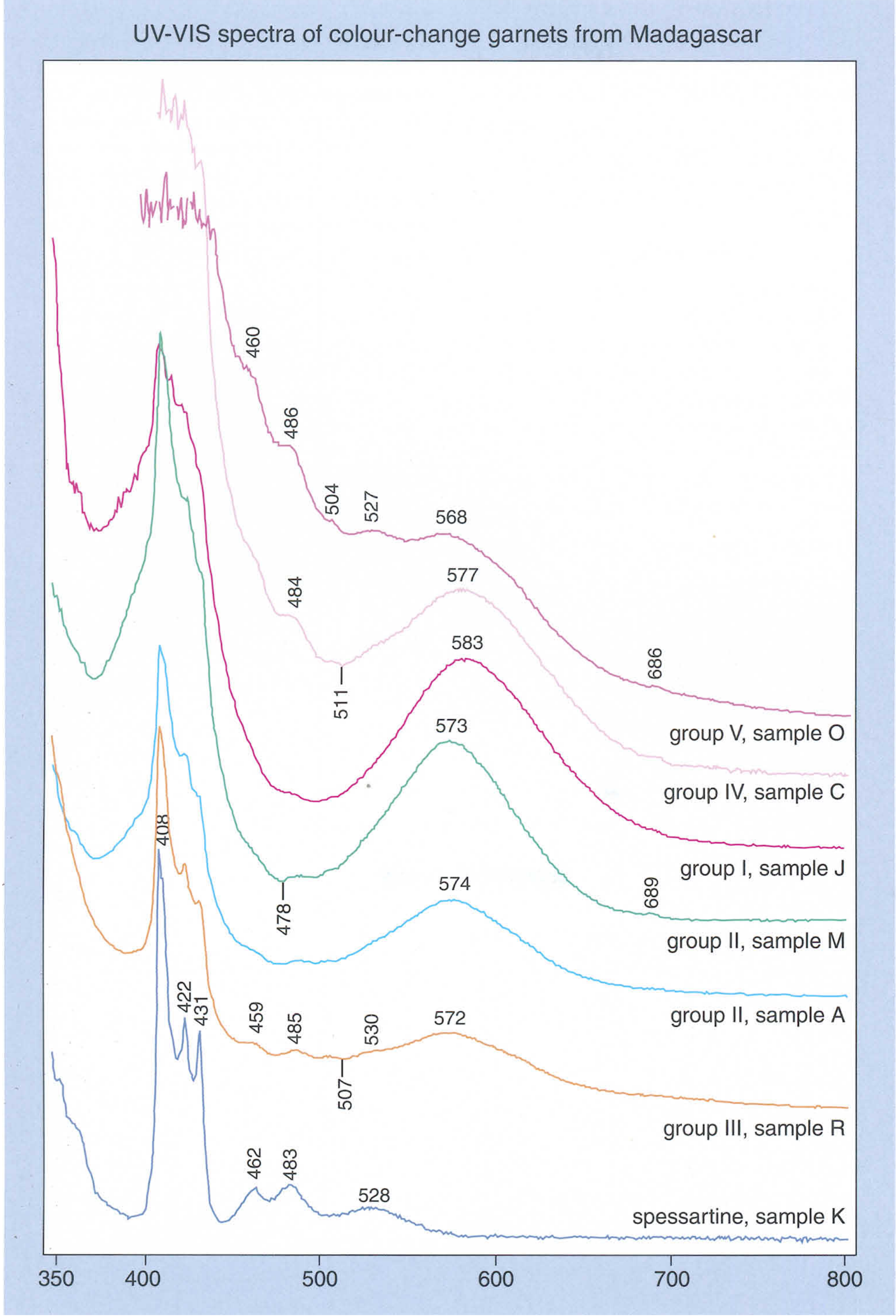

Figure 7: *UV-VIS spectra of colour-change garnets (groups I-V) compared with spessartine.*

Spectrometric data in the UV-visible range

The colours of the present suite of stones are made up of the contributions of each of the solid solution components or garnet end members. Pyrope is colourless and has no absorption bands in the visible region of the spectrum. Pure spessartine is orange and shows its presence even in low quantities by the well known set of absorption bands (see below). Iron, vanadium and chromium contribute to the observed colour as chromophore elements (Nassau, 1983), modifying the basic colour set by the main constituents (pyrope and spessartine). *Figure 7* shows representative UV-VIS absorption spectra of garnets from the different colour change groups (I-V, see *Table III*). They are compared with the spectrum of

Table IV: *Comparison of colorimetric with chemical data of garnets from Madagascar.*

		Hue angle		*Hue angle difference*	*Saturation*		*Chemistry*		*End-members*
Sample	*Colour group*	*Ω(D65)*	*Ω(A)*	*ΔΩ*	*δ(D65)*	*δ(A)*	*MnO wt%*	*V_2O_3 wt%*	*Spessartine mol%*
J	I	210.3	243.2	32.9	48.2	46.0	18.49	1.61	39.5
A	II	161.9	340.0	178.1	3.4	12.8	14.75	0.43	30.5
B	II	158.5	340.6	177.9	7.0	11.5	15.47	0.49	32.0
T	II	137.3	350.1	147.1	3.5	8.0	13.13	0.38	27.6
Q	II	175.9	319.0	143.1	6.3	7.3	n.a	n.a	n.a
L	II	1.79.7	321.4	141.7	5.1	7.6	21.93	0.93	46.8
U	II	192.2	326.8	134.6	4.3	12.1	16.71	0.90	34.7
W	II	183.4	316.7	133.2	12.8	14.6	20.80	1.20	47.9
G	II	193.2	315.8	122.6	9.4	14.0	19.55	1.14	43.0
I	II	190.3	306.7	116.4	12.3	13.1	22.16	1.24	48.7
H	II	171.9	285.1	113.2	17.0	6.6	16.33	0.77	34.6
V	II	212.7	314.8	102.1	6.1	13.4	16.34	0.94	34.7
F	II	210.6	305.3	94.7	11.0	16.5	19.59	1.08	41.8
D	II	212.8	297.7	84.9	13.4	17.9	19.11	1.19	40.6
Y	II	221.3	288.6	67.3	3.8	5.3	19.63	0.87	42.6
Z	II	219.2	281.9	62.7	6.9	8.4	21.60	1.31	47.9
M	II	265.3	324.7	59.5	7.6	25.7	21.31	0.91	43.8
N	II	257.9	311.3	53.4	10.5	21.3	17.36	0.80	36.2
P	III	125.0	35.9	89.2	14.4	11.2	n.a.	n.a.	n.a.
S	III	103.1	59.8	43.3	17.1	15.6	18.90	0.29	40.7
R	III	84.1	42.9	41.2	14.5	17.9	18.89	0.27	41.0
C	IV	84.6	49.4	35.2	27.3	31.8	33.69	1.30	76.9
X	IV	85.2	51.8	33.3	12.8	14.6	28.63	0.89	58.6
O	V	58.3	52.5	5.8	51.3	59.1	34.41	0.44	80.1
K	Spessartine	72.2	65.7	6.6	29.6	33.7	42.27	0.01	99.4

The table has been arranged in order of decreasing hue angle differences ΔΩ within each group of colour-change behaviour.

The colorimetric data (hue angle Ω and saturation δ) are given for both illuminants D65 (daylight equivalent) and A (tungsten equivalent).

n.a. – not analysed chemically by electron microprobe.

spessartine of light orange colour. All spectra show characteristics of spessartine with Mn^{2+} peaks (see e.g. Manson and Stockton, 1984; Schmetzer and Bernhardt, 1999) at 408, 422, 431 nm (or complete absorption around 431 nm). All colour-change garnets (group II-IV) show a distinct broad absorption band with a maximum at about 573 nm. This maximum has been attributed to V^{3+} probably with some Cr^{3+} (see Schmetzer and Ottemann, 1979; Manson and Stockton, 1984; Schmetzer and Bernhardt, 1999). The absorption minimum for garnets changing from bluish to purple is located about 476 nm, whereas garnets with a yellowish-green to pink colour-change have a minimum around 507 nm (Schmetzer and Bernhardt, 1999). Two different spectral characteristics may result in garnets displaying only a very slight change of colour hue (group I and group V). The blue garnet (sample J, group I, *Figure 5*) has the highest vanadium content (1.61 wt% V_2O_3) of all the samples and shows a similar spectrum to colour-change garnets. However, the maximum of the broad absorption band is centred about 583 nm, and is thus slightly above the narrow range between 562–577 nm defined by Schmetzer and Bernhardt (1999) for alexandrite-like colour change materials. The brownish garnet (sample O, group V, *Figure 6*) shows distinct superposition of the characteristic V-absorption band by Fe^{2+} (almandine component) and Mn^{2+} (spessartine component). Due to this no distinct minimum in the range of 507–476 is present. This results in only a very slight change of colour hue, although the vanadium content is the same as in the colour-change garnets of group II (see *Table III*).

Colorimetric calculation

By means of colorimetric calculations, somewhat subjective colour descriptions can be displayed as coordinates in a colour space. In accordance with previous studies (Liu *et al.*, 1994, 1999) the CIELab space was chosen to calculate colour coordinates, as it is a uniform colour space which takes into account the chromatic adaptation of the human eye. In the CIELab space, colour differences are proportional to the distances of the represented colour coordinates (for a detailed discussion of colorimetry in gemmology, please refer to Liu *et al.*, 1999).

Colour is always an integration of hue (spectral colour, e.g. blue), saturation (depth of colour, weak to strong) and brightness (from light to dark). Based on the UV-VIS transmission spectra of our samples, we calculated L* (brightness) and a*, b* (colour coordinates, determining the colour hue) in the CIELab colour space (*Table IV* and *Figure 8*). Formulae can be obtained in any standard colorimetry textbook (Kuehni, 1997) or on the internet (e.g. http://www.cs.rit.edu/~ncs/color/t_convert.html).

The saturation δ of a colour is the distance between the colour coordinates (a*, b*) to the centre point (0, 0) and thus:

$$\delta = \sqrt{(a^2 + b^2)}$$

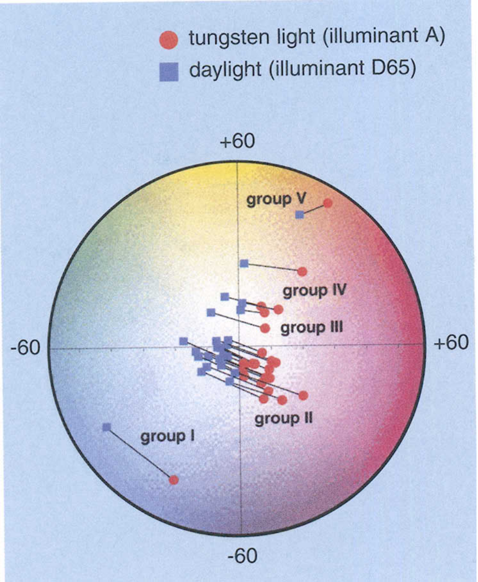

Figure 8: *Colour coordinates of all studied colour-change garnet samples (see Table III) in the CIELab colour space. Daylight coordinates in blue, incandescent coordinates in red. The lines connect the colour coordinates of each sample calculated with illuminants D65 (daylight equivalent) and A (tungsten light equivalent).*

In 1986 the 'Commission International de l'Eclairage CIE' proposed several standard illuminants (theoretical light sources); these include D65 for daylight (light emitted by a blackbody at 6504 K) and A for incandescent (tungsten) light (2856 K). Based on these illuminants and on so-called matching functions (2° standard colorimetric observer), which take into account the ability of the human eye to adapt chromatically between different 'white' light sources, the CIELab coordinates for the samples under each illumination were calculated using our own computer program. All equations and data for variables (i.e. illuminants and matching functions) were found on the internet (see references).

Using a simple trigonometric equation, colour hue angles Ω for each sample under the illuminant D65 and A were calculated:

$$\Omega = \arctan(b/a)$$

The difference between hue angles $\Delta\Omega$ of each sample is an expression of the calculated colour change behaviour of a gemstone under daylight and incandescent light, respectively.

$$\Delta\Omega = |\Omega D65 - \Omega A|$$

Comparison of colorimetric data with chemical data

The colour appearance of the samples were well reproduced by the calculated colour hue values (*Figure 8*) and we think colorimetry may become a more important tool for colour investigation in gemmology.

A close examination of the calculated hue angle differences $\Delta\Omega$ (*Figure 9*) fits well with the visual separation into five groups of colour-change behaviour (I-V, see *Table II*).

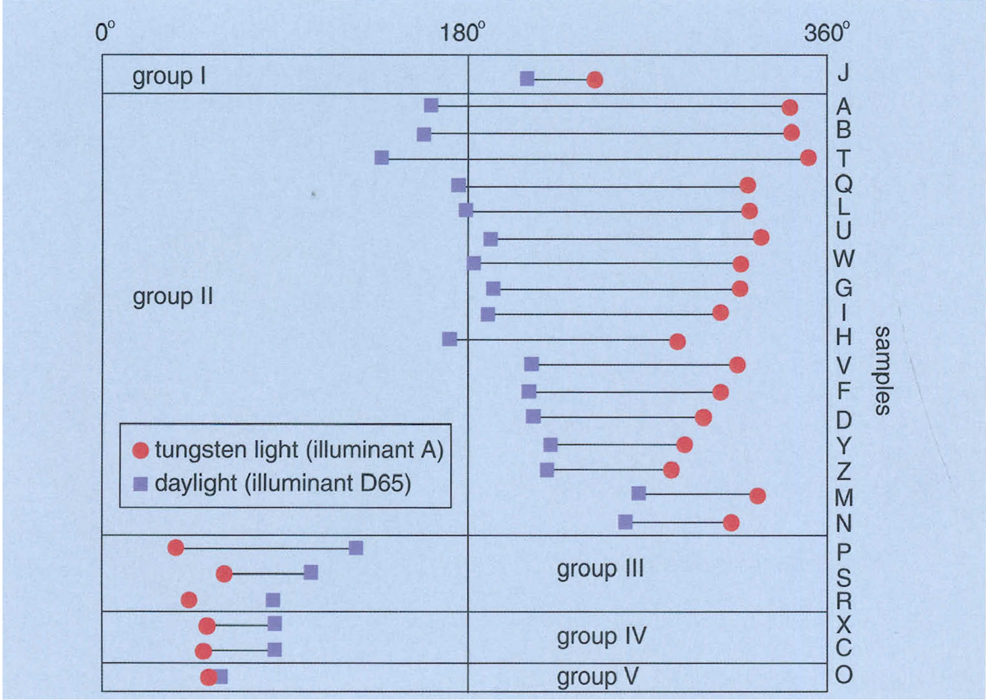

Figure 9: *Calculated hue angle differences $\Delta\Omega$ of the garnets, listed in five groups of colour-change behaviour and arranged in order of $\Delta\Omega$. In daylight, all samples tend in direction to the hue angle 180° (blue-green). Samples such as A, B and Q are characterized by very large $\Delta\Omega$ but visually appear with a rather slight to moderate colour-change due to their low colour saturation (compare with Figure 10).*

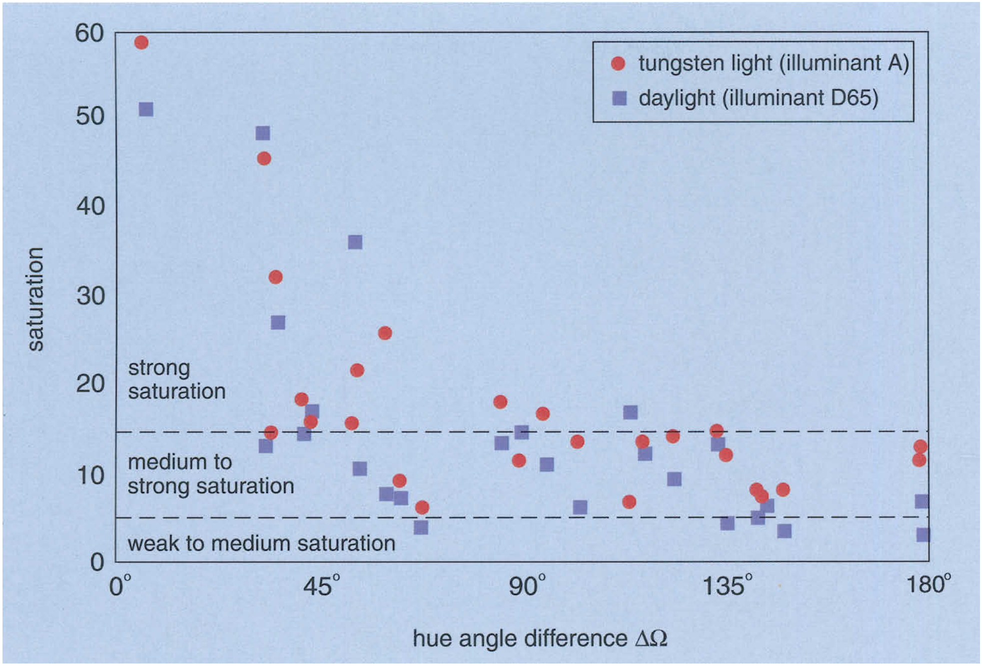

Figure 10: *Calculated saturation δ versus hue angle difference ΔΩ of the garnets. A general trend of reduced saturation for samples with a very large hue angle difference ΔΩ is apparent.*

However, the extent of calculated colour-change, i.e. hue angle difference ΔΩ seems quite high, reaching values almost up to 180, and representing colour-change from nearly red to its opponent colour blue in the CIELab colour space. However, the influence of colour saturation δ (*Table IV*) and brightness L* must also be taken into account. In *Figure 10* the colour saturations are plotted against hue angle differences ΔΩ. Obviously there is a general trend toward weak to medium saturations with increasing hue angle differences ΔΩ. Liu *et al.* (1999) proposed a minimal saturation δ = 5 to rely on colour-change data. All samples with lower saturation than 5 have their coordinates so close to the white centre point of the CIELab colour space (*Figure 8*), that even a barely visible change in colour hue might result in a large hue angle difference ΔΩ. Thus the colour saturation δ of a sample is highly relevant to the visual extent of any colour-change. The calculated values of hue angle differences ΔΩ should be compared only between samples with similar saturation to describe the extent of colourchange in qualitative terms as minor, moderate or distinct.

The correlation of observed colour and colour-change behaviour with the chemistry of the garnets is rather complex. Obviously the vanadium (and some chromium) are responsible for the colour-changing effect in these garnets. However, as shown in *Figure 9*, there is not a simple direct relation between vanadium concentration, colour and extent of colour change. Samples with quite low vanadium may exhibit a large extent of colour change (e.g. sample T, *Figure 9*), whereas vanadium rich samples may show only slight colour hue changes (sample C, *Figure 9*). By plotting the MnO versus V_2O_3 contents (*Figure 11*), the behaviour of the colour-changing garnets may be explained in a more suitable way.

In *Figure 11*, no evident correlation between manganese Mn^{2+} and vanadium V^{3+} ions can be expected, as they are substituting for Mg^{2+} and Al^{3+} on two different lattice positions. However, by attributing to each

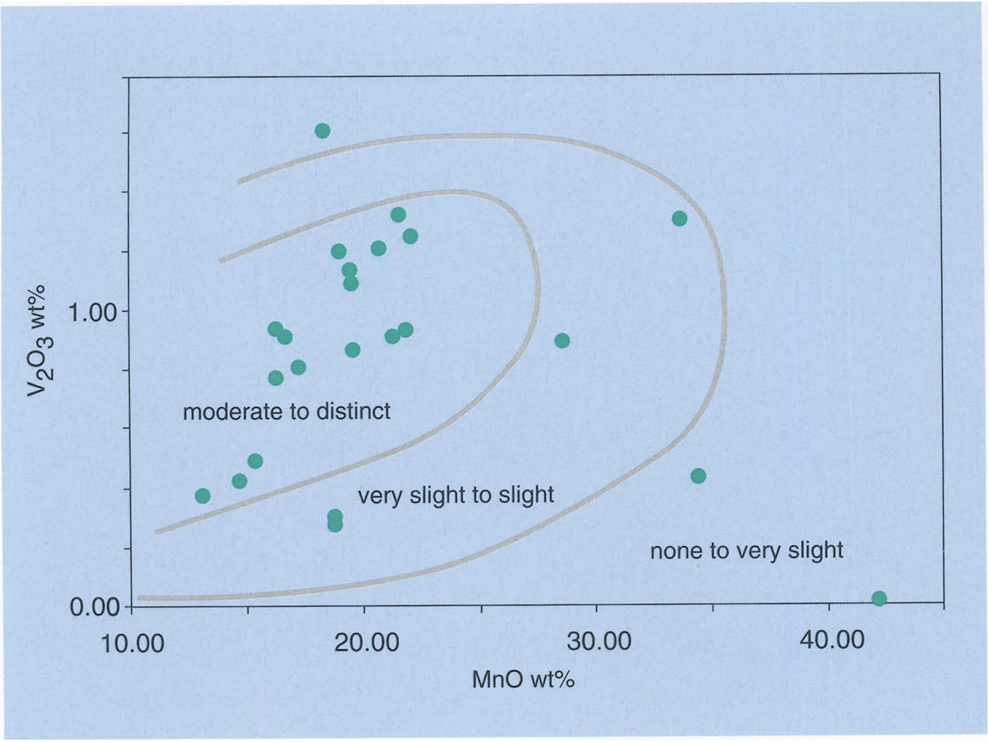

***Figure 11:** Bivariate diagram of V_2O_3 versus MnO for colour-change garnets of the pyrope-spessartine series. Three main fields of colour change strength have been introduced qualitatively. The limits of the fields represent a gradual transition rather than steps of different colour-change behaviour.*

sample the observed extent of colour change (i.e. none to very slight, very slight to slight, moderate to distinct), we gain a qualitative diagram with three fields of colour-change behaviour for vanadium bearing garnets of the pyrope-spessartine solid solution series. The limits of these fields should rather be thought of as gradual intervals, e.g. from a slight to moderate colour change, rather than as steps from one field to the other. Garnets of the pyrope-spessartine series containing no vanadium and/or chromium display no colour change at all (e.g. sample K). Their colour saturation δ is correlated to the manganese content (*Figure 10*). Samples characterized by a MgO/MnO ratio of about 1 are potentially colour-change garnets. When containing only low concentrations of vanadium and/or chromium (below about 0.5 wt% V_2O_3) they display a slight to moderate colour change from greenish in daylight to pink in tungsten light (*Figure 11*). The colour saturation remains weak to moderate. The vanadium concentration has to exceed 0.5 wt% V_2O_3 to result in a moderate to distinct colour change from bluish in daylight to purplish in tungsten light and a medium to medium strong colour saturation (*Figure 11*). According to Schmetzer and Otteman (1979) and Schmetzer and Bernhardt (1999), there is an upper limit for the vanadium concentration (about 1.60 wt% V_2O_3, sample J), above which only a slight, if any colour change can be observed. The garnet remains more or less blue under both lighting conditions with strong colour saturation (*Figure 11*). The saturation of all previously mentioned samples is basically proportional to the vanadium concentration. To understand the absence of colour change in vanadium-rich pyrope-spessartine garnets, we assume that above a critical vanadium concentration the lattice parameters are slightly modified by the goldmanite component. Although still showing an absorption spectrum similar to colour-changing garnets (*Figure 7*), the maximum of the vanadium (and chromium) absorption band has moved to a slightly higher wavelength (583 nm), thus taking it beyond the upper limit for an alexandrite-like colour-change material (562–577) as defined by Schmetzer and Bernhardt (1999).

With increasing MnO content the potential for colour-change behaviour is reduced. Even high vanadium contents (1.30 wt% V_2O_3, sample C) only result in slight colour changes from brownish-green in daylight to brownish-red in tungsten light. For low vanadium contents (0.44 wt% V_2O_3, sample O), a very slight change of colour hue from brown to reddish-brown is observed. In both cases however, the colour saturation δ is strong (*Figure 10*), mainly controlled by high manganese contents.

Conclusions

In this study of colour-change garnets from a new gem deposit in south west Madagascar the complex relationship between chemistry and colour-change effect has been investigated. The study shows that several intrinsic chemical variables such as the content of vanadium related to chromium, manganese, magnesium and iron contribute to the variations in the visual appearance of these garnets under different 'white' illuminations (daylight and incandescent light). A qualitative diagram for colour-change garnets (*Figure 11*) of the pyrope-spessartine series has been introduced. The diagram shows several fields of different colour change behaviour. Leaving the field of moderate to distinct colour-change due to higher vanadium or manganese concentrations results in a drastically reduced colour-change behaviour (or no colour-change at all), coupled with a high colour saturation. Similar garnets with low vanadium (and chromium) contents display only a weak colour-change coupled with low colour saturations. To conclude, the observed variations of the colour-change effect in garnets is generally an effect of chemical variations in the concentrations of the trace elements, vanadium and chromium and of the major constituents manganese and iron. Using colorimetric calculations, the visual separation into different groups of colour-change behaviour was confirmed and the saturation δ and the extent of colour-change ($\Delta\Omega$ difference of hue angle under daylight and incandescent light) was calculated. It is, however, important to understand that the term colour-change and its qualitative differentiation into several categories (e.g. slight, moderate, strong), is based on a combination of observed colour hues, colour saturation and brightness, and not only on pure colour difference, i.e. change of colour hues. Therefore, colorimetric data have to be used with caution when drawing conclusions about the degree (strength) of colour-change (*Figure 9*), as the saturation δ (see *Figure 10*) and brightness (L^* value in the CIELab colour space, see *Table IV*) both play an important role in how strongly the colour-change is perceived.

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Rubies from the Vatomandry area, eastern Madagascar

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ABSTRACT: Since the beginning of 2001, large amounts of rubies from the Vatomandry area in eastern Madagascar have appeared on the international gem market. Quality and colour of the new production show a pronounced variation, some being comparable to the best Burmese rubies. The Vatomandry rubies have a combination of mineralogical and gemmological properties that allows a distinct separation from rubies from Thailand and Myanmar (Burma). The three most specific inclusion features of Vatomandry rubies are (a) the complete lack of growth structures; (b) the presence of short oriented rutile needles; and (c) innumerable small colourless, transparent or white birefringent zircon crystals, so-called 'zircon clusters'. High iron contents (0.1 – 0.7 wt.% Fe_2O_3) are also characteristic and comparable to those of basaltic type rubies from Thailand.

Introduction

During the last few years, the island of Madagascar has become one of the most important gem-producing country in the world. A large variety of coloured gemstones, including rubies and sapphires, are mined in economically interesting deposits distributed over the entire island. The explanation for the enormous variety and richness in gemstone mineralisations in this new gem paradise lies in the very special and complex geological situation of the island. Madagascar is regarded as part of the eastern border of the so-called Mozambique Belt (Kröner, 1977). This belt hosts many interesting gemstone deposits in East Africa, especially in Kenya and Tanzania. Probably, at least part of the Malagasy gem occurrences result from geological events that took place when Madagascar was still adjacent to East Africa in the former Gondwanaland (see for example Mercier *et al.*, 1999). A geological map of Madagascar reminds one of a patchwork quilt. Sedimentary, metamorphic and volcanic rocks are present. The juxtaposition of different rock types in relatively small areas has created some very special genetic environments, favourable for the formation of a large variety of gem minerals.

Several sapphire and ruby occurrences have been known for decades in Madagascar (Schmetzer, 1986). But only since the beginning of the 1990s has Madagascar become a significant supplier of gem quality sapphires of different colours. The Andranondambo deposit in the south-eastern part of the island is related to skarn-mineralizations, and has produced variable amounts of medium and top gem-quality blue sapphires since 1994 (see for example Schwarz *et al.*, 1996; Kiefert *et al.*, 1996). Since 1996, blue, yellow and green sapphires from basalt-related deposits, situated near the northern tip of the island in the Antsiranana Province (Schwarz *et al.*, 2000) have been on the market. Then a really

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Figure 1: *Map of Madagascar showing location of Vatomandry and Andilamena .*

dramatic impact on the sapphire market was made by the discovery of huge secondary deposits (producing mainly sapphires of different colours, but also some rubies) west and south of the Isalo National Park (Ilakaka, Sakaraha, Ranohira; Schmetzer, 1999).

Compared to sapphire, Madagascar ruby deposits have been of little importance in the past. Some ruby-producing areas have been mentioned in the literature, but none of these had a significant impact on the national or international gem market; these include Gogogogo and Ejeda-Fotadrevo at the south-western tip of the island (Mercier *et al.*, 1999); Tolanaro at the south-eastern edge; Betroka-Ihosy in the central south; Antanifotsy in the central-eastern region (about 100 km south of Antananarivo). Some of these have been 're-discovered' recently, and this applies to the occurrences in the Vatomandry area. Rubies from this region were reported by Lacroix (1922-23) and the area also supplied small quantities of gem-quality rubies in the 1980s (Schmetzer, 1986).

The new finds in the area of Vatomandry (*Figure 1*) and in another region near Andilamena seem to change drastically the ruby situation in Madagascar. Vatomandry is situated about 140 km south of the eastern coastal town Toamasina/Tamatave and ca. 160 km east/south-east of the capital Antananarivo. The mining area (which comprises mostly eluvial deposits) lies about 30 km south-west of Vatomandry (A. Leuenberger, pers. comm., 2001). Andilamena is situated ca. 240 km north-east of Antananarivo. There is no detailed geological information about the ruby host rocks in the two mining areas yet.

The aim of this paper is to present the first gemmological and mineralogical data to characterize the new rubies originating from the Vatomandry area. Their properties are compared to those of rubies from the 'classic'mining areas in Thailand/Cambodia and Myanmar (Burma). Criteria for the separation of Vatomandry rubies from their south-east Asian counterparts are presented.

Market impact

According to trade information, ruby material from at least two new mining areas in Madagascar became known towards the end of 2000. Since January 2001, larger amounts of gem-quality corundum from these two regions, Vatomandry and Andilamena, have been available in Madagascar and quickly reached the Thai markets in Bangkok and Chantaburi. Holewa (2001) states, that from early March to mid-April 2001, Madagascar ruby rough worth more than US$ 60 million entered the Thai market.

Most of the better-quality rubies are reported to come from secondary deposits in the Vatomandry area. Andilamena produces larger amounts of variously coloured sapphires and relatively dark, somewhat brownish rubies. Many samples from this area show well-developed short-prismatic or plate-like habit. However, the Andilamena rubies and sapphires are mostly of cabochon quality. According to preliminary mineralogical and gemmological examinations of several lots of differently coloured samples from this area, Andilamena corundums display a larger variation in their properties.

An interesting aspect of these new sources, especially, in a market that has not yet fully recovered from long discussions regarding topics such as 'heat treatment', 'residues' and 'glass fillings' in rubies, is that a considerable portion of the ruby rough does not require heat treatment. But it may be that a promising opportunity to establish an authentic source of good quality untreated ruby may have been lost for the following reason: the relatively low prices of the Malagasy rough material, and the early good results obtained by the Thai 'ruby cooks' with the new production, led to a situation, 'where now nearly all of the ruby material is heat treated to produce stronger reds' (Holewa, 2001).

Most faceted Vatomandry rubies (*Figure* 2) are in the 0.50 to 2 ct range. Stones from 2 to 3 ct are also common. Larger stones (up to 8 ct) are available, but much rarer. No exact production figures for the Madagascar rubies are available and it is impossible to predict reserves. Whilst some dealers believe that the new ruby finds could have an impact comparable to that of the sapphire occurrences in the Ilakaka region, others are more sceptical.

Materials and Methods

Some samples were purchased from or were made available for research purposes through different Thai/Malagasy companies in Bangkok and Chantaburi. Others came from German and Israeli gem merchants who bought the rubies directly in the Vatomandry area.

The total sample set used for this study consisted of 25 faceted rubies in the 0.50 to 8 ct range (including some top-quality stones) and about 80 rough samples. Some of the latter were 'windowed' (i.e. two parallel faces were polished) to facilitate testing. The sample set covered the whole colour range produced in the Vatomandry area. With the exception of a few stones, the rubies were not heat treated.

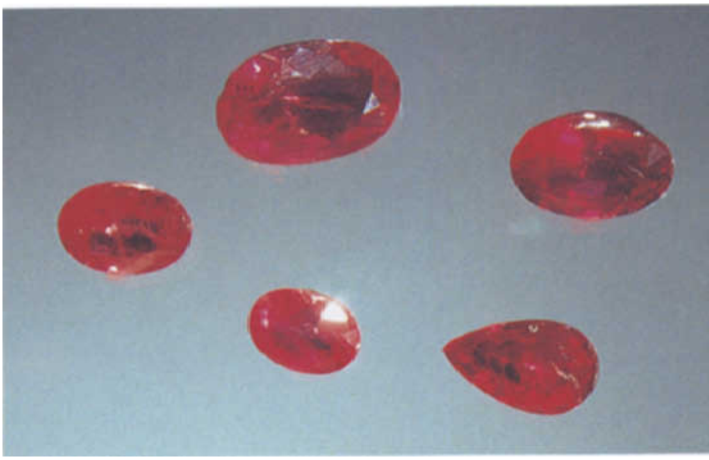


Figure 2: *Faceted rubies from Vatomandry, east Madagascar. Weight of samples ranging from 0.39 to 1.15 ct; the size of the largest ruby is 5 x 7 mm. Photo by M. Glas.*

About 50 samples (all the faceted stones and some 'windowed' material) were tested by standard gemmological methods for optical properties, fluorescence and density. The inclusion features of the total sample set were examined with standard gemmological microscopes and some samples were also examined with a horizontal microscope using an immersion cell. Solid inclusions were identified by laser Raman micro-spectrometry with a Renishaw microprobe. Twenty-five rubies covering the full colour range of the available samples were analysed by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy (see Schwarz *et al.*, 2000). This method furnished also some additional data for the identification of mineral inclusions, intersected at the surface of the corundum host.

Results

Gemmological properties

All the rough samples seen by the authors were variably rolled pebbles with the typical appearance of gem materials from secondary (alluvial or eluvial) deposits. Quality and colour of the Vatomandry rubies (see again

Figure 3: Vatomandry ruby with 'chessboard-like' pattern, caused by twin lamellae forming angles of almost 90°. 40x; photo K. Schmetzer.

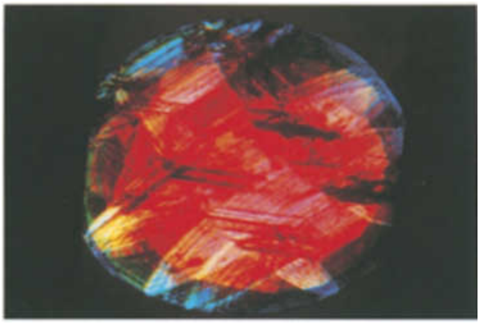


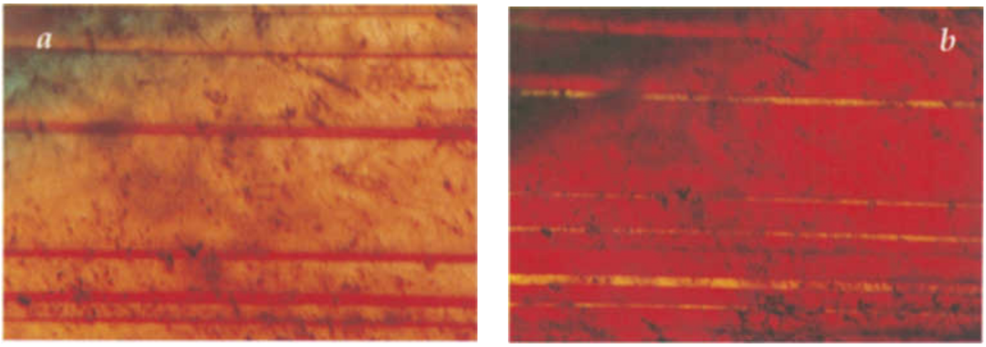
Figure 4: Twin lamellae and 'intersection tubules'. 30x, crossed polarizers; photo K. Schmetzer.

Figure 2) display a pronounced variation from purplish-red to a more pure red, the best being colours comparable to those of Burmese rubies; others looked more like rubies from the Thai/Cambodian border region. Some of the new material has been offered as Burmese or Thai rubies in the Thai trading and cutting centres.

Values for optical properties (n_o, n_e, Δn) and density were found to fall into the range considered typical for rubies from different localities. The fluorescence behaviour shows a distinct variation: most Vatomandry rubies do not show any reaction or only a very weak to weak reddish fluorescence when exposed to short-wave UV-irradiation. Under long-wave UV-irradiation, the red chromium-fluorescence is, generally, weak to medium. In a few stones, however, it was quite strong.

Microscopic properties

Quite common in Vatomandry rubies are twin lamellae, oriented in two directions. Three-dimensional arrangements are rarer. Two sets of twin lamellae result in a 'chessboard-like' pattern with angles that are almost 90° (*Figure* 3). Intersections of sets of lamellae are indicated by tube- or needle-like agglomerations of boehmite particles (*Figure* 4). Twin lamellae and 'intersection tubules' (three sets) in Vatomandry rubies look like those observed in Thai rubies and in corundums from the Umba Valley in Tanzania. Pronounced polysynthetic twin lamellae are quite frequent in Vatomandry rubies and are easily visible when observed in polarized light (*Figure* 5). Rubies with similar inclusions are also known from Sri Lanka.



Figures 5 a and b: *Pronounced polysynthetic twin lamellae, observed in polarized light, in different orientations of the polarizer. 50x. Photos K. Schmetzer.*

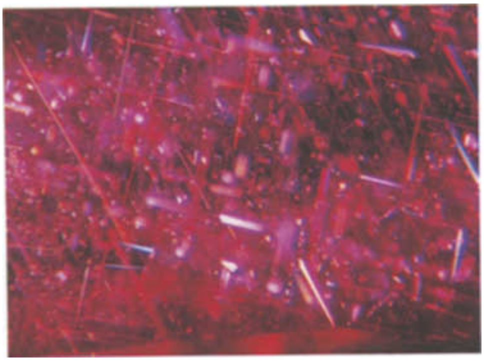


Figure 6: *Rutile inclusions: short needles, elongate plate-like inclusions, and twin crystals. 25x; photo E. Gübelin.*

Figure 7: *Rounded-elongate, dark brown and black opaque rutile crystals, displaying strong lustre. 50x; photo E. Gübelin.*

Growth structures have not been seen, so far, in Vatomandry rubies, and in this respect they resemble Thai/Cambodian rubies, and Umba as well as part of the Ilakaka corundums.

The commonest mineral inclusions in Vatomandry rubies are rutile and zircon. Rutile is present mostly as short needles, and also as twinned or elongate plate-like crystals (*Figure 6*). The rutile needles are generally oriented in three directions in planes perpendicular to the c-axis. The appearance of the rutile inclusions in Vatomandry rubies may be quite similar to that of the rutile needles common in rubies from the Mogok district in Burma. But in contrast to their Burmese counterparts, the Vatomandry rubies do not display any growth zoning and they lack the compact nests or clusters of rutile inclusions in certain parts of the host crystal. In the Vatomandry rubies the distribution of the rutile inclusions is more homogeneous with quite an 'open' structure. In several samples, small, rounded-elongate, transparent orange-brown or black-opaque rutile crystals were observed (*Figure 7*). At the surface, these crystals displayed a metallic lustre.

Another specific inclusion type in Vatomandry rubies consists of typical 'clusters', composed of innumerable small, colourless-transparent or whitish, prismatic or elongated to irregularly rounded, birefringent crystals (*Figures 8* and *9*). Some of these crystals have been identified as zircon, but

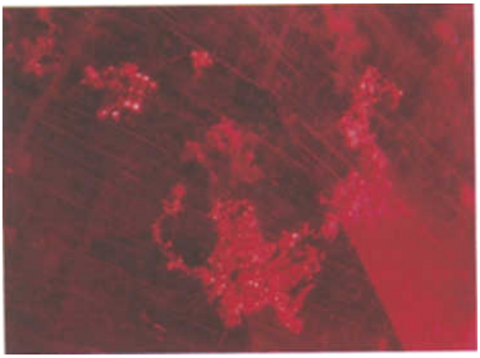


Figure 8: *Small transparent colourless or white prismatic or elongate to irregularly rounded birefringent crystals form a 'zircon cluster'. 66x; photo E. Gübelin.*

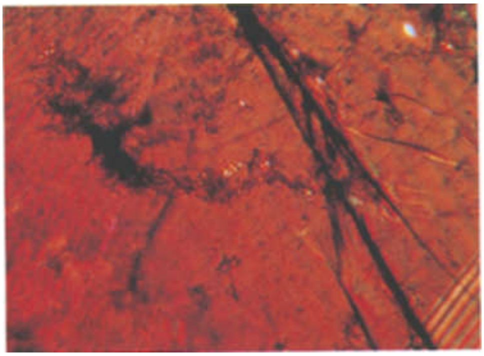


Figure 9: *Small birefringent mineral inclusions, mostly zircons, in a 'zircon cluster'. 60x, crossed polarizers; photo K. Schmetzer.*

Table I: *Trace and minor element concentration in rubies from Madagascar, Thailand and Burma.*

wt. %	*Vatomandry*	*Thailand/Cambodia** *'basalt-related'*	*Mogok (Burma)** *'marble type'*	*Mong Hsu (Burma)** *'marble type'*
Cr_2O_3	0.2–0.8	0.1–1.0	0.1–1.5	0.2–2.0
Fe_2O_3	0.1–0.7	0.3–0.8	bdl–0.05	bdl–0.05
TiO_2	bdl–0.03	0.01–0.05	bdl–0.05	0.01–0.25
V_2O_3	0.005–0.07	bdl–0.01	0.01–0.15	0.03–0.10
Ga_2O_3	0.01–0.02	bdl–0.01	bdl–0.03	bdl–0.015

bdl = below detection limit, about 0.005 wt. %

* based on the data bank of the Gübelin Gem Lab, Lucerne, Switzerland

the presence of other mineral species such as apatite or xenotime is likely. The 'clusters' are, sometimes, accompanied by delicate reflective tension fissures with a mirror-like aspect. Although the appearance of the 'zircon clusters' in the Vatomandry rubies is similar to that in Umba or Ilakaka corundums, the 'clusters' in the Vatomandry rubies are generally distinctly smaller.

In addition to twin lamellae, rutile and 'zircon clusters', a very few larger apatite crystals were also identified in the Vatomandry rubies. They also contain healed fissures, displaying varying patterns, and unhealed, reflective fissures.

Heat treatment

As is well-known from rubies and sapphires from other localities, heat treatment may have a pronounced effect on colour and transparency. Thermal alteration effects (for example changes in the texture of healed fissures, melting or dissolution phenomena) displayed by mineral inclusions allow, in general, the experienced gemmologist to detect an annealed stone, and for most of the Vatomandry rubies that had undergone heat treatment (about 15 samples), the indications of heat treatment were quite clear. However, in a few samples that contained only rutile and/or 'zircon clusters' as inclusions reliable indications of heat treatment were not easy to detect. At least some of the Vatomandry rubies seem to have been heat treated at relatively low temperatures (i.e. below 1450°C), sufficient to remove part of the purplish colour of the samples. In such rubies, the thermal alteration effects suffered by rutile and zircon inclusions may be quite minor and subtle.

Chemical composition

Concentration ranges for chromium, iron, titanium, vanadium, and gallium in 25 rubies from the Vatomandry area, eastern Madagascar, are given in *Table I*. For comparison, the concentration ranges considered typical for the basalt-related rubies from the Thai-Cambodian border region, and for the marble-type Burmese Mogok and Mong Hsu rubies are also listed.

The chromium contents of Vatomandry rubies fall into the range known for gem-quality samples from other important ruby producing localities of different genetic environments. The iron concentration shows a large variation, but is always relatively high (0.1 - 0.7 wt.% Fe_2O_3). In many Vatomandry rubies, iron may reach levels considered typical for basalt-related rubies. Vanadium also shows a considerable variation: in some samples, its concentration is near the detection limit of the analytical method, in others the concentration may be as high as in Mogok or Mong Hsu rubies (up to 0.07 wt.% V_2O_3). The highest titanium concentrations in the Vatomandry rubies are about 0.03 wt.% TiO_2. The gallium contents of Vatomandry rubies are surprisingly uniform in the range of 0.01 - 0.02 wt.% Ga_2O_3.

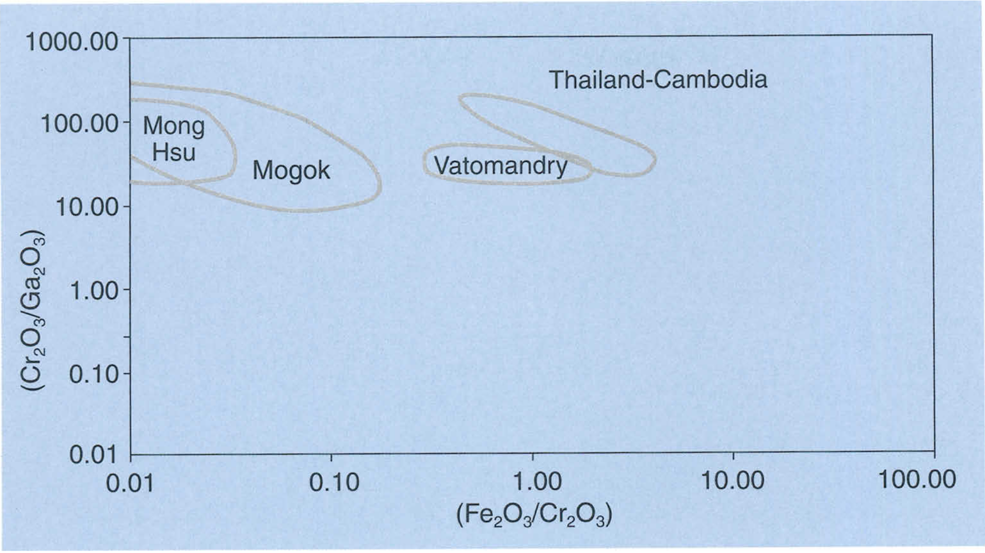


Figure 10: *Correlation diagram of* Cr_2O_3/Ga_2O_3 *versus* Fe_2O_3/Cr_2O_3 *for from Mong Hsu, Mogok, Thailand/Cambodia and Vatomandry.*

The correlation diagram (Cr_2O_3/Ga_2O_3) vs. (Fe_2O_3/Cr_2O_3), shown in *Figure 10*, gives the population fields occupied by rubies from the Burmese mining fields in Mogok and Mong Hsu, the Thai-Cambodian border region, and the Vatomandry area. Mong Hsu rubies fall into a small field, characterized by low Fe_2O_3/Cr_2O_3 ratios (< 0.04). The Mogok field is much larger. It completely overlaps the Mong Hsu field and extends to Fe_2O_3/Cr_2O_3 ratios of ca. 0.2.

Both Vatomandry and Thai/Cambodian rubies display Fe_2O_3/Cr_2O_3 ratios that are distinctly higher than those for Burmese rubies ranging from 0.3 to 2 for Vatomandry, and 0.5 to 5 for Thai/Cambodian rubies. However, the overlap for these two populations is so far quite small.

Discussion

The trace and minor element contents (the so-called 'chemical fingerprinting') and the nature of the inclusions (mainly the so-called 'zircon clusters', short rutile needles and the lack of growth structures), permits a reliable distinction of Vatomandry rubies from their Asian counterparts from the Thai-Cambodian border region and the Mogok and Mong Hsu areas of Burma. Iron contents in the Vatomandry rubies are always considerably higher than those known for Burmese rubies from both, the Mogok and Mong Hsu mining areas. In contrast to the Vatomandry rubies, Burmese rubies commonly display various forms of growth patterns. Compared to the basalt-related Thai/Cambodian rubies, which have consistently low contents of vanadium (up to 0.01 wt. % V_2O_3), most Malagasy rubies contain more than 0.02 wt. % V_2O_3 and this is valuable for the separation of these stones from Thai/Cambodian rubies. However, Vatomandry rubies can best be distinguished from Thai/Cambodian rubies by their inclusion features: Thai rubies have no rutile inclusions or 'zircon clusters', and some of the typical Thai inclusion features (for example, different minerals or negative crystals, accompanied by 'rosette-like' healed fissures, or thin primary two-phase fluid films) have not been observed in the Vatomandry samples.

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A discussion on the origin of irregular shapes of type II diamonds

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ABSTRACT: Natural type II diamonds are characterized by their irregular shapes, which are very different from the generally observed octahedral or rounded dodecahedral morphologies of type I diamonds. Daily sorting of type II rough diamonds has been empirically based on this morphological characteristic. The reason why type II diamonds exhibit such an irregular morphology is simple. They are not as-grown crystals, but are the result of crystals fractured during their ascent in magmas. Type II diamonds are much purer with much smaller contents of nitrogen than type I diamonds, making them plastically much weaker than type I. When both type I and type II diamonds experienced similar amounts of stress while being transported from the depths to the surface of the Earth, only type II diamonds were plastically deformed and further fractured into pieces, while type I diamonds retained their original as-grown morphology.

Introduction

Moses *et al.* (1999) have recently reported that more than 80% of GE POL diamonds were fancy cut brilliants, although they gave no explanation as to why this is so. If enhancement of colour grade by HPHT treatment could be realised on any type of natural diamond crystal, this statistic would sound odd. We should expect a much higher proportion of round brilliant cuts, since octahedral or rounded dodecahedral morphologies suitable for the round brilliant cut are more commonly encountered in natural diamond populations. The statistics imply that the rough stones used for HPHT treatment to realize enhancement of colour grade are limited to a particular type of natural diamond, more than 80% of which should have flattened or irregular shapes. It is now well known that only type IIa diamonds can be used to produce GE POL diamonds, as discussed in recent papers by Moses *et al.* (1999), Schmetzer (1999) and Smith *et al.* (2000).

It has been empirically known among diamond sorters that unlike type I diamonds, type II diamonds occur in very irregular or flattened shapes, and do not show crystallographic faces (Wilks and Wilks, 1991). This morphological characteristic has been used as a criterion in the daily sorting of rough diamonds, and this empirical procedure has been proved to be reliable by UV transmission or IR absorption investigations.

The origin of irregular shapes of type II diamonds has been a subject of arguments. Wilks and Wilks (1991) summarized the proposed origins as follows:

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1. the irregular shapes are due to fracture either (a) in the earth at some time in the earlier history of diamond formation or (b) during mining and extraction;
2. variation in rates of dissolution of diamond in the surrounding magma;
3. determined by the contours of the surrounding rocks while diamonds were growng in the interstices of solidified minerals; and
4. octahedral faces can appear due to the presence of nitrogen as an impurity element which affected the growth rates of {111} faces.

The argument (4) considers that type I diamonds contain nitrogen as an impurity which suppressed the normal growth rate of octahedral faces and thus type I diamond crystals exclusively develop as octahedral habit, whereas type II diamonds are much purer containing no impurity nitrogen, and thus they may take any form and not necessarily the octahedral one. It is perhaps fair to state that no conclusive explanation has so far been given to answer why type II diamonds take irregular shapes, while type I diamonds take octahedral or rounded dodecahedral shapes.

In this paper, it is intended to discuss the problem, and to put forward an answer, based on an understanding of growth morphology of crystals in general, and of observations on collections of type II diamonds and their X-ray topographs.

Morphology and internal strain of type II diamond

Morphology

Figure 1 shows a few examples of rough stones grouped as type II. Neither octahedral, rounded dodecahedral nor cuboid forms are encountered. All the crystals are irregular or flattened shapes, showing no crystallographic flat faces. Even when somewhat flattened surfaces are present (see for example *Figure 1 D,E*), they are not crystallographically flat faces, and do not show surface morphological characteristics commonly observed on natural {111} or rounded dodecahedral faces, such as trigons, network ditches, superimposed ring patterns (dissolution features), and growth hillocks (growth features) (Sunagawa, 1984). However, it is commonly observed that the surfaces are rounded or mottled (see for example *Figure 1 A,B,C*), indicating that dissolution took place after an initial irregular shape was formed. Another characteristic of gem quality type II rough is that the majority of stones are colourless, and only a small fraction are tinted brown. The proportion of brown tinted stones of type II in industrial diamonds is reported to be much higher than this (Wilks and Wilks, 1991). This difference in the proportions of pale brown stones between gem quality and industrial stones is attributed to the fact that the stones had already been sorted into gem and industrial categories. The brown coloration is probably due to point defects associated with dislocation induced by plastic deformation.

Internal strain

It has been well known for some time that type II diamonds are more heavily strained than type I diamonds. They show under polarized light anomalous birefringence and the so-called tatami-mat patterns (Takagi and Lang, 1964), which are not seen in type I diamonds. Tatami-mat patterns are easily detectable under crossed polarizers, and have been explained as due to crossing slip lines induced by plastic deformation.

X-ray topography is a well-established powerful method to investigate spatial distribution of lattice defects and strains in nearly perfect crystals. Extensive X-ray topographic investigations have been carried out on natural and synthetic diamonds, see for example Lang (1965). Most X-ray topographs of diamond crystals reported so far are of type I diamonds, which typically show dislocation bundles radiating from a centre nearly perpendicularly to {111} faces. Far fewer X-ray topographs have been reported from type II diamonds.

Figure 1: *Examples showing irregular shapes of type II natural diamonds. A-C from the DTC Research Centre collection, magnification ca. 5-10x photomicrographs. To secure better views of surface features, combined illumination was used, which resulted in the appearance of brown tinted stones, B, C, being darker than they really are. D and E are from the DTC Sorting Room collection, macrophotographs, ca. 2x.*

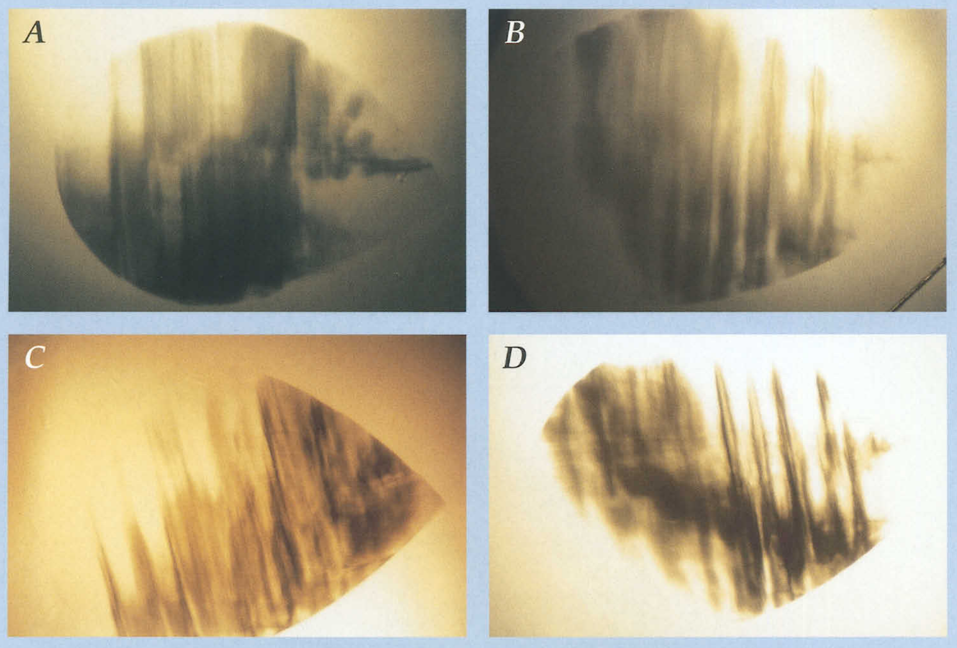

Figure 2: Examples of X-ray topographs of type II diamond. A and B after HPHT treatment, C and D before treatment of the same pear-shaped brilliant. Topographs were taken by Mr T. Kikuchi; Mo target, 50 kV, 10 mA. Focus size 0.4 mm H x 0.8 mm W. By courtesy of GAAJ.

At the request of GAAJ, X-ray topographs were taken by Mr T. Kikuchi, Analytical Laboratory of Rigaku-Denki Co., Akishima, Tokyo, of a pear-shaped brilliant cut type II diamond, both after (A, B) and before (C, D) High Pressure High Temperature (HPHT) treatment. These are shown in *Figure 2*. The X-ray topographic images before and after HPHT treatment show no essential difference. In addition, four type II diamonds have been investigated by X-ray topography to investigate changes in perfection before and after HPHT treatment. All five stones examined indicate no significant change in their X-ray topographs after HPHT treatment. They show contrasting images of properly diffracted areas juxtaposed with areas of poor diffraction. The properly diffracted areas show parallel contrast images, whereas the poorly diffracted areas show no contrast. This indicates that the stone is not a perfect single crystal throughout, but consists of mutually bent (inclined or twisted) domains. Parallel contrast lines represent slip lines, due to plastic deformation, and not growth-induced dislocations. The stones, both before and after HPHT treatments, are so highly deformed that the growth-induced dislocations, like dislocation bundles and growth banding are not discernible. In this respect, type II diamonds are markedly different from type I diamonds.

To confirm the validity of this observation, the present author investigated a stock of X-ray topographs of type II diamonds in the DTC Research Centre and confirmed the above observation to be generally applicable. Type II diamonds usually show X-ray topographic images characteristic of heavily distorted or strained crystals. We therefore can conclude that type II diamonds are plastically more deformed than type I diamonds. This is perhaps the reason why less X-ray topography has been reported so far on type II diamonds. Any interesting information relating to crystal perfection and homogeneity, growth morphology, or the growth history of the crystals is disguised by the deformation.

Discussion

Morphology

Growth morphologies of crystals are determined both by internal structural factors and by external factors affecting growth parameters (phases, solute-solvent interaction energies, impurities, driving forces, temperatures, pressure, etc., see Sunagawa, 1987). Much work has been done in the last 200 years to understand theoretically and experimentally how growth and/or dissolution morphologies of crystals are determined. Assuming that the morphology of polyhedral crystals is determined purely by internal factors, and entirely neglecting the effect of external factors , we may deduce a structural or an abstracted morphology of a polyhedral crystal which can be used as a criterion to analyse the effect of external factors on the morphology of polyhedral crystals. Along this line of reasoning, various models have been put forward (see for example Sunagawa, 1987), among which Hartman-Perdok's PBC analysis (Hartman and Perdok, 1955, and also Hartman, 1987) has been most widely accepted. In this model, crystal faces are classified into three types depending on the number of Periodic Bond Chains (PBC) present in different faces. A face containing more than 2 PBCs is called an F (Flat) face, which can develop as a large habit-controlling face. An F-face is an atomically smooth interface, on which growth proceeds through two-dimensional spreading of growth layers parallel to the interface. In other words, an F-face grows either by a two-dimensional nucleation growth mechanism or by a spiral growth mechanism, and thus can develop into a large habit-controlling face. A face containing only one PBC is called an S(Stepped)-face, while a face containing no PBCs is a K(Kinked)-face. These two faces are atomically rough interfaces. The growth of S and K faces is, therefore, not due to two-dimensional spreading of growth layers, nor is it due to spiral growth, but takes place through addition of chains (S face) or growth units (K face). It follows from this that K faces will not appear, and S faces will only develop to a small extent, if at all, on polyhedral crystals. S and K faces cannot be habit-controlling faces. Only when their interface structures are modified by some external factor, which transforms the S or K to an F face, can they develop significantly.

From the diamond structure, we see that the {111} face is the only F face on which growth layers can develop, leading to the well developed, habit-controlling octahedral face. The {110} and {100} faces are S and K faces respectively on which two-dimensional nucleation growth or spiral growth are not expected. Diamond crystals will, therefore, take a simple octahedral habit bounded by flat {111} faces, probably associated with narrow striated {110} but not {100} faces, when they grow under near-equilibrium conditions and with no effects from external factors to modify their interface structures.

This morphology is indeed the morphology of many natural diamond crystals, and single crystalline diamonds are the main source of gem-quality rough stones. Although natural diamond crystals are usually rounded, due to dissolution processes experienced during ascent from depth to the surface of the Earth, we may assume that the as-grown morphology of natural diamond polyhedral crystals is octahedral. It has been well established through surface microtopographic observations of cuboid faces (Sunagawa, 1984) and X-ray topographic investigations of growth banding in {100} growth sectors which display the centre cross pattern (Lang, 1965), that the {100} interface always behaves as a rough interface in natural crystallization. There have been no reliable observations showing that {100} behaves as a smooth interface. We never see natural diamonds with a cubic habit, on whose {100} faces growth layers are observable. It is clear that in natural diamond growth, only {111} behaves as a smooth interface, and {100} exclusively behaves as a rough interface (Sunagawa, 1984). Isotropically rounded or irregular forms cannot be expected as growth forms of single crystalline diamonds when they grow in nature under near equilibrium conditions. Such forms may be expected for polycrystalline aggregates of diamond, but not for single crystals (Sunagawa, 1984; 1995). It is evident from this that the octahedral habit is a morphology of diamond crystals which is to be expected from the structural considerations and is not a function of the effect of nitrogen impurity. We therefore exclude the argument (4) as a possible origin of the octahedral habit of type I diamond. We can also exclude the argument (3) which says that irregular shapes of type II diamonds are determined by the contours of surrounding rocks, because natural diamonds grow in magma or in a liquid droplet formed by partial melting in high pressure metamorphic rocks, and not by solid state crystallization (Sunagawa, 1984).

If interface roughness is modified for some reason, and an S or K face transforms to an F face, {110} or {100} faces can develop as habit-controlling faces, in addition to the {111} face. Among various external factors which have been suggested as candidates to modify the habit of polyhedral crystals, impurities and solvents are particularly important, since these may newly introduce or break PBCs and modify the interface structure. We have already demonstrated that only the {111} face behaves as a smooth F face, that {110} is an S face and {100} is a K face in the crystallization of natural diamonds grown in magma, or silicate solution, where silicate (or oxygen) is the solvent. Modification or reconstruction of interface structure is not expected to take place in this solvent. In contrast to this, HPHT synthetic diamonds grown in metallic or alloy solution take a cubo-octahedral habit, bounded by flat {111} and {100} faces, on both of which growth spirals may be observed (Sunagawa, 1984, 1995). This implies that in metallic solution, not only {111} but also {100} behave as smooth interfaces, enabling spiral growth to take place on both, resulting in the appearance of a cubo-octahedral habit. There is a clear difference in solute-solvent interaction energies between silicate and metallic solutions, which will modify the interface roughness.

In both natural and synthetic growth environments, when diamond grows under near equilibrium conditions, polyhedral crystals bounded by crystallographic faces are generated and neither spherical nor irregular forms are expected. This is due to anisotropy inherent in the structure, as already explained in terms of F, S and K faces, and smooth and rough interfaces. The {111} face is the only face on which two dimensional nucleation growth or the spiral growth mechanism operates (which therefore develops well in natural diamond formation), whereas {100} behaves as a rough interface, on which neither growth layers nor spirals develop. In HPHT synthetic diamond formation, both {111} and {100} behave as smooth interfaces, and grow by the spiral growth mechanism. Arguments that the irregular shapes of type II diamond are due to chemical purity, and that the octahedral habit of type I is due to the effect of impurity nitrogen do not make sense. Polyhedral crystals of both types of natural diamond should take an octahedral habit, irrespective of the presence or absence of nitrogen, or the difference between types I and II. High partitioning of nitrogen in type I diamonds is a result of selective and directional element partitioning in different growth sectors through the growth processes, and cannot be the cause of the octahedral habit of type I diamond. We therefore have to search for another reason for the origin of the irregular forms of type II diamonds.

Stress

It has been well established that pure metals are plastically much weaker than alloys, and that this is due to the presence of precipitated (exsolved) impurities which act as obstacles to dislocation movement. A representative example is duralumin, an aluminium alloy containing less than 2% Cu. The impurity Cu forms platy precipitates in crystallographic orientations, which act as obstacles to dislocation movement. Duralumin is much harder than aluminium metal. When pure aluminium and duralumin receive the same amount of stress, aluminium deforms plastically at much lower temperatures than duralumin. Plastically highly deformed materials are more likely to be fractured into pieces than plastically less deformed ones, as they are closer to the plastic limit and fracturing occurs beyond that. By analogy, type II diamonds correspond to pure aluminium, and type I to duralumin. When both types of diamond crystals receive the same amount of stress, type II will be plastically deformed, and even broken into pieces by fracture due to extended deformation, while type I crystals maintain their original as-grown morphology.

Anomalous birefringence, the tatami-mat pattern and X-ray topographic features characteristic of type II natural diamond crystals, which are not seen in type I are all evidence to support the idea that type II diamonds are more heavily plastically deformed than type I. It is likely that type I and type II diamonds experienced similar amounts of stress during transport to the Earth's surface by kimberlite or lamproite magma, but only type II crystals responded and demonstrate the plastic deformation, because they are purer than type I crystals. In such conditions, the plastically deformed type II diamonds are more likely to be fractured than the less deformed type I diamonds. And it is also likely that fracturing took place during ascent and not much later during the mining operation. Readers may argue that if type II diamonds are fractured pieces, there should be cleavage flakes, with flat {111} cleavage surfaces, and not irregular shapes. Indeed flat shapes are commonly encountered among type II diamonds, but the equally common irregular shapes can also be accounted for if we take into consideration that many type II diamonds are plastically deformed and composed of mutually inclined or twisted domains.

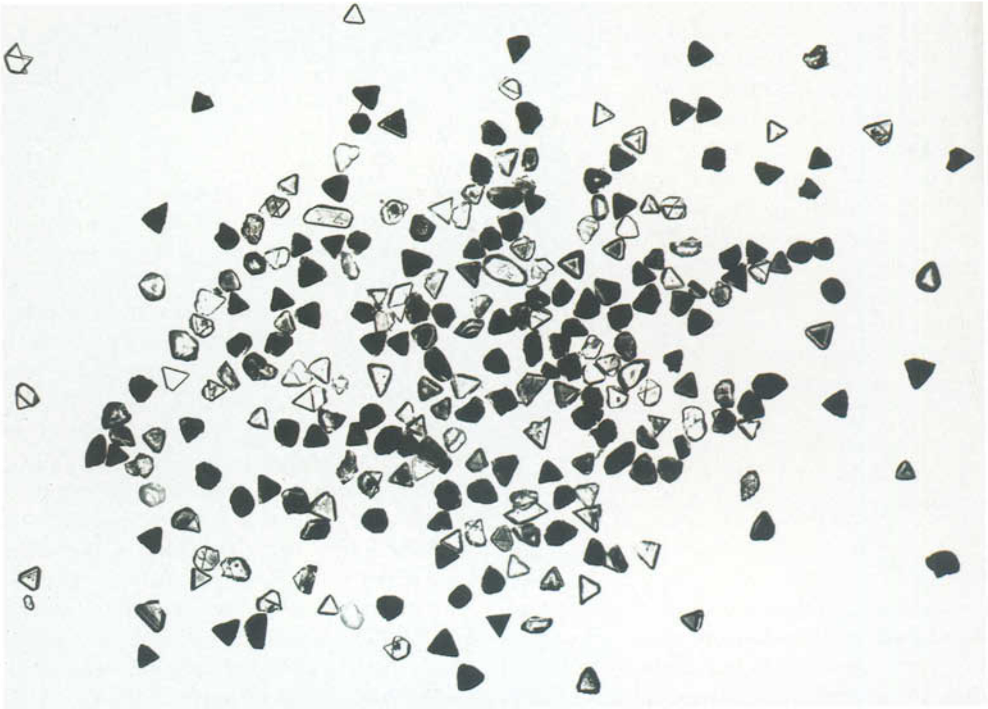

Figure 3: *Positive image of micro-diamonds on a photographic plate under UV irradiation of $\lambda = 2537\text{Å}$ Black images correspond to type I, transparent ones to type II, and grey crystals composed of types I and II. Magnification x4. No essential difference in morphology is noted between type I and II crystals. Reproduced from Figure 1 of Tolansky and Komatsu, (1967). By courtesy of Prof. H. Komatsu.*

It follows from these arguments that the irregular shapes of type II diamonds do not represent their original as-grown morphology. Although the present shapes are irregular, the original as-grown morphology of type II must be octahedral, similar to that of type I diamonds. This is clearly seen in Figure 1 of Tolansky and Komatsu's paper (1967) where a much higher population of type II diamond in micro-diamonds than in larger diamonds was reported. They observed UV transmission at λ =2537 Å of a sample of micro-diamonds averaging 0.0015 ct (0.8-1.2 mm across), and reported that 16% were completely transparent to UV (i.e. type II), 27% were completely absorbent (i.e. type I), and the remainder transmitted UV partially. The photograph, which is reproduced as *Figure 3* in this paper, clearly shows that type I and II mostly have a good octahedral habit, and that there is no essential difference in morphologies between the two types.

For larger crystals, type II diamonds are too heavily strained to detect and visualize any original as-grown features, such as growth zoning, or radiating dislocation bundles under polarizing microscopy or by X-ray topography. They are also too pure to detect growth zoning by cathodoluminescence. Since features due to plasic deformation are superimposed on growth-induced original features, it is not easy to obtain convincing evidence in larger stones to prove that the original as-grown morphology of type II diamonds was octahedral and the same as that of type I. What we can say definitely is that the present irregular shapes of type II diamonds do not represent the original as-grown form, but the form of fractured pieces.

Dissolution

Surfaces of irregular shapes of type II diamonds are neither flat, nor shiny. They are wavy and mottled. These features indicate that the irregularly shaped fragments were subject to partial dissolution. The argument (2) which suggests that the irregular shapes of type II diamonds are due to variation in dissolution rates in the surrounding magma is not acceptable, since a very anisotropic (and highly unlikely) oxygen fugacity distribution in the magma around a crystal would have to be assumed to account for transformation from a roughly equant near-octahedron to an irregular shape.

Concluding Remarks

It has been demonstrated that the irregular shapes typically shown by type II diamonds are likely to be the result of plastic deformation and fracturing into pieces, while type I crystals retained their original as-grown octahedral morphology and size. Plastic deformation and fracturing probably took place during transportation from the depths to the surface of the Earth. After having been fractured, type II diamonds were present in the ascending magma together with unfractured type I diamonds, and both were similarly subject to partial dissolution. Fracturing is not due to later mining operations.

Moses *et al.* (1999) and Smith *et al.* (2000) reported that the HPHT-treated GE POL diamonds show strong anomalous birefringence colours under cross polarized light. The same optical characteristics may also be exhibited by untreated type II diamonds so a simple qualitative observation of birefringence may therefore not be used as a diagnostic feature in distinguishing between HPHT-treated and untreated type II diamonds. GE POL treatment is applied to irregularly shaped type II brown tinted stones. This is the reason that more than 80% of GE POL are fancy cut stones. In subjecting type II diamonds to HPHT treatment, additional stress is applied to already deformed stones, and the resultant plastic deformation is superimposed. The treatment, in a sense, is more of the same kind of deformation and makes it more difficult to distinguish between natural type II and GE POL stones. However, there must be a way to distinguish between naturally experienced and artificially applied stress through study of their resultant features. To quantitatively investigate the difference in birefringent features between treated and untreated type II diamonds will be an interesting future subject of study.

Acknowledgements

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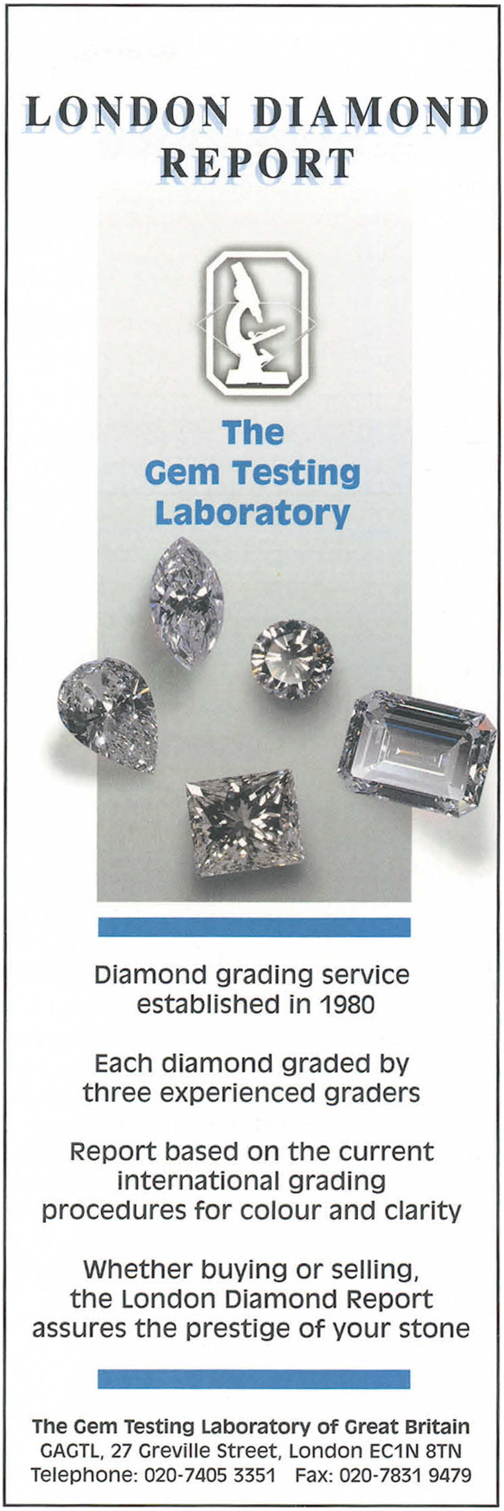

Disclose, describe, dress-up, disguise, deceive . . . credibility and gem descriptions

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ABSTRACT: Terminology used in the gem and jewellery industry at the end of the twentieth century is discussed. Distinction is made between a statement of identification and advertising. A comparison is made of differing wording, euphemisms and jargon used in purported disclosure statements. Propriety of language is examined from the perspective of a gemmologist's responsibilities.

Keywords: disclosure, origin, condition, synthetic, treated, natural.

Introduction

There is a credibility gap in the gem and jewellery industry regarding disclosure of gem origins and treatments. The industry's reputation is compromised each time someone buys something and later learns it is not what they thought it is and is of less value than they were led to believe!

Public confidence can be increased by a point-of-sale disclosure. Many retailers now use accompanying documentation such as a laboratory report, a certificate of authenticity or a valuation certificate, as a means of public disclosure (and selling tool). But disclosure is only good when it avoids misunderstanding. Misunderstanding damages reputations as easily as misrepresentation. It is only human to try and gloss over defects, and this is often done using euphemism or jargon with, perhaps, a disclaimer: "The opinions expressed here represent the opinions of the author and do not necessarily represent the opinions of those who hold other opinions."(i) The gemstone industry is about as international as any industry can possibly be. Rules and regulations vary significantly between jurisdictions; so rather than consider regulations, let us discuss proprieties and when and how they should be applied.

Then and now

Years ago, when synthetic gems first appeared, the question "Is it natural?" in reference to a gemstone was understandably presumed to be a request for information about origin. It was assumed that the full query the questioner intended was "Is it of natural origin or is it man-made?" Basil Anderson's concern was "...namely, is the stone natural or synthetic?"(ii) and Robert Shipley's definition was "natural stone. A stone that occurs in nature; as distinguished from a man-made substitute..."(iii). Over the years, the situation has changed and public knowledge about treatments applied to gems has caused the issue of condition also to become a significant concern.

Nowadays, someone looking at a D colour diamond might similarly ask "Is it natural?" in a request for information about condition. In this case, it would be assumed the full query the questioner intended was

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"Is it natural, or high temperature/high pressure (HPHT[(iv)]) treated?" The same question in reference to an expensive ruby would sensibly be presumed to be requesting information about both origin and condition. The full query intended for the ruby would be "Is it natural or synthetic in origin, or have its properties been altered by a treatment?"

Unfortunately, old habits die hard. Much literature and even course materials speak of 'natural ruby' or 'natural emerald' in contexts where synthetic alternatives are not specified. In each case, the unstated presumption is that only origin is being addressed by the adjective. This unstated presumption, appropriate in a context when identification of synthetic material was the only issue, has induced many in the trade to consider the word 'natural' as jargon unique to the gem industry with the narrow meaning 'neither synthetic in origin nor a man-made substitute'.

The example of the D-colour diamond makes it clear that the adjective 'natural' is context-sensitive as far as limiting presumptions are concerned. We are now in a situation where changes in technology have produced a case within the industry where a widely accepted standard limiting presumption (that gave rise to a jargon label) is refuted by a contrary presumption. In the modern context it is clear to knowledgeable people in the trade that, contrary to the 1940's presumption of what was significant, the possibility of HPHT treatment makes the D colour suspect and condition is the germane point, not origin. Let us examine the issue of jargon.

Jargon

Jargon is terminology peculiar to a particular job or to a field of study. Jargon may be words or phrases that do not exist outside the field, or may use words that exist elsewhere but which have a field-specific narrow meaning.

The purpose of jargon may be one or more of several:

1. to label a concept that does not exist outside the specialized field;
2. as coded communication to limit information to those within a field;
3. for comfortable communication between peers in a field;
4. as 'bafflegab' to impress people outside the specialized field.

An example of jargon, where a specialized field gives a word a meaning that differs markedly from the day-to-day usage, is the word 'form'. This word has a very particular narrow meaning in crystallography. Novice crystallography students may misunderstand 'form' to mean shape, but in this field it is a jargon label that represents a concept so narrow in meaning as to not have a label in ordinary conversation. A crystallographic form is the complete assemblage of all faces required by the symmetry when one face is given. In this example the jargon clearly serves the first purpose, helping clarify basic concepts.

The word 'natural', as gem industry jargon meaning 'not synthetic in origin', is clearly used for a different purpose; originally probably point 3 above. The first purpose cannot be justified because the concept certainly does exist outside the field of gems and jewellery. This and other jargon as well as euphemisms being used in documents purporting to be statements of disclosure are often used for purpose 2, an internal code that limits information about condition.

The five Ds

In the marketing of gemstones, the consumer may encounter declarations serving various functions for vendors. From the perspective of the final consumer, the five declaration Ds in decreasing order of desirability are: disclose, describe, dress-up, disguise and deceive.

More often than not, arms-length disclosure documents are commissioned by prospective vendors of the subject item(s). Vendors are particularly interested in using such documents as selling tools. Other writing that a vendor may commission to assist in marketing would include advertising copy. A gemmologist should be able to accept either (or both) of these commissions. Difficulty develops, however, when no distinction is made between the two different sets of requirements. The limits as to what should be said differ in each case.

Concern has been expressed that tight restrictions on how gems may be described limit the ability of vendors to 'romance the stone'. There is a difference between selling the steak and selling the sizzle. Anyone who has done the slightest bit of marketing knows that history, mystery, romance and intrigue can greatly increase desirability of a gem. Problems arise from not discriminating between an identification statement and selling the sizzle. Failing to recognize adjectives or jargon that could be misleading to the public can exacerbate difficulties.

The phrase 'diffusion-treated natural sapphire' has been offered as an identification statement suitable for lab certificates or valuations. Proponents of the terminology would claim that 'diffusion-treated' is a full and complete disclosure of how the material's properties have been altered by human intervention, and that 'natural sapphire' is a full and complete disclosure of the origin of the material to which the treatment was applied. There have been cases of diffusion treatment having been applied to synthetic material, and the full disclosure statement for such material would be 'diffusion-treated synthetic sapphire', to which even detractors of the 'treated natural' terminology would agree.

Proponents would point out that an unscrupulous person might misleadingly employ partial disclosure using the phrase 'diffusion-treated sapphire', where the disclosure of the treatment is provided while information about the origin of the material to which the treatment was applied is intentionally omitted because it was synthetic. By specifying the treatment process and confirming the natural origin of the material that was treated, they claim to be acting in the best interest of the consumer. They readily admit that a description emphasizing natural origin makes the subject material easier for vendors to sell. They suggest that, rather than detracting from their arguments, this is a positive thing. They would say that this terminology is good for both the consumer and the trade.

To paraphrase the proponent's argument, "Because some people may lie by omission, we should be able to use the adjective 'natural' to describe this treated product". Does a claim that others might cheat validate using language that some might consider misleading?

If a colourless stone that underwent diffusion treatment had chromium added instead of titanium and iron, would proponents of '... treated natural ...' terminology speak of 'ruby-colour diffusion-treated natural sapphire'? Of course not! Vendors would never market a red corundum as a sapphire, but the raw material that was treated could never have been called ruby. This makes it clear that the intent of the language is to mislead, not inform. The ordinary person, lulled into a purchase by the word 'natural', is likely to be grievously disappointed when apprised of the true situation and unimpressed that the raw material to which the treatment was applied was not synthetic!

The American Gem Trade Association (AGTA) gem identification certificate indicates the extensiveness of treatment present in stones that are identified as ëenhanced naturalí and 'treated natural' with additional qualifying adjectives. The Director of the AGTA Laboratory said "... For the moment, I am happy with using the word Natural for enhanced stones providing that the enhancement is declared."(v)

The Gemological Institute of America (GIA) Emerald Report classifies degrees of enhancement while saying **"Conclusion – NATURAL EMERALD"**, in bold print in the centre of the document surrounded by lots of white space. When the issue of inappropriate use of 'natural' was raised(vi), a GIA Gem Trade Lab spokesman responded, "... we feel his interpretation of the word 'natural' is too strict."(vii)

The Thai Gem and Jewelry Traders Association's 'Ruby Disclosure System'[(viii)] included three categories:

Category A, Natural Ruby

> Defined as "The ruby has been enhanced by heat, but at 10x magnification no residue from the heating process is visible on or within the stone."

Category B, Heat Enhanced Natural Ruby

> Defined as "The ruby has been enhanced by heat, and at 10x magnification residue from the heating process is visible within the stone."

Category C, Heat Treated Natural Ruby with Foreign Substances Present

> Defined as "The ruby has been enhanced by heat, and at 10x magnification residue from the heating process is visible on the surface of the stone as well as within the stone."

By these definitions, a ruby with obvious evidence of heat treatment (heat-altered inclusions) would qualify as natural ruby without any further comment as long as there was no evidence of glass or other foreign residue in the stone. This 'disclosure' system does recognize the existence of what in normal conversation would be called natural ruby by the added *sub-Category A, Unheated Natural Ruby*, which is a curious convolution in logic to require addition of a modifying adjective for the word *natural* to have its real meaning.

One argument supporting the use of jargon says that all gemstones have been cut and polished. This processing of gems keeps any of them from qualifying as natural. To counter that, it may be observed that cutting someone's hair does not preclude it from being termed natural because cutting of hair, to make it easier to wear and to show it to best advantage, is entirely expected. It is also entirely expected that most gems will be cut to make them easier to wear and show them off to their best advantage. Cut untreated gems are natural gems. Uncut untreated material is natural rough or natural mineral. Uncut untreated crystals are natural crystals.

To identify a lady's stone as 'enhanced natural emerald' is at best inappropriate jargon romancing the stone, and at worst a deliberate attempt to mislead. The euphemism 'enhanced' does not have the same meaning outside the gem industry as the adjective 'treated' and the adjective 'natural' means far more to the average person than 'not synthetic'. She may believe that the identification statement confirms that accompanying diamonds enhance the beauty of her natural condition/natural origin emerald. Such jargon may be considered the norm by some, but it's a sad thing when those of good will blindly accept a self-serving 'norm' as the standard. Inappropriate use of the (unnecessary) jargon reflects the power of the adjective 'natural' as a selling tool, but it is misleading and a disservice to the entire industry. The only place for internal jargon is inside the industry, not to those outside the industry who can't be expected to understand it!

Of course, the word 'natural' can correctly apply in a more limited way when it is referring to one property of an object rather than to the object itself. Examples are the natural origin of a ruby that has been heat treated, or the natural colour of a cultured black pearl. Those examples should not be called 'natural ruby' or 'natural pearl' because it's only one aspect of each that is natural, not the entire stone. When we mean natural origin, we should say exactly that, not 'natural emerald'!

Let's 'get real'

From a perspective sometimes ascribed to the purist "... when a stone is sold as ... sapphire that term alone is sufficient ..."[(ix)], the name of any gemstone when used without qualification should always mean the genuine article, not an imitation or synthetic gem. If any material originated in nature and has had none of its properties altered by man, then the unqualified name of that material is sufficient and complete to identify it and the adjective 'natural' would be accurate but entirely redundant. If the origin of the material is not natural, the material's name should be modified by an adjective such as 'synthetic'.

A material that originated in nature and which shows evidence of, or is known to have had, properties altered by man should be identified by the name of that material in equal prominence with the name of the process that altered its properties.

The International Jewellery Confederation (CIBJO) rules in their 1997 *Blue Book* required accurate identification of gemstones and delineated a number of treatments that specifically required disclosure. CIBJO uses the word 'natural' in its everyday meaning, and doesn't suggest anyone should use it as part of the description of a treated stone.

The *Gemstone Enhancement & Man-Made Product Information Guide* was developed by representatives of the American Gem Society, American Gem Trade Association, Jewelers of America, Jeweler's Vigilance Committee, and Manufacturing Jewelers and Silversmiths of America, in 1987. It offered a concise, accurate system for disclosure using letters of the alphabet as symbols to indicate the general frequency of occurrence of enhancement (or the warranted lack of enhancement) and, if enhanced, the specific method of enhancement used. It avoided using the term 'natural' and defined the symbol 'N' to mean 'has Not been enhanced' rather than natural.

Conclusions

Most countries have laws against misleading advertising, usually backed by serious penalties. In Canada, guidelines adopted by the Government in 1994[(x)] specifically state that it is a misuse of terminology to use the term 'natural' for anything that has undergone any treatment or enhancement. By these rules, descriptions such as those discussed earlier are clearly misleading.

Overstating quality or misrepresenting condition is not a prerequisite to successful competition in the market place. There is nothing wrong with romancing a stone in the selling process, a bit of artistic licence is to be expected in advertising. There's no reason why advertising copy cannot include redundant adjectives, fanciful expressions and seductive language. But gemmologists worth their salt should understand two things. Artistic licence is not a licence to mislead, and the romancing should be entirely separate from any identification statement.

When commissioned to produce a 'disclosure document', as a gemmologist one should consider that the job is to disclose and describe. When commissioned to write advertising copy, the job as a wordsmith is to describe and dress-up. A gemmology background here helps us to understand the product and avoid misrepresentation.

A statement of identification (including disclosures) should be factual. To be accurate it needs to include all known or reasonably presumed information about both origin and treatments. The identification must be accurate and unadorned. Dressing it up with superfluous or misleading adjectives, jargon, or euphemisms is entirely counterproductive.

Critical analysis of wording used in the identification of goods offered for sale allows us to recognize intentional manipulation of the language. When producing an official record of expert opinion that may be used as a 'disclosure document', it is an important responsibility of the gemmologist to exert due diligence and integrity as an expert and present information clearly and concisely with content and format that, as much as possible, precludes anyone misrepresenting the expert opinion to a third party.

An easier approach to avoid innocently adopting misleading words and phrases is to choose, and consistently follow, strict rules that have been carefully crafted to protect the final consumer. Strict rules may yield small improvements by coercing some of the unscrupulous away from fraud, but integrity cannot be forced on anyone. Rules are much more useful for guiding those of good will. The public can rely on the integrity of those who follow strict rules.

There are sensible rules laid out by people of integrity even though the unscrupulous may evade or ignore them. The key to earning credibility lies in being seen to be forthright and truthful in identifying the goods we sell. In deciding what to say in the identification section of any communication, it helps to put oneself in the shoes of the ultimate consumer and try to see things from their point of view. We, as individuals, must be vigilant at recognizing and avoiding deceptive language and be consistent in following strict rules. When we romance the stone we should remember the five Ds and disdain to disguise and deceive.

References

i. This disclaimer, used (with the plural 'authors') in letters to the editor columns *(AIR vents) of Annals of Improbable Research (AIR)* ISSN 1079-5146, is copied here with the specific intention of poking fun at the tendency of some valuers to hide behind the concept of 'opinion' with every identification statement.

ii. Anderson, B.W., 1947. *Gem Testing*, 4th edition, chapter VI, opening paragraph

iii. Shipley, R.M., 1945. *Dictionary of Gems and Gemology*, 2nd edition. Gemological Institute of America, Los Angeles, p. 148

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vii. Moses, T.M., 2000. 'In Reply' *Gems and Gemology*, **36** (2), 97

viii. Elmore, M., 1998. *Coloured Stone*, **11** (6), 1, 30-4

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Abstracts

Diamonds

Gems and Minerals

Synthetics and Simulants

Instruments and Techniques

Diamonds

Die Mineralogie und Gemmologie der Diamanten aus der Serra do Espinhaço, Minas Gerais, Brasilien.

A. Banko and J. Karfunkel. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(3), 2000, 127-150. 18 photographs, 1 map, 8 tables, 2 graphs, bibl.

Diamonds from the Espinhaço range deposits are related to three geological periods ranging from the Precambrian, the Precambrian hydraulic redistribution time, to the Phanerozoic period. Up to 98% of these diamonds are cuttable; 34-39% are dodecahedrons, 17-27% octahedrons. These two crystal forms together with combinations of the two types make up 75% of stones found. The average diamonds have clarities in the VS-SI range and colours of I-K. Many have a green or brownish coating. Blue to milky-blue and green to greenish-yellow are the most frequent luminescence colours. 90-95% are type Ia. E.S.

NovaDiamond – colour enhanced yellow and yellow-green diamonds.

A.S. Barnard. *Australian Gemmologist*, **20**(12), 2000, 517-22, 6 illus.

Research by Novatek into the high pressure high temperature (HPHT) treatment of diamond began in 1991. Instead of the GE (GE POL) 'whitening' process, Novatek researchers began focusing on the activation rather than the de-activation of colour using HPHT techniques. In order to activate new colours in diamond it must be exposed to greater temperatures and pressures than those experienced during its formation, and these are obtained by using a specially designed 'Geodynamic' press. The NovaDiamond process transforms natural brownish diamonds of type Ia, or a mixture of type Ia and IIa, into fancy yellow or yellow-green diamonds. Identification features of NovaDiamonds include strong green fluorescence, significant 'bearding' of the girdle and frosted naturals. P.G.R.

Gemmologisches Symposium 2000. Zusammenfassungen/Abstracts.

Gemmologie. Z. Dt. Gemmol. Ges., **49**(3), 2000, 159-71.

A summary of papers presented at the symposium held in Idar-Oberstein. E. Fritsch, J.P. Chalain and H.A. Hänni presented a paper on the identification of diamonds treated at high pressure and high temperature by General Electric. Some of these stones contain characteristic inclusions, but most show luminescence induced by a laser and measured using a Raman spectrometer; in many stones also the width of the 637 nm line in the luminescence spectrum is broader in treated than in untreated stones. V. Lorenz read a paper on the genesis of diamondiferous kimberlite and lamproite diatremes. N.V. Sobolev talked about the influence of mineral inclusions on the quality of diamonds. E.S.

Gems and Minerals

Gemmologie Aktuell.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(3), 2000, 121-6, 6 photographs.

Grandidierite from Madagascar is a bluish-green boron bearing magnesium-iron-aluminium silicate, orthorhombic, hardness 7, RI 1.590-1.623, DR 0.033, lower than textbook values. SG 3.00. Also from Madagascar a rhodolite coloured corundum; this comes from the south of the island and is found together with blue, yellow, orange, pink and reddish-violet sapphires. Their gemmological values are slightly higher than those of average corundums. A transparent actinolite was found in a parcel of peridot crystals from Pakistan; it was cut and polished; RI 1.60-1.63, DR 0.030. E.S.

Moonstone – a rare Queensland gemstone.

H. Bracewell. *Australian Gemmologist*, **20**(12), 2000, 523-8, 9 illus. in colour, one map.

Although members of the feldspar group of gemstones are mined extensively worldwide, the colourless variety displaying a bluish schiller and termed moonstone is comparatively rare. Sri Lanka is one of the main sources of quality specimens of moonstone, but a small, yet prolific, deposit of this rare gem feldspar exists at Moonstone Hill, north of Hughenden in North Queensland. P.G.R.

Australia's gemstone resources and their markets.

G. Brown. *Australian Gemmologist*, **20**(12), 2000, 534-9.

Australia is the world's largest producer of diamond (by volume) and of precious opal, cultured white South Sea pearls, chrysoprase and nephrite. It is also a major

Abstractors

P.G. Read P.G.R. E. Stern E.S.

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

ISSN: 1355-4565

producer of sapphire and a minor producer of commercial man-made gemstones (namely the Biron hydrothermally grown synthetic emerald). This paper updates the status of Australia's commercial gemstone resources and discusses known trends in their production and export. Exploration for additional gemstone resources is ongoing but tends to be overshadowed by the search for higher yielding commodities such as coal, iron ore and gold. P.G.R.

Gemmologisches Symposium 2000. Zusammenfassungen/Abstracts.

Gemmologie. Z. Dt. Gemmol. Ges., **49**(3), 2000, 155-71.

A summary of papers presented at the symposium held in Idar-Oberstein. G. Brown talked about Chinese freshwater pearls and solving some problems of their identification. O.W. Flörke discussed the twinning in amethyst, including synthetic amethyst and chalcedony. R.R. Harding disucssed current gem testing and the role of laboratories. U. Henn talked about the problems of nomenclature for padparadscha, while J.I. Koivula described inclusions he had recently studied. C.C. Milisenda discussed the connection between gemstone occurrences and plate tectonics. E.S.

Klar durchsichtiger Rhodonit aus Brasilien.

U. HENN AND H. BANK. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(3), 2000, 151-4. 6 photographs, 1 graph, 2 tables, bibl.

A new occurrence of clear gem quality transparent rhodonite has been found in Minas Gerais, 85 km south of Belo Horizonte, near Conselheiro Lafaiete, similar to the material from Broken Hill, Australia. There are two types, one with lower RI, DR and SG than the Broken Hill material, the other with higher values due to higher iron content. E.S.

Gemmologische Kurzinformationen. Verschiedenfarbige Saphire aus Brasilien.

U. HENN AND E. PETSCH. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**, 2000, 173-4. 6 photographs, 1 graph, bibl.

A new occurrence in the Municipio de Manhuacu near Sacramento in Minas Gerais produces transparent sapphires in pink, violet-red, violet, lilac and blue-lilac, and some specimens are bi-coloured, mainly yellow-blue and yellow-violet. RIs and SGs correspond to average corundum values. Zircons, apatite, mica and crystallographically orientated rutile needles have been observed as inclusions. Healing cracks, twinning lamellae and growth zoning are present. E.S.

Instruments and Techniques

Dispersion measurement with the gemmologist's refractometer - Part 1.

D.B. HOOVER AND T. LINTON. *Australian Gemmologist*, **20**(12), 2000, 506-16, 6 illus.

Part 1 of this paper first discusses the history of the development of the critical angle refractometer from the Bertrand instrument in 1884 and the Pulfrich version in 1886, to the series of more compact models that began to appear from 1920 onwards. However, an important though neglected aspect of the critical angle refractometer is that the measurement of refractive index can be obtained by means of the grazing incidence of light directed into the gemstone under test as well as via light introduced into the rear of the reference glass hemisphere or truncated prism. In the case of grazing incidence the critical angle is determined by the angle above which no light enters the reference glass prism. One advantage of the grazing incidence method is that the contrast between the viewed light and dark fields is more pronounced than that obtained by the more widely used total internal reflection method. Although there are difficulties in the use of grazing incidence measurement of refractive index, the authors indicate how these can be overcome. Another gemstone constant largely ignored by gemmologists is dispersion, measured as the difference in a gem's RI between light wavelengths at the B and G intervals. Only three recent references in the literature have discussed the measurement of dispersion using a refractometer (two by Suhner and one by Hanneman). On the assumption that such a measurement can be a useful identifying feature, this paper first reviews the basic principles of the optics of a refractometer. From this is derived a means of correction for apparent dispersion which disagrees with both Suhner's and Hanneman's methods. Although not simple, practical aspects of dispersion measurement using standards of known dispersion will be discussed in the second part of this paper. P.G.R.

Synthetics and Simulants

Gemmologie Aktuell.

H. BANK, U. HENN AND C.C. MILISENDA. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(3), 2000, 121-6, 6 photographs.

Power beads are very fashionable at the moment, but many are not what they are said to be; dyed quartzites are offered as carnelian, onyx may be marble beads with plastic covering, white howlite may be magnesite. A 2.88 ct Paraiba tourmaline turned out to be dyed. A blue transparent to partly translucent fine grained aggregate from Afghanistan was offered under the name 'Aowien', measurements showed it to be blue diopside. A synthetic colourless diamond weighing 0.25 ct was shown to be a type IIa; strong green fluorescence under UV could be observed. A transparent faceted green stone turned out to be a synthetic quartz, the green colour being due to a green seed plate orientated parallel to the table of the otherwise citrine coloured stone. Several faceted, translucent, red stones from Afghanistan were found to be dyed with the colour concentrated in cracks. E.S.

Gemmologisches Symposium 2000. Zusammenfassungen/Abstracts.

Gemmologie. Z. Dt. Gemmol. Ges., **49**(3), 2000, 170-71.

Summary of a paper by I. Sunagawa on gemmology and the science of crystal growth presented at the symposium held in Idar-Oberstein. E.S.

BOOK REVIEWS

The power of gold.

P. Bernstein, 2000. Wiley, New York. pp xiv, 432, hardcover. ISBN 0 471 25210 7. £17.99.

Brisk and entertaining study of the part played by gold in antiquity and today, with a good deal of interesting material on Greek and Roman history and legend in which the metal has been concerned. There are also fascinating accounts of the gold standard and the upheaval caused by varying attitudes to it and of gold in today's electronic markets. Since gold plays so large a part in the jewellery trade it is worth while learning as much as possible about its unique history. The book is competitively priced and well-produced: there is a 10-page bibliography and a carefully constructed index. M.O'D.

Treasury of the world: jewelled arts of India in the age of the Mughals

M. Keene with Salam Kaoukji, 2001. Thames and Hudson in association with The al-Sabah Collection, Dar al-Athar al-Islamiyyah, Kuwait National Museum. pp 160, illus. in colour, softcover. ISBN 0 500 97608 2. £18.95

The exhibition of which this book is a catalogue is, as the review is being written, displayed at the British Museum and is set to travel to the United States later in 2001. A high proportion of the artefacts on show are illustrated in the catalogue which falls into sections on varieties in stone settings, inlaid hard stones, relief in hammered precious metal, engraved gold-backed jewels, gemstones on gold floral ground, developments in enamels, gold-embellished steel, three-dimensional expressions, relief-carved ornament, carved set gemstones, gemstone forms, inscribed royal gemstones and jewelled magnificence. There is a glossary and a bibliography. Each item illustrated and catalogued is fully described, sized and attributed with later provenance given where known. The photographs are first-rate: readers should look at the inscribed royal gemstones chapter in which the gemstones are rough red spinels and emeralds and also at the chapter on gemstone forms where diamond set items are described. There is a good deal of jade in the exhibition and from the stones less often used in such high company, some attractive carnelian and rock crystal.

The introductory chapters include a map showing the sub-continent during history and details of how Sheikh Nasser formed his collection. Those who wish to see the Timur ruby (red spinel) at closer quarters than usual should try to see the exhibition which contains so many beautiful items. M.O'D.

Jadeite jade [in Chinese]

C. M. Ou Yang, 2000. Cosmos Books Ltd, Hong Kong. 2 vols, pp 511 [about 50 pages outwith the pagination], hardcover, in slip case. ISBN [vol.1] 962 993 080 3 [vol.2] 962 993 081 1. Price HK $1000 for each volume.

Beautifully presented and exhaustive survey of jadeite with comprehensive details of the mineral itself, its geology and occurrence, mining, sale and fashioning. The author has visited many occurrences herself and her visits are preserved by a number of cheerful photographs in which she is accompanied by miners and by examples of jadeite boulders of different qualities. The first volume by and large deals with the geology and mineralogy while the second introduces gem testing, simulants, enhancements and marketing. Jadeite auctions are described (for the first time a monograph identifies the view before a sale as the very best place to examine the finest specimens) as well as the open-air jade markets in Hong Kong and elsewhere. Almost every opening carries at least one photograph and some of them are very good indeed. The print is exceptionally clear to read and very generously spaced; diagrams illustrating jadeite formation are very lucid and usefully coloured.

The bibliography is placed at the end of the second volume and arranged in two sections, Chinese-language and European-language works. Readers familiar with the very large literature of the jade minerals will see that no effort has been made to include every possible work of significance but enough are present to satisfy the present-day gemmologist. The last 50 or so pages of the second volume, unpaginated, include the bibliography and a number of examples of outstanding specimens described from auction house catalogues, giving in some cases the prices paid.

This is a large and expensive book but, though written in a language which will pose problems to European readers (my own studies in Chinese were a long time ago!) it is not too difficult to work out the points made by the author and the photographs are worth paying for. It is worth mentioning, to forestall the occasional question "why do all modern Chinese books on jade deal only with jadeite and not nephrite?" to remind readers that nephrite objects are considered first for their antiquarian, historical and literary value and only then for any ornamental attraction that they may display. In the catalogues of the major auction houses nephrite artefacts appear in oriental antiquities sale catalogues rather than in jadeite ones. M.O'D.

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

PHOTOGRAPHIC COMPETITION

The 2001 Photographic Competition on the theme ***Born Yesterday*** drew entries of a very high standard. Gemstones are minted, cut and refashioned every day, with many more stones being 'created' in laboratories around the world. To celebrate the new Millennium, members were invited to submit pictures of gemstones 'born' (or even 'reborn') during 2000.

First Prize

Marc N. de Regt FGA, Goes, The Netherlands

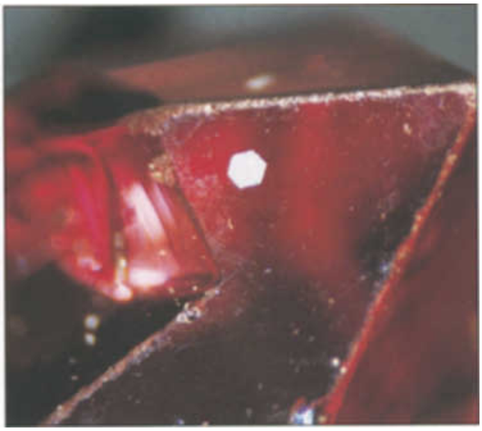
Rock crystal with hematite base and rutile needles (illustrated on front cover).

'Tom Munsteiner gave birth to this stone,' explained Marc de Regt. 'I bought it from him at Intergem 2000 and immediately the image inspired me. It looked at me like a frozen moment of creation. In the picture the stone seems to come loose, celebrating the new Millennium.'

Second Prize

John Harris FGA, Durdar, Carlisle, Cumbria

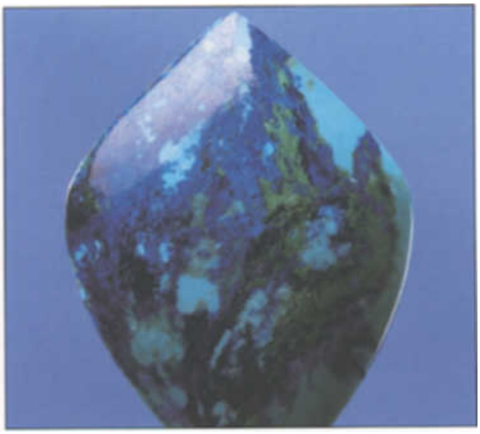
Platinum birthmark in Russian flux-grown crystal of synthetic red spinel.



Third Prize

Bob Maurer FGA DGA, London

Chrysocolla from Mexico.



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OBITUARY

Margaret J. Biggs, FGA

A tribute by David Callaghan

The death of Margaret Biggs at the age of 90 saddens all of us who knew her, and particularly those of us who worked with her. I did not do so in the conventional meaning of the word, but Margaret became President of the National Association of Goldsmiths (NAG) in 1977 during my term of office.

In 1958 I was sitting the NAG Diploma examination at Goldsmiths' Hall and I was taken from the Livery Hall, where we were sitting the exam, to the Drawing Room where the practical tests were taking place. Somehow I managed to skate past the table with the clocks on, and found myself in front of a lady. She had the appearance of a kind of great-aunt and she had a comforting warm voice. All I remember of the questions that she asked was one that involved me in handling a piece of silver – probably I was asked to identify the date. She then asked me what I should do when I had finished showing it to a customer. I replied that I would replace it in the showcase, and close the door (our showcases behind the counters were not locked). She asked me what else would I do. I thought for a while and couldn't think of anything else I should do, and said so. The kindly great-aunt then said to me: "You should clean off any finger marks before putting the piece back in the showcase." I thought this was being very 'picky' I suppose, being thoroughly spoiled by working in the West End and so I replied: "Oh, I never thought of that! You see where I work we have a man who cleans all the silver for us!" That was the end of the interview and I crept out, confident in my heart of hearts that I had 'blown it'. But I hadn't, so obviously the kind great-aunt had taken pity on the precocious student!

Margaret Biggs was the first woman to pass her FGA with Distinction (1929), sitting the exam that year in the company of none other than Robert Shipley of Los Angeles, Mr R. W. Yeo and Mr E. Trillwood, who was to become Secretary of the NAG in 1933. Margaret had studied for the exam for two years by correspondence, and her own sister Mary followed her in 1931. Interestingly, Mr E.T. Biggs, their brother, qualified in 1933 with Distinction and joined his sisters in the family business in the Maidenhead shop. He translated the Diploma course into German just for practice! He did not stay in the family business preferring the Diplomatic Service as a career.

Margaret Biggs

Margaret and Mary were to form a unique team in running a family business, at a time when male chauvinism in the jewellery trade was the norm. Margaret was responsible for all aspects of buying and selling and Mary was responsible for all aspects of display and advertising. She was very successful too, winning the NAG Window Dressing Competition several times.

Margaret's great interest was in education and she was chairman of the NAG Education Committee for many years, laying the groundwork for the Diploma Course that has been the backbone of the NAG's lasting success in training. She was the first woman to be NAG Chairman (1948/49) and to date is, uniquely, the only woman to hold the office of NAG President (1977/78).

Many sons and daughters of family jewellers received their training with Margaret and Mary Biggs of Farnham, and the style of their business was very special. Margaret was especially kind to all young people in the trade, generous with her time in imparting her knowledge and always very encouraging. She was such a fine example to all. An example of her generosity of spirit is the letter of welcome and congratulations to Eric and Anne Bruton when they opened their shop 'The Diamond Boutique' in Maidenhead in 1967. After all they were to be Margaret's competitors, but rather than be downhearted or negative about it, she welcomed the healthy competition.

GIFTS TO THE ASSOCIATION

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

Hossein Bordbar, London, for a bag each of tumbled chrysoberyl and rough corundum (ruby).

Gemsafrica, Richmond, Surrey, for rough rubies from Malawi.

Dr Ulrich Henn of the German Gemmological Association, Idar-Oberstein, Germany, for a copy of his book *Edelstein kundliches Fachworterbuch* with CD Rom

Michael Hendri, San Antonio, New Mexico, U.S.A., for a piece of yellow opal rough.

Kyaw Khaing Win, Yangon, Myanmar, for a brown amphibole crystal from Kyat-pyin, Mogok, and a colourless amphibole cabochon from Ohn-pinsye-htaret, Mogok.

Dan Ly, Cambodia Blue Zircon Co., California, U.S.A., for a brown zircon rough and two pieces of blue heat-treated zircon rough, both from Cambodia.

Penny O'Connor, Grays, Essex, for a simulated jade carving.

Peter G. Read, Bournemouth, Dorset, for a hardback copy of *Fire into ice* by Vernon Frolick.

Susannah van Rose, Glastonbury, Somerset, for a collection of gem-set jewellery.

Pierre Vuillet, Villards d'Heria, France, for a cut fluorite and a euclase crystal from Colombia, and a copy of *Revue de Gemmologie* containing a paper relating to material similar to that donated.

George Weller, Tunbridge Wells, Kent, for a collection of *The Journal of Gemmology* from the 1950s to the present day.

I remember especially her warm voice, her comforting smile and her quiet composure. In her presence the world was a quieter, well mannered, kinder and infinitely more hopeful a place. Although I had not seen her for many years, I realize now how much she is missed. Those of us who knew her will be always grateful to her. To Margaret, and to Mary her sister, we say thank you for all you have done for us.

Dr John Wilson Franks, B.Sc., Ph.D., FGA, DGA

Born in Beverley, Yorkshire, in 1930, John Franks obtained his B.Sc. in botany and zoology at Leicester University and his Ph.D. In 1956 he was appointed Scientific Officer in the Department of Palaeontology at the Natural History Museum, Kensington, moving to the position of Keeper of Botany at the Manchester University Museum in 1959 until his retirement 1994. He regarded gemmology as his 'second string' and qualified for his FGA in 1979 and DGA in 1980.

John Franks supported the North West Branch of the GAGTL for many years, serving as Chairman in 1984 and 1985, and Treasurer from 1997. His interests were manifold and no aspect of gemmology escaped his attention and enquiring scholarship, and he was always ready to share his knowledge.

Despite his failing physical health, he determinedly pursued his cultural interests and in these he was encouraged and supported by his wife Eileen, who is also a member of the North West Branch. His gentlemanly ways and quiet authority shall be missed by all who knew him.

Irene Knight

* * *

Evelyn Twemlow-Krzempek FGA DGA (D.1963), Calvereton, Nottinghamshire, died on 25 April 2001.

MEMBERS' MEETINGS

London

On 27 April at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8TN, Dr Kurt Nassau from Lebanon, NJ, USA, presented an illustrated lecture entitled *My 40 years with gems*.

On 3 May at the Scientific Societies Lecture Theatre, New Burlington Place, London W1, Dr Kurt Nassau gave a lecture and demonstration entitled *Light and colour – beautiful complexity*.

During his presentation he explained that our knowledge of colour comes primarily from our first few years in school and much of what we were taught there is wrong or at least misleading. For example, there are *three* sets of primary colours and *two* very different ways of mixing colour. The

GemA *The Gemmological Association*

The Gemmological Association of Great Britain can trace its origins back to 1908 and has long been renowned for its dedication to the study of gems. Now meeting new challenges, it is putting itself at the cutting edge of communication whilst maintaining the high level of analysis, education and support for the diamond and gem trades which it has provided for almost a century.

To optimize communication the Association now has one easily recognizable and identifiable image and name: ***Gem-A***. As an abbreviation for 'The Gemmological Association and Gem Testing Laboratory of Great Britain' (GAGTL), ***Gem-A*** has many functions. It allows the Association to work efficiently on the internet, it helps with branding and provides a quality trademark for specific projects. ***Gem-A*** will streamline the Association's marketing by enabling Education, Instruments, the Laboratory, Membership and Publications to benefit from a common heritage and a common purpose. It will continue to be the approved UK awarding body and gemmological examination centre.

As well as continuing to support the trade, ***Gem-A*** will serve as a key for people from outside the allied industries and interest groups. The public will be able to access a wealth of information that has never been easy to find. ***Gem-A*** will regenerate public interest in diamonds, gems, jewellery and gemmology. Because of the global nature of the Association, ***Gem-A*** will help to expand this mission: the name ***Gem-A*** is easily understood in many languages and is a truly international symbol.

On the legal and business front, ***Gem-A*** is not replacing 'GAGTL' or superseding the Association's commitments, interests or remits. ***Gem-A*** is the vehicle that will unify, support and expand the existing structure.

nature of light itself remains mysterious. These and other basic concepts also help in understanding the 15 physical and chemical causes of colour, 13 of which occur in gems and minerals.

On 25 June at the Gem Tutorial Centre the Annual General Meeting was held, a full report of which will be published in the October issue of the *Journal*. This was followed by the Reunion of Members and Bring and Buy Sale. During the evening the winners of the 2001 Photographic Competition were announced and Rod Coleman of Harley UK, sponsors of the competition, presented the prizes. The event also included the launch by Jean-Paul van Doren of *Gem-A*, the new image for the GAGTL (see above).

Midlands Branch

On 27 April at the Earth Sciences Building, University of Birmingham, Edgbaston, the Branch Annual General Meeting was held at which David Larcher, Gwyn Green, Elizabeth Gosling and Stephen Alabaster were re-elected President, Chairman, Secretary and Treasurer respectively. This was followed by a lecture by Dr Jamie Nelson entitled *A new combination gemstone finger-printer and high refractive index refractometer*.

On 29 April at Barnt Green Dr Kurt Nassau gave a lecture entitled *Light and colour – beautiful complexity*.

A Summer Supper Party was held at Barnt Green on 23 June.

North West Branch

On 25 April at Church House, Hanover Street, Liverpool 1, Dr Kurt Nassau gave a lecture entitled *My 40 years with gems*.

On 16 May at Church House Alan Hodgkinson ran a workshop as well as presenting a talk entitled *Poking in gemmological corners*.

On 20 June at Church House a Bring and Buy Sale was held.

Scottish Branch

The Annual Conference of the Scottish Branch was held in Perth from 4 to 7 May. A report was published in the June 2001 issue of *Gem and Jewellery News*.

On 12 June at the British Geological Survey, Murchison House, Edinburgh, Murdo McLeod gave a talk entitled *Scottish pebble jewellery*.

FORTHCOMING EVENTS

13 September	**London**. *The literature of gemstones.* Micheal O'Donoghue
19 September	**North West Branch**. *Reading silver hallmarks.* Charles Preston
24 September	**Scottish Branch**. *Gemstones and geology of South Central Africa.* Roger Key
28 September	**Midlands Branch**. *The implications and problems of gemstones in jewellery valuations.* Richard Taylor
10 October	**London**. *A portrait of jewels.* Moya Corcoran
17 October	**Scottish Branch**. *Inclusions: highlights from twenty years of gemstone photomicrography.* Clive Burch
17 October	**North West Branch**. *Pawnbroking throughout the 20th century.* Ray Rimmer
26 October	**Midlands Branch**. *Beautiful opals, Australia's national gemstone.* John Wheeler

Gem-A Annual Conference

Sunday 4 November – Barbican Conference Centre, London

Keynote speaker: George Bosshart, Lucerne, Switzerland

Further developments in the detection of HPHT – annealed diamonds

Heat treatment of rubies: the Gübelin Gem Lab's disclosure and classification system

Dr Simon Lawson, DTC Research Centre, Maidenhead

Practical screening of HPHT treated diamonds

Haywood Milton and Stephen Whittaker

Auctioneers and Pawnbrokers: our unpopular 'lot'?

Terry Davidson

Who or what is a jeweller?

CONFERENCE VISITS:

Friday 2 November: Guided tour of the gem and mineral galleries at the Natural History Museum

Monday 5 November: **Diamond Trading Company**

Full details and application forms available from Gem-A on 020 7404 3334

20 November	**Scottish Branch**. *Jade.* Rosamond Clayton
21 November	**North West Branch**. *AGM and social evening*
21 November	**London.** *Analysis of precious stones under thick glass by Mobile Raman Microscopy (MRM).* *Compositions of jade and garnets by non-destructive Raman Microscopy.* Two Lectures by Professor David Smith
30 November	**Midlands Branch**. *Wonderful emeralds.* Alan Hodgkinson
8 December	**Midlands Branch**. *Annual Dinner, 49th year*

Contact details

(when using e-mail, please give GAGTL as the subject):

London:	Mary Burland on 020 7404 3334 e-mail: gagtl@btinternet.com
Midlands Branch:	Gwyn Green on 0121 445 5359 e-mail: gwyn.green@usa.net
North West Branch:	Deanna Brady on 0151 648 4266
Scottish Branch:	Catriona McInnes on 0131 667 2199 e-mail: cm@scotgem.demon.co.uk
South West Branch:	Bronwen Harman on 01225 482188 e-mail: bharman@harmanb.freeserve.uk

GAGTL WEB SITE

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

South West Branch

On 10 June at the Royal Literary and Scientific Society Institute, Bath, the second meeting of the newly-formed South West Branch was held. Talks were given by Michael O'Donoghue on the Sapphires of Montana and by Branch Chairman Richard Slater on *Jewellery at Auction.*

ANNUAL REPORT

The following is the report of the Council of Management of the Gemmological Association and Gem Testing Laboratory of Great Britain for 2000.

Officers, councils and committees

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. At the Annual General Meeting in June, Professor A.T. Collins was elected President to succeed Professor R.A. Howie whom we thank for his strong support during two terms of office. Sadly, our recent President and Vice President, Eric Bruton died in December. The other Vice Presidents, A.E. Farn, D.G. Kent and R.K. Mitchell, continued in office.

Following the poor financial results in 1999, the Council of Management set up a working party to review policy. The decision for some immediate action resulted in the loss of three staff, one each in Membership/Education, Accounts and the Laboratory.

Further deliberation by the working party on GAGTL structure led to the creation of the new post of Chief Executive Officer and J-P. van Doren was appointed to it; he was co-opted onto the Council in December. The Council thanks the working party for all their efforts.

C.M. Woodward continued as chairman of the Board of Examiners, which was strengthened by the addition of S. Hue-Williams of London and Li Li Ping of Wuhan, China. E. Stern continued as vice-chairman. J. Monnickendam (chairman) and J. Kessler (vice-chairman) continued in office on the Trade Liaison Committee, which again provided a valuable forum for discussion of contentious trade matters such as diamond treatments and laboratory report terminology. C. Winter (chairman) and P. Dwyer-Hickey (vice-chairman) continued in office on the Members' Council; however, at the AGM in June, R. Shepherd stepped down after seven years support – we thank him for his contribution.

Education

At the Gem Tutorial Centre in Greville Street, the Gemmology and Gem Diamond courses were well subscribed, with students coming to London from many different countries. Development of the *Diamond Grading Manual* was brought to fruition with its publication in the autumn, and new Gem Diamond Diploma theory notes were produced for the start of the term. Development of the gemmology theory and practical course materials continued.

The frequency and variety of tutorials and practical workshops increased significantly in 2000. In response to a request from a major company in the jewellery trade, the Diamond Practical Certificate course was brought forward and will be fully operational in 2001. Overseas tutorials were held in the USA, the AGS Conclave and in Sweden, Norway and Ireland.

A new Allied Teaching Centre was brought closer to establishment in Thailand. Enhanced arrangements for translations have been put in place in Finland and Japan. Talks took place for education in China and the USA.

A total of 891 students entered the GAGTL examinations in 2000 which is fewer than in recent years. Although student quality is relatively good and pass rates were high, no single student was judged worthy of the Tully Medal. In diamond studies, however, the Bruton Medal was awarded to N. Rose of North Yorkshire. Dr L. Joyner of London was awarded the Anderson Bank prize for the best diploma paper in gemmology, and the Diploma Trade Prize was awarded to Mina Shin of Seoul, South Korea. Both the Anderson Medal and the Preliminary Trade Prize were awarded for the best paper in the preliminary gemmology examination to H. Dimmick of London. The Presentation of Awards again was held at Goldsmiths' Hall. J. Monnickendam chaired the ceremony and the president, Professor A.T. Collins, addressed the assembly and presented the prizes and diplomas.

The GAGTL has received sponsorship for two prizes during the year: the first from Christie's who have undertaken to support the prize for a student in the jewellery trade – to be called the Christie's Prize for Gemmology; N.W. Deeks has undertaken to support a new prize for best paper in the Gem Diamond Diploma examination. The Council thanks both sponsors for their generosity.

Two meetings of the Board of Examiners were held to assess results and consider developments, and the Education Review Meeting – including examiners, tutors, lecturers and GAGTL staff – was held as usual in November.

The GAGTL continued to hold the Secretariat of the Federation for European Education in Gemmology (FEEG) and the 4th General Assembly was held in Leiden, Holland, in January. Four students sat the FEEG examinations in London – a small number compared to the total of 68 throughout Europe.

The Laboratory

Diamond grading work in the Laboratory continues to increase and the team was strengthened in May with the arrival of C. Furze. Coloured stone work also showed a small increase but pearl identification declined. S.J. Kennedy represented the GAGTL at the international laboratory meeting in Tucson, USA, in February and again at the CIBJO annual meeting held in Kobe, Japan. 'Notes from the Laboratory' were published in the April issue of *The Journal of Gemmology* and a further instalment was prepared for publication in the January 2001 issue. In addition to carrying out their normal duties, Laboratory staff are actively involved in teaching and supporting courses at the GAGTL.

The Millennium Trade Dinner

To celebrate the 75th anniversary of the founding of the Laboratory, the GAGTL joined with the London Diamond Bourse and Club (LDBC) to hold a dinner at Goldsmiths' Hall on 5 June. The guest of honour was G. Ralfe, Managing Director of De Beers globally, and in his speech he outlined the De Beers' approach to key issues in the diamond market. F. Hager, President of the LBDC, welcomed guests, the speaker was introduced by J. Monnickendam (chairman, Trade Liaison Committee) and a vote of thanks was given by T.M.J. Davidson (Council of Management).

Trade Fairs

The GAGTL exhibited at three major fairs during the year: in June at Las Vegas (USA), in September at Earl's Court, London, and in Hong Kong. Opportunities were taken at each venue to promote education, laboratory and membership services, new instruments from Gemmological Instruments Ltd, and to widen contacts in the trade.

Visits

In February a group visit to Tucson was organized for GAGTL members, and in April the sixth annual visit to Idar-Oberstein took place in which a coach load of 40 participants enjoyed a week exploring the wide range of gems in what is probably the coloured stone capital of Europe. Visits closer to home were organized for members to De Beers, Kingston University, Goldsmiths' Hall (Treasures of the 20th century) and Somerset House (Gilbert Collection).

Membership

Overall membership remained steady with recruitment just compensating for loss. Much recruitment comes through educational activities and it remains difficult to attract general jewellery trade members.

Activities in the Branches, however, are showing resurgence. The Midlands Branch held eight lectures, an AGM, an Annual Dinner and several 'playgroups' wherein gem activity is spontaneous and inspired by the group. The North West Branch ran five lectures and an AGM, and the Scottish Branch ran five lectures and a very successful Millennium Conference in Perth with overseas and UK speakers. Arrangements were also made to start a South West Branch with the first meeting in Bath. The effort in organizing all these events throughout the country by the Branch officers and their colleagues is much appreciated. In London, a varied programme of ten lectures ranging from British precious minerals to amber, and stone cutting to jewellery design, was held throughout the year.

The GAGTL Annual Conference was again held at the Barbican Centre, London, and attracted a record audience from many European countries, Hong Kong and the USA. The morning session was devoted to diamonds with talks by Professor A.A. Levinson and Dr P. Spear, and in the afternoon Dr J. Kinnaird spoke about Somali gems, H. Levy discussed aspects of disclosure of treatments in gems, and R. Fawcett described the current market in South Sea cultured pearls.

A special appeal was made at the end of 1999 to provide development funds, and Council would like to thank all those who gave generously. Many donors specified instruments or stones for teaching and these wishes have been fulfilled.

Publications

In *The Journal of Gemmology*, 20 papers were published with topics ranging from Russian synthetic sapphires to yellow tourmaline deposits in East Africa, and from nephrite jade to HPHT-treated diamonds. Abstracts totalled 186 and there were 53 book reviews; a special thank you should go to M.J. O'Donoghue for his prolific contributions in these sections. Council would also like to thank the other Assistant Editor, P.G. Read, the thirteen Associate Editors and the Production Editor, M.A. Burland, for their invaluable support.

Gem and Jewellery News is published jointly with the Society of Jewellery Historians, and in 2000 contained a wide range of reviews and comment on new exhibitions both in the UK and overseas, on new books and on lectures, conferences and courses. We thank the editors for continuing a stimulating and widely-read newsletter and particularly H. Levy for pertinent and authoritative views on the trade.

Photographic competition

The 2000 Photographic competition was on the theme 'The light fantastic: optical effects in gems' and drew a record number of entries of a high standard. The judges are independent of GAGTL and they selected three prizewinners and several more images to grace the calendar for 2001 which is distributed free to members. The winner was D. Durham of Kingston-upon-Hull and he received his prize at the Reunion of Members in June. Council is most grateful to Harley UK, printers of *The Journal of Gemmology*, for their sponsorship of these prizes and for their contribution to Annual Conference expenses.

Finance

The financial result in 2000 for the GAGTL was a great improvement on the previous year; turnover increased in excess of £100,000 with a swing in profitability of almost £140,000. Gemmological Instruments Limited was marginally down on the previous year's turnover, but produced a slightly improved profit.

Gemmological Instruments Limited

Gemmological Instruments Limited is a wholly-owned subsidiary company of the GAGTL with a policy of providing good quality gemmological equipment and books to members and students. The Brewster Angle Meter, developed by P.G. Read and N.W. Deeks, is selling well. Development of gemmologically themed sets of cut stones and gem crystals continues and they sell well to students and Allied Teaching Centres.

The staff and supporters

Financial constraints meant that the year 2000 was not an easy one, but in spite of this the staff have given their full support to all the activities and events in working towards a more effective gemmological presence for the GAGTL. The Council of Management extend their sincere thanks to them for a most positive attitude and trust that it will lead to a buoyant and expanding organization.

The Council also thanks all the committee members, those who selflessly contribute to the education activities and those who supported the GAGTL through bequests, gifts and donations during the year.

MEMBERSHIP

The following have been elected to membership during April and May 2001:

Fellowship and Diamond Membership (FGA DGA)

Sutton, Daniela Nicola, Worcester. 1994

Wong Kwok Man, Shatin, Hong Kong. 2001

Fellowship (FGA)

Bartholomew, Jürgen C., Shoreham by Sea, West Sussex. 1986

Bastos, Ana Pestana, Porztela, Portugal. 2001

Chalmers, Marie L., Redditch, Worcestershire. 2001

Cheng Mei Yun, Singapore. 2001

Cheung Suk Yin, Hong Kong. 2001

Douvis, George, Athens, Greece. 2001

Farrer, Alison Mary, Nympsfield, Gloucestershire. 2001

Henn, Ingo, London. 2001

Hughes, Anthony, Harden, West Yorkshire. 1968

Jealous, Rosa Mary, London. 2001

Kanacher, Marly, Singapore. 2001

Lam Chi-Hing, Hong Kong. 2001

Long, Charlie, Richmond, Surrey. 2001

Loxton, Sam Capel, South Norwood, London. 2000

Quirino Cabrita, Miguel, Turnhout, Belgium. 2001

Rweyemamu, Edward J., London. 2001

Teramae, Ikumi, West Ealing, London. 2001

Tsoha, Theodora, Volos, Greece. 2001

Welsh, Fiona, Wynward Woods, Cleveland. 2001

Xanthoudaki, Aristea, Chania, Crete, Greece. 2001

Yedunath, R., Chennai, India. 2001

Diamond Membership (DGA)

Campbell, Paul., Erdington, Birmingham, West Midlands. 2001

Jones, Adrian Matthew, Harrow, Middlesex. 2000

Kwan, Susana, Central, Hong Kong. 2001
Mayne, Glen Robert, Reston, Virginia, U.S.A. 2001
Pala, Sunil, Coventry, West Midlands. 2001
Pattison, Noel, Eaglescliffe, Cleveland. 2001
Pelser, Stephan, Freiburg, Germany. 2001
Tsoi Karen Pui Pui, Kowloon, Hong Kong. 2001
Wong Lai Mun Phyllis, Hong Kong. 2001

Ordinary Membership

Bockett, David Allen, Rathgar, Dublin, Ireland
Cartmell, Alan Paul, London
Caswell, Amelie Margrit, Bristol, Avon
Chapman, Jackie, London
Davies, Dorian Wynne, Pontardawe, Swansea
Hearn, Caroline Sarah Jane, Aspley Guise, Buckinghamshire
Howitt, Peter J., Westbury, Wiltshire
Ingram, Simon M., Forestmill, Alloa, Scotland
Loyens, Jan, Ghent, Belgium
Muggenburg, Anna Julia, West London
Novak, Maria, London
Perry, David Edwin, Knowle, Solihull, West Milands
Turner, Jon, Walmley, Sutton Coldfield, West Midlands
Vanderhaeghen, Ivan F.D., Gent, Belgium

TRANSFERS

Ordinary Membership to Fellowship (FGA)
Blairs, Lawrence I.J., Llanrwst, Conwy, N. Wales
Eineljung, Lars E., Lannevaara, Sweden
Kulukundis, John C.A., London
Pace, Michael, Elk Grove, California, U.S.A.
Photiou, Mariana-M., San Francisco, California, U.S.A.
Plant, Monica, Knutsford, Cheshire
Squires, Caroline, Tring , Hertfordshire

Ordinary Membership to Diamond Membership (DGA)

Armati, Alexander, Badgemore, Henley on Thames, Oxfordshire
Basch, Elizaveta Z., Hyde Park, London
Chitondo, Martin C., Edmonton, London
Cruse, Toby, Eastbourne, East Sussex
Efejuku-Inegbenebho, Rosemary, London
Ko, Yuksan, Frindsbury, Rochester, Kent
Moltke, Nicholas, London
Ngan Hin Wah, Michael, Hong Kong.
Parmar, Sejal, Southgate, London
Ricard-Elbek, Rebecca, London
Susser, Jennifer L., London

Fellowship to Fellowship and Diamond Membership (FGA DGA)

Ayukawa, Yasuyo, Suginami-Ku, Tokyo, Japan
Bruce-Lockhart, Simon, London
Checkley, Emma, Smethwick, Warley, West Midlands
Cooke, Caroline M., St Margarets, Middlesex
Deljanin, Branko, New York, U.S.A.
Greslin-Michel, Valerie, London
Ito, Eiko, Kawasakishi, Kanagawa-ken, Japan
Kessler, Paul, Berden, Essex
Rimmer, Ray Ian, Bootle, Merseyside
Sherman, Gregory E., Sea Bright, New Jersey, U.S.A.
Thomas, Allyson R., Birmingham, West Midlands

Diamond Membership to Fellowship and Diamond Membership (FGA DGA)

Comar, Ankush, Bushey, Hertfordshire, Keating, Shelley, Surrey Quays, London

ADDENDUM

Following publication of 'Gem-quality clinohumite from Tajikistan and the Taymyr region, northern Siberia' by U. Henn, J. Hyrsl and C.C. Milisenda (*J. Gemm.*, 2001, 27 (6), pp 335-9), C.R. Cavey has drawn attention to the detailed gemmological features of five clinohumites, published in '*Notes from the Laboratory*' in *J. Gemm.*, 1984, **19**(2), pp 115-19. No locality was stated for these clinohumites other than USSR, but the optical constants are closer to those of the Pamir stones.

ERRATA

The colour of diamond and how it may be changed by Alan T. Collins. *J. Gemm.*, 2001, 27(6), pp 341-59 (see adhesive label enclosed)

'mm' should read 'µm' on page 342, col. 2, line 2; page 343, col. 1, line 15; page 347, col. 2, line 13

'B peak' should read 'B$'$ peak' on page 345, col. 1, lines 18, 21 and 24

$(N–V)^0$ should read $(N–V)^-$ on page 347, section 1.7, line 9

$(N–V)^\circ$ should read $(N–V)^0$ on page 347, section 1.7, line 15; page 356, section 3.3.2, line 6

$(N–V–N)^\circ$ should read $(N–V–N)^0$ on page 348, col. 1, line 2

The box on page 350 relates to the first paragraph of section 2.2

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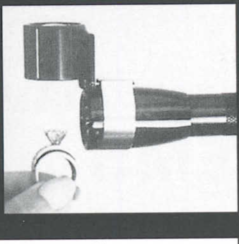

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Guide to the preparation of typescripts for publication in *The Journal of Gemmology*

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.

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 centred on a separate line.

B *This is a second level heading*

Second level headings are in italics and are flush left on a separate line.

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. Collins, 2001, 341). 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 Collins 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 Collins, A.T., 2001. The colour of diamond and how it may be changed. *J.Gemm.*, **27**(6), 341-59

Books Balfour, I., 2000. *Famous diamonds*. 4th edn. Christie's, London. p. 200

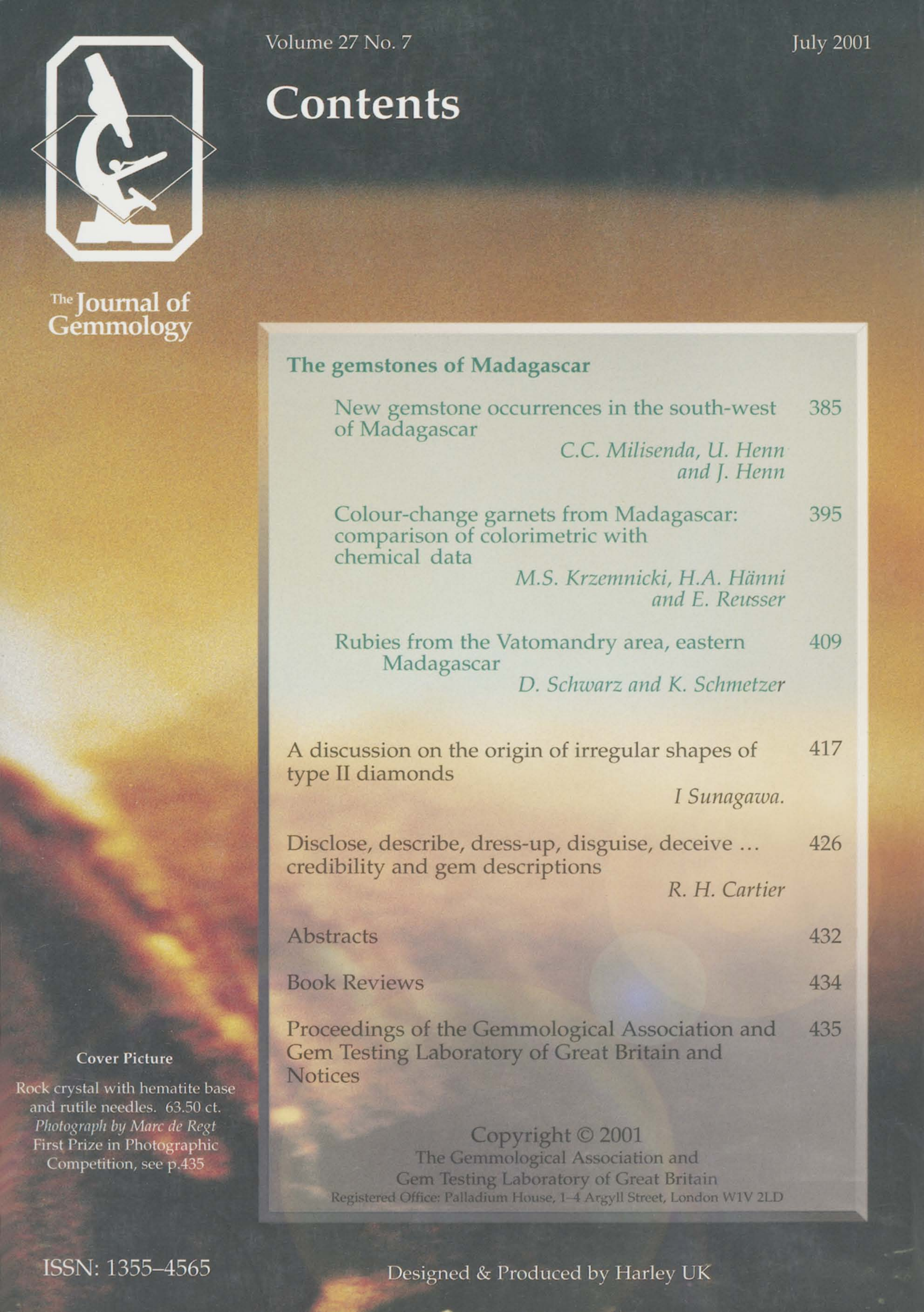
Abbreviations for titles of periodicals are those sanctioned by the *World List of scientific periodicals* 4th edn. The place of publication should always be given when books are referred to.

Volume 27 No. 7

July 2001

Contents

The Journal of Gemmology



Cover Picture

Rock crystal with hematite base and rutile needles. 63.50 ct. *Photograph by Marc de Regt* First Prize in Photographic Competition, see p.435

The gemstones of Madagascar

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