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Sapphires from the Andranondambo mine in SE Madagascar: evidence for metasomatic skarn formation

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ABSTRACT: Mineral inclusions in gem quality sapphires from the new mining area in southern Malagasy (Andranondambo) include calcite, fluor-apatite, fluor-phlogopite, fluorite, baddeleyite, zirconolite, potassium-feldspar, anorthite, scapolite (meionite), thorianite (thorianite-uraninite solid solutions) and varieties of spinel, such as green Mg-Al-spinel, spinel-hercynite and spinel-hercynite-gahnite solid solutions. These minerals are typically found in various rocks in the mining area belonging to the so-called U-Th skarns (various types of calcsilicate marbles). Therefore, these skarns are considered to be the host rocks for sapphire formation.

Based on the different generations of primary fluid inclusions in the sapphires, various generations of solid inclusions and the absence of hibonite inclusions, it is concluded that the Andranondambo sapphires have formed during several different metasomatic events. The later blue sapphire generations have grown from CO_2-rich fluids of complex chemical composition with minor concentrations of fluorine, water and metals such as aluminium, titanium, iron, chromium and zinc as well as other elements (Mg, Si, Ca, Na, K, P, Zr, U, Th).

Introduction

Malagasy's (Madagascar) highly variable topography and her fascinating landscapes indicate that highly active tectonic powers have affected her geology, which as a result is very complex. This conjecture has been confirmed by the results of modern geological research and by the wealth of gemstones which has been found over the last hundred years. Indeed, Malagasy nowadays has become an important producer of a wide range of gemstones *(Figure 1)*, and the occurrences are undoubtedly comparable with those of Sri Lanka. Beryls of various colours (aquamarine, emerald, heliodor, morganite), corundums (ruby, sapphire), feldspars (amazonite, orthoclase and labradorite), garnets (almandine, rhodolite and spessartine), kunzite, quartz (macro and cryptocrystalline), tourmalines (e.g. liddicoatite) and also a large variety of rare gems such as kyanite, danburite, epidote, hambergite, kornerupine and titanite (sphene) are being excavated. Furthermore, hibonite $(Ca, REE, Th)(Al, Ti, R^{2+})_{12}O_{19}$ with Ti = Ti, Si; $R^{2+} = Mg^{2+}, Fe^{2+}, Zn^{2+}$; Al = Al^{3+}, Fe^{3+} and REE = $Sm^{3+}, Nd^{3+}, Ce^{3+}, La^{3+}$ – a rare mineral

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Figure 1: *Map of Malagasy showing some of the most important gem deposits (from the World Map of Gem Deposits by E.J. Gübelin).*

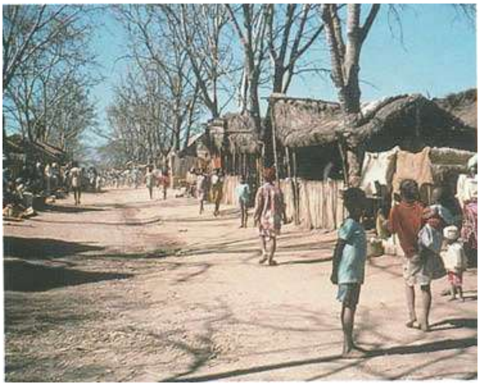


Figure 2: *Main thoroughfare of Andranondambo making a lively impression.*

Figure 3: *Gem collection at the Andranondambo mine by one of the authors (EG) in early 1996.*

Figure 4: *Sapphire samples obtained from a source in Switzerland (Source C, see text) with eye visible inclusions. On the right, a rock fragment collected at the mines is shown. The section on the left demonstrates how the minerals were prepared for SEM-work.*

first found in meteorites – occurs at Andranondambo together with sapphires (for a chemical analyis of a hibonite from this locality, see Rakotondrazafy *et al.*, 1996). The classical expert in Malagasy mineralogy, Lacroix (1922), stated that corundum is commonly associated with metamorphic rocks. Gem quality corundum has, however, rarely been found up to now and the production was mainly limited to relatively small pieces of low quality. Chikayama (1989) referred to various deposits of cuttable corundum in the southern part of the island, while Koivula *et al.* (1992) were the first to mention a source of multicoloured sapphire south-west of Betroka.

The recently discovered new deposits of pale to saturated blue sapphire are situated in

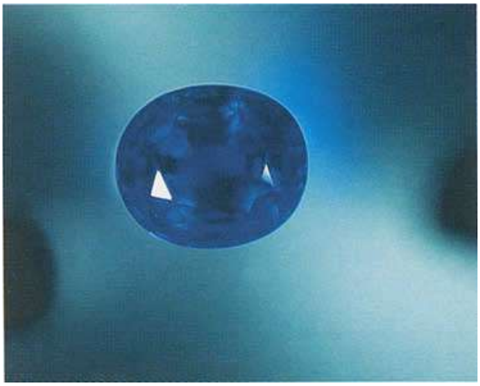


Figure 5a: *Superb royal blue sapphire of about 4 ct (not heat-treated) (Source D, Bangkok).*

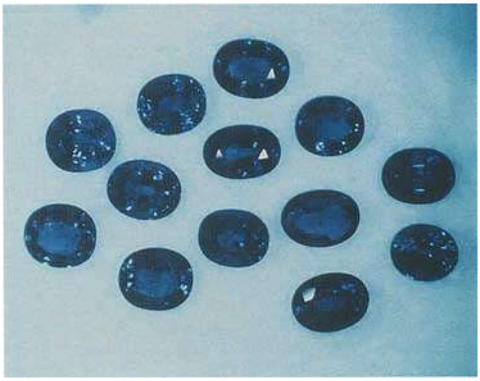


Figure 5b: *Faceted stones (about 1 ct) typical of sapphires after heat-treatment (Source D, Bangkok).*

the south-eastern part of Province Toliara, near the village of Andranondambo, approximately 100 km north-north-east of Fort Dauphin *(Figures 1 and 2).* This source is probably the first large deposit of cuttable sapphire to be found on Malagasy. New mines have been reported by Johnson and Koivula, 1996, and at least three mining companies (a Swiss, a Thai and a joint venture enterprise) have been founded to excavate and market the sapphires.

Kiefert *et al.* (1996), Milisenda and Henn (1996) and Schwarz *et al.* (1996) have described the occurrence, genesis and gemmological properties of the sapphires. But although very characteristic properties of this new material have been established, considerable differences have arisen in the interpretation of the formation of the sapphires. According to Milisenda and Henn (1996), the sapphires were formed by high-grade granulite facies metamorphism of altered marbles and calcsilicate-gneisses. In contrast, Kiefert *et al.* (1996) relate the formation of the sapphires to pegmatites or pegmatite-like veins such as those of the Kashmir mining area (Peretti *et al.,* 1990). Schwarz *et al.* (1996) interpreted the genesis of the sapphires as the result of metasomatism. An in-depth petrographical study of the metamorphic and metasomatic events leading to the formation of hibonite has recently appeared (Rakotondrazafy *et al.,* 1996). This work provides excellent further data on the metasomatic events which occurred in the mining area and which led to the formation of hibonite and other minerals, including corundum, in skarns. The present paper provides further results of inclusion research relevant to the genesis of the sapphires. The material originates from the expedition of one of the authors (EG) to the gem mines in Madagascar including those of Andranondambo in early June 1996 (Source A) *(Figures 3 and 4).* Further rough and faceted specimens and rocks containing sapphires were obtained from Dr D. Schwarz (Schwarz *et al.,* 1996) (Source B), rough material was obtained from a source in Switzerland (Source C, *Figure 4*), faceted samples were acquired in Bangkok, Thailand *(Figures 5a, b)* (Source D) and rocks containing sapphires were obtained through Dr K. Schmetzer (Source E, *Figure 7b*). The research material obtained from sources C and D offer a lesser degree of certainty about the veracity of their origin. However, the authors are confident that all the sapphires are from the new mining area (including the mines mentioned by Johnson and Koivula, 1996). The material was tested by different methods, including XRF-analysis for the chemical composition, SEM-EDS-analysis of solid inclusions and immersion microscopic examination for growth structures, and spectroscopic analysis. Based on comparison with published results (Milisenda and Henn, 1996; Kiefert *et al.*, 1996; Schwarz *et al.*, 1996) some of the most typical characteristics have been summarized below. However, the present report concentrates mostly on analyses of the inclusions in the sapphires. Based on these data and the very detailed petrological framework of the mining area as presented by Rakotondrazafy *et al.* (1996), further conclusions are presented here about genetic aspects of the sapphire formation.

Geological petrographical and tectonic background

Malagasy is the world's fourth largest island. It extends over almost 600 000 km^2 (i.e. ten times the area of Sri Lanka). About 165 million years ago, it separated from Gondwanaland (which is known nowadays as the mainland of Africa) and drifted about 400 km east into the Indian Ocean where it came to a halt, while other subcontinents and continents, such as India and Australia respectively, continued their journey to their present positions. Within the framework of this paper, concentration is centred on the southern part of Malagasy, whose greater part consists of high-grade metamorphic rocks (Milisenda and Henn, 1996, p. 179). These are part of the Proterozoic crust and were metamorphosed to granulite grade during Pan-African times about 500–600 million years ago. These thermotectonic events affected vast parts of Africa, southern India and Sri Lanka (Kennedy, 1964; Kröner, 1980). In the context of Gondwanaland, the granulite of Malagasy formed the eastern part of the Mozambique belt which is interpreted as the result of a continent–continent collision that occurred about 600 million years ago.

According to Rakotondrazafy *et al.* (1996) the Andranondambo mine is situated in the metamorphic rocks of the Proterozoic Tranomaro group located in the south-east of the island. This group consists of varied granulite facies rocks of mainly sedimentary origin such as different gneisses (including pyroxene scapolite gneisses) and calcitic marbles. A schematic diagram of the minerals present in these rocks is shown in *Figure 6a.* Chemical and mineralogical alteration of these rocks by metasomatic infiltration of fluids produces different rocks generally termed skarns. The marbles and calcsilicate gneisses are altered to various skarns *(see Figures 6a and b)*, now mainly composed of impure calcitic marbles, diopside-pyroxenites with variable amounts of scapolite and spinel, pargasite amphibole-rich types and peraluminous rocks made up of plagioclase and/or scapolite with spinel, corundum, hibonite and phlogopite. According to the detailed petrographic framework of Rakotondrazafy *et al.* (1996), the rocks containing the corundum crystals, such as the anorthite-hibonite-spinel-corundum calcsilicates, occur as zones at the contacts

Figure 6a: *Ca–Al–(Fe + Mg) diagram showing minerals and rocks important in the skarns (after Rakotondrazafy et al., 1996).*

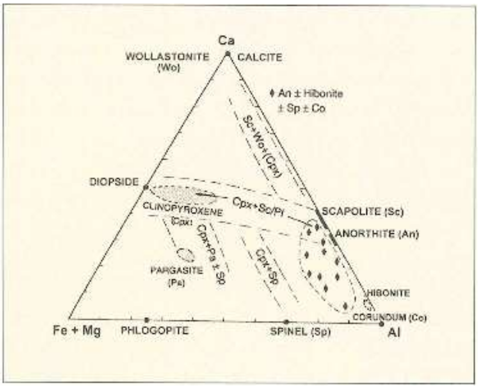
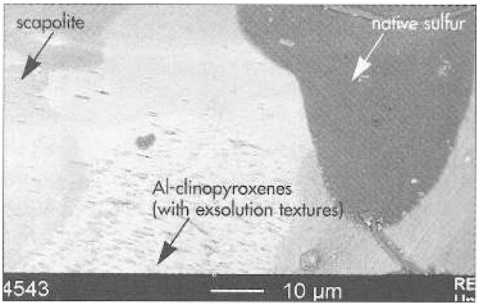


Figure 6b: *Section of scapolite diopside granulite rock collected at the mine (SEM – backscattered image). The dark area is native sulphur, lower centre is aluminous diopside with exsolution lamellae, and scapolite lies in the top left of the picture.*



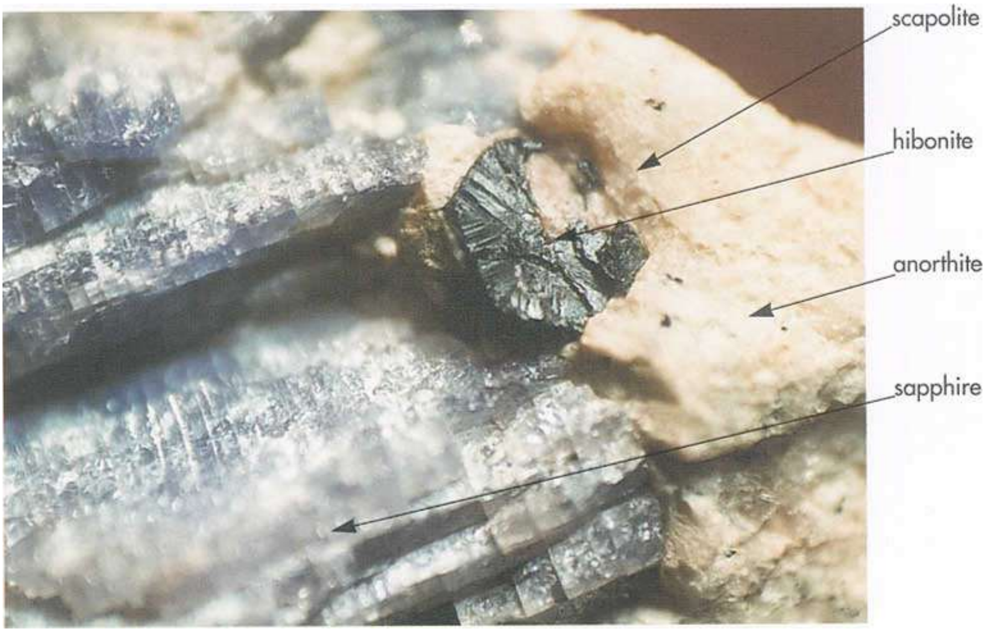
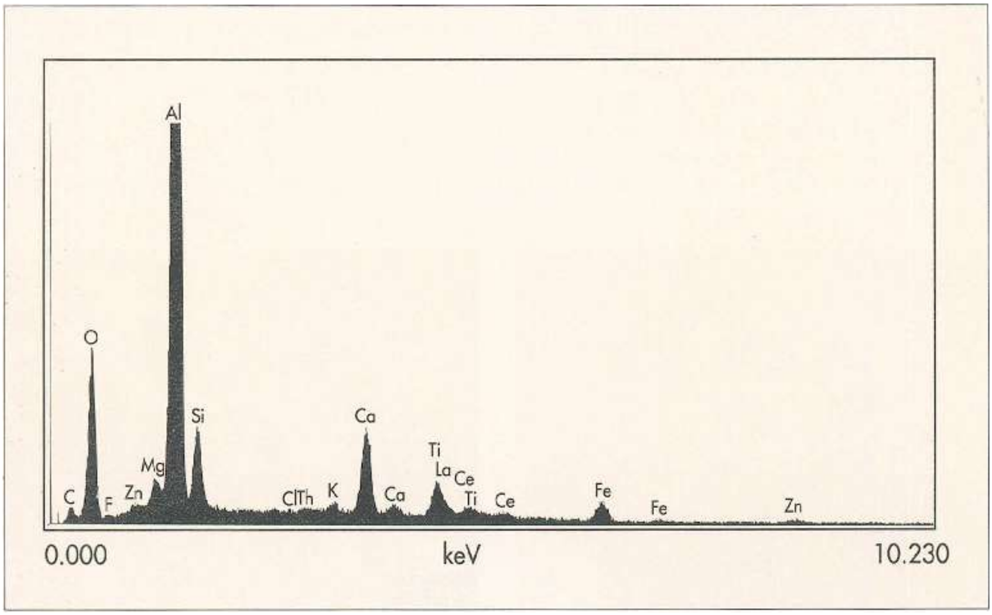


Figure 7a: *Madagascan sapphire (5 cm in diameter) from the Andranondambo mine in the host rock. The sapphire occurs in a skarn rock predominantly composed of anorthite on the right, minor Ca-rich, Cl-bearing scapolite (between anorthite and sapphire in the picture), hibonite (8 mm diameter) adjacent to local nests of calcite, isolated fine-grained local enrichments of spinel, isolated yellowish-green fluor-apatite crystals (up to 5 mm in size, see Figure 15), isolated fluor-phlogopite aggregates, poorly characterized pyroxene crystals and very small blackish crystals with radioactive haloes (most probably thorianite). SEM-EDX analysis of hibonite (see spectrum) gave a composition in weight percent of approx.:* $Al_2O_3 = 72.6$, $MgO = 1.1$, $SiO_2 = 7.4$, $CaO = 6.6$, $TiO_2 = 4.1$, $ZnO = 1.2$, $Fe_2O_3 = 3.1$, $La_2O_3 = 1.6$, $Ce_2O_3 = 2.2$, $Nd_2O_3 = 0.1$, $ThO_2 = 0.2$ *and minor concentrations of Cl and F. Sample from Dr D. Schwarz.*



between marbles and intrusions of granite or charnockite, which is consistent with their metasomatic origin.

The different stages of metasomatism can be summarized as follows (Rakotondrazafy *et al.*, 1996):

Stage 1

Metasomatic transformation of the rocks due to CO_2-rich fluids at relatively high temperatures and medium pressures (850°C and 5 kilobar). Peraluminous and calcium-rich segregations made up of meionite, spinel and corundum are formed within titanite-bearing scapolite-clinopyroxene skarns. Concentrations of REE and Ti were low enough to preclude the crystallization of hibonite and since the quartz activity was below the zircon-baddeleyite-buffer, baddeleyite (ZrO_2) rather than zircon ($ZrSiO_4$) was formed during this phase. Typical, stable minerals are: aluminous diopside, carbonate, scapolite, titanite (sphene) or spinel, thorianite, corundum, baddeleyite.

Stage 2

Metasomatism of the rocks due to the infiltration of F-rich, Ti-rich, and REE-rich fluids at relatively lower temperatures and pressures (approx. 800°C and 3.5 kbar). Reaction of these fluids with corundum and spinel produced hibonite and there was breakdown of meionite into calcite plus anorthite. Quartz activity was below the zircon-baddeleyite-buffer and baddeleyite rather than zircon was formed. Newly formed thorianite (ThO_2) as well as fluor-phlogopite are also typical of this stage. Typical, stable minerals are: fluorine-rich pargasite, anorthite, calcite, thorianite, fluor-apatite, fluor-phlogopite, hibonite and baddeleyite. Later veins containing REE-rich calcites, zircon, titanite, diopside, scapolite and thorianite cut across these skarns.

Figure 7b: *Sapphire-anorthite-phlogopite nodule from the Andranondambo mine. The sapphires are about 10 mm across, calcite is absent but 1 mm crystals of yellow–brown monazite are present plus one unidentified silicate (probably scapolite). SEM-EDX analysis indicates the monazite to be rich in U and Th. (Source E.)*

Due to the unusual mineralogical compositions of the metasomatized rocks described above, their overall chemical compositions are characterized by low concentrations of SiO_2 and high concentrations of Al_2O_3 (Rakotondrazafy *et al.*, 1996). According to these authors, the chemistry is also characterized by a relatively high concentration of Zr, and Zr, Th and U are interpreted as typical, mobile elements in the metasomatism deduced for these skarns. Baddeleyite alone (without zircon) occurs in hibonite-bearing rocks. Metamict Ca–Zr–Ti oxides with variable amounts of Th, U and Nb, with compositions close to that of zirconolite [(Ca, Th, Ce) $Zr(Ti, Nb)_2O_7$] (Bayliss *et al.*, 1989) are also present in rocks containing hibonite. The coincidental occurrence of hibonite and sapphire in the mines at Andranondambo *(Figure 7a)* is confirmed by Kiefert *et al.* (1996), and Schwarz *et al.* (1996).

Figure 8a: *The miners work in narrow deep pits.*

Figure 8b: *Miner prospecting in a pit at the Andranondambo sapphire mine.*

Mining operations

The mining area extends over a hilly region of approximately 2 to 3 km^2 and is squeezed like a wide trough between the mountains of ortho- and para-gneisses to the east and the old Precambrian granites and volcanic rocks to the west. The white skarns exposed at the mines and embedded in the green surroundings of hills and mountains afford a very beautiful sight. In the mining area, the sapphires are found in altered marbles and calcsilicates. At the visited localities, mining is accomplished by very simple means, in that narrow shafts are sunk into the snow-white and hard skarn to 20 and 30 metres depth; they are sunk in great numbers and close together so that only narrow walls are left. This creates a very dangerous landscape. The miners work in small groups using wedges, hammers, crowbars, shovels and buckets on ropes to hoist the loosened rock on to the surface. The calcareous rock is then hammered to ever smaller pieces *(Figures 8a, b and c)* to reveal any gems.

Production and distribution of sapphires from Andranondambo, Malagasy

When one of the authors (EG) visited the village in June 1996 and showed some interest in buying sapphires, he was soon surrounded by a large crowd of miners and village folk showing and offering sapphires, and the

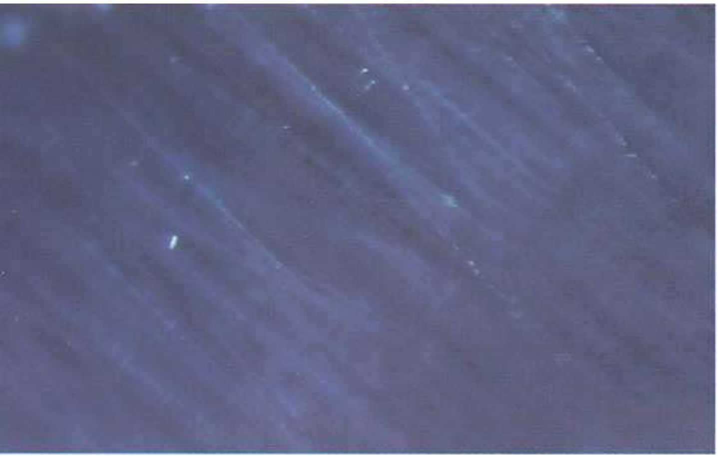
Figure 8c: *Bucket to be filled with excavated material and hoisted to the surface on a rope.*

Figure 9: *Sapphire from Andranondambo (Source A): beautifully developed blue colour phantom. 28x.*

***Figure 10:** Sapphire from Andranondambo (Source A): a striking picture of the structure of the crystal faces which demonstrate a rhombohedral morphology. 40x.*

impression was gained that there were great quantities of gems in the hands of the natives. Most of the stones were small (between 0.5 and 2.0 ct) and of medium to low gem quality, yet good enough for gemmological research *(Figures 9 and 10)*. The occurrence of sapphire crystals at the Andranondambo mine is reported to be erratic and, considering the number of workers on the mine, the output appears to be limited at times. Gem traders are regularly present in the village and mostly acquire the day's spoil from the miners in the evening. The major proportion, estimated by some at 90%, of the production is shipped to Bangkok or Chantaburi for heat treatment and cutting *(Figures 5a and b)*. Dealers report a monthly average of 100 kg of rough, of gem or near-gem quality. The stones seem to be primarily marketed through Thailand. A large proportion of the crystals are less than 4 mm in size, but approximately 15% of the gem quality stones are reported to yield cut gems above 2 ct. To date, a number of 15–20 ct cut specimens have been seen in the trade, with exceptional stones which are even larger (Schwarz *et al.*, 1996). The largest piece of rough Madagascan sapphire, which was found in the first half of 1996 and later appeared in Bangkok, weighs 895 000 ct (17.9 kg), though this was not from Andranondambo.

***Figure 11a:** Exsolved rutile needles as fine dust parallel to growth zones in unheated sapphire from Source B.*



Madagascar sapphires at auction

During the regular examination of goods at the auctions of Christie's and Sotheby's in 1995 and 1996 by one of the authors (AP), a few lots were identified as Madagascar sapphires. Additional market studies were performed in Bangkok. The approximate prices for best qualities without visible colour zoning, without heat treatment, in different shapes of pleasing face-up appearance and not too heavily cut are listed below:

Sapphire weight	*Price*
more than 15 ct	above US $5000/ct
10–15 ct	US $3500–4500/ct
below 10 ct	US $1000–3000/ct
around 1 ct	around US $120 to 200/ct

These figures demonstrate that Malagasy sapphires have rightfully established themselves on the world market.

Growth structures and colour distribution

Growth structures have been extensively investigated by Kiefert *et al.* (1996), and Schwarz *et al.* (1996). The colour of the gems

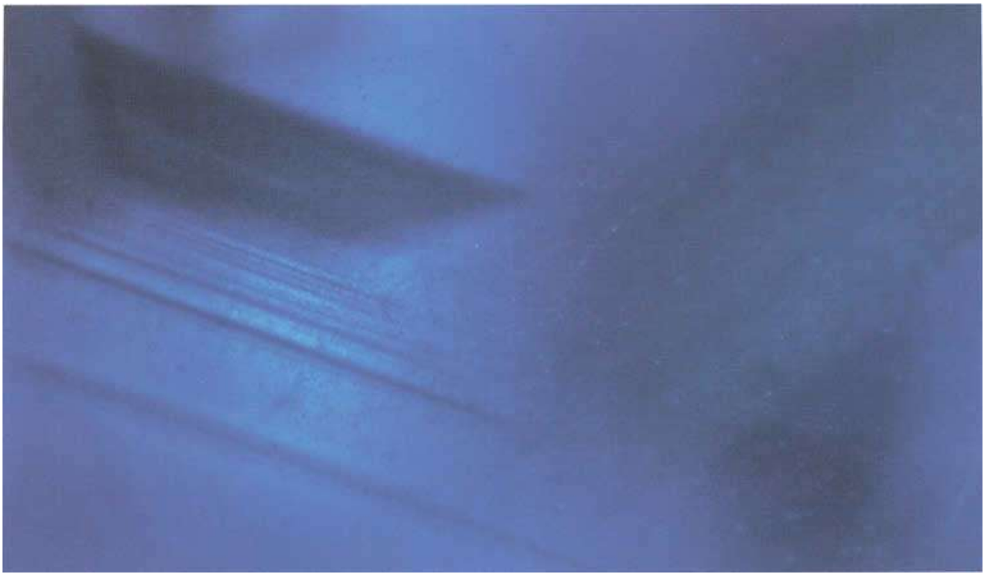


Figure 11b: *Phantom with milky growth structure parallel to basal pinacoid, in unheated faceted sapphire from Source D (typical for Andranondambo sapphires).*

varies from colourless to ordinary blue to fine royal blue *(Figure 5a)*. Some inky overtones may also be present. In most specimens the blue colour is not homogeneously distributed but rather forms blue phantoms or irregular blue patches and zones *(Figure 10)*. This patchy coloration may be evened out by heat treatment resulting in a more homogeneous coloration and improvement in the quality of the hue but colour zoning is commonly still present. Additional features include different types of streamers and 'clouds' as well as rutile needles *(Figure 11a)*. Such inclusions are also very often found in sapphires originating from Kashmir, Burma and Sri Lanka. Most conspicuous at first sight are the blue phantoms and colour zones (Sources A, B and D). The phantoms very often represent a precise replica of the crystal's habit at initial growth stages *(Figures 11b, 12)*. Especially it may be noted that the basal pinacoid is sometimes strongly emphasized by repeated striations parallel to it, inside the phantom. Apart from these, strongly coloured zones running parallel to dipyramids, the rhombohedron and the basal plane may also be observed *(Figure 9)*. Kiefert *et al.* (1996), and Schwarz *et al.* (1996) found that iron was the most common

Figure 12: *Sapphire, Andranondambo, Malagasy (Source A): a blue phantom containing a calcite fragment. 65x.*

Figure 13a: *Sapphire from Source A: negative crystals oriented parallel to the dipyramid n(22$\bar{4}$3) and yellow tablets of K-feldspar. 66x.*

Figure 13b: *Sapphire from Source A: negative dipyramids n(22$\bar{4}$3) aligned along the c-axis, and blue colour phantom. 40x.*

minor element (with 0.12 to 0.61 wt%), followed by Ti (with 0.01 to 0.10 wt%); Ga, V, Cr and Mn are also present in trace quantities (mainly between 0.01 and 0.04 wt%). Our data from representative samples are within these ranges. UV-VIS-NIR-investigations showed a high variability of absorption spectra, commonly assigned to variable contributions of Fe^{2+} and Ti^{4+} as well as Fe^{2+}–Fe^{3+} charge transfers. In conclusion, a wide range of chemical composition and absorption characteristics have been established for the Andranondambo sapphires which overlaps the ranges of observations recorded from a wide variety of other sapphires such as those from Myanmar (Burma), Sri Lanka and Kashmir.

Fluid inclusions

Occasionally, partially healed fractures with net-like patterns of the residual fluid inclusions have been observed. These, as well as the numerous negative crystals which are often aligned along crystal directions, appear to be mostly of monophase character when observed at room temperature, since no gas bubbles have been perceived *(Figures 13a, b)*. Detailed data on the chemical compositions of the fluids, predominantly CO_2, may be found in Bruder (1996), who also recorded occasional diaspore daughter minerals. The homogenization

Figure 13c: *P–T diagram with different isochores (after Rakotondrazafy et al., 1996) and reconstruction of the formation conditions (P,T) for different generations of sapphires and hibonite. Isochores (0.85 and 0.95) for two different generations of primary inclusions in sapphires are included on the basis of fluid densities published by Bruder (1996) (the two isochores constructed by inter- and extrapolation.) Range of A to B is estimated P–T range of sapphire formation (P = primary, S = secondary, Ps = pseudosecondary, Me = meionite).*

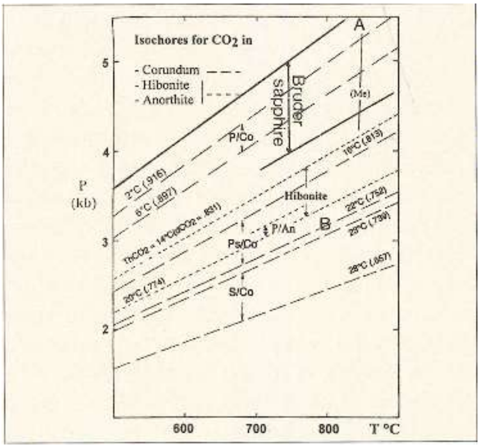


Table I: *Mineral inclusions in Madagascan sapphires (Andranondambo mine) from the literature and this work.*

Minerals found as inclusions in sapphire	*Milisenda and Henn, (1996)*	*Kiefert et al., (1996)*	*Schwarz et al., (1996)*	*This work*
Dolomite	x			
Calcite	x	x	x	x
Spinel	x?	x	x?	x
Hercynite-spinel s.s.				x
Hercynite-spinel-gahnite s.s.				x
Hedenbergite			x	
Mg-hornblende			x	
Feldspar (general)	x?		x	x
K-feldspar			x	x
Plagioclase (not specified)			x	
Anorthite				x
F-phlogopite				x
Phlogopite-annite			x	x
F-apatite				x
Apatite (not specified)	x	x	x	x
Ca-Na-silicates (scapolite?)			x	x
Thorianite-uraninite			x?	x
Baddeleyite				x
Zircon		x		
Zirconolite				x
Rutile	x?		x	
Diaspore (as daughter minerals in fluid inc.)	x?	x		
Clay minerals	x			
Fluorite				x

temperatures for primary inclusions range between 1°C and 19°C (Bruder, 1996), which is the reason that no bubbles are seen in the fluid inclusions above room temperature. Two different generations of primary inclusions were found by Bruder (1996) and additional fluid inclusion data on primary inclusions, pseudosecondary and secondary inclusions were reported by Rakotondrazafy *et al.* (1996). From these data different isochores have been prepared *(Figure 13c)*. It is evident that different generations of sapphires or corundum were formed in different conditions of pressure and temperature (*P* and *T*). Late sapphires grew most probably in similar *P/T* conditions as hibonite, but probably from different fluids, as will be discussed later.

Solid inclusions

The range of inclusions found during these investigations is shown in *Table I* next to those

Figure 14a: *Sapphire from Source A: two light calcite crystals beside botryoidal accumulation of F-phlogopite. 66x.*

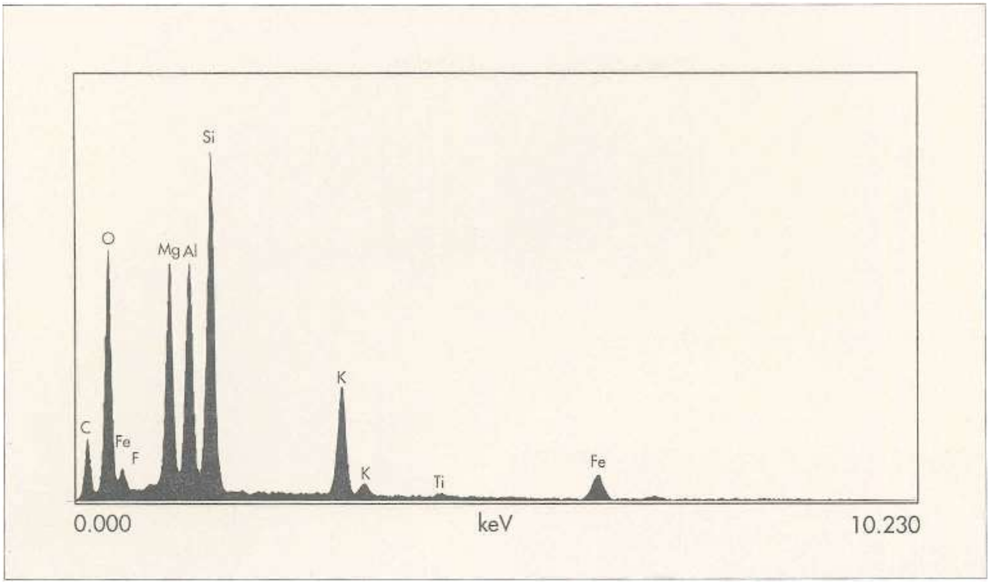
Figure 14b: *Sapphire from Source A: calcite crystals; picture taken with polaroid filter. 66x.*

Figure 15a: *Sapphire from Source A: loose group of whitish inclusions comprising F-apatite, K-feldspars and calcites. 40x.*

Figure 15b: *Sapphire from Source A: group of more or less resorbed, colourless fluor-apatite crystals. 26x.*

found by other authors. In this investigation, inclusions were identified by a combination of optical and scanning electron microscope with energy dispersive system (SEM-EDX) analyses. Mineral inclusions are common and the most abundant in samples from source A – in order of their frequency – are colourless calcite as rhombohedral or rounded, resorbed crystals with many faces and twin planes *(Figures 14a, b)*; hexagonal, more or less well shaped prisms of colourless apatite *(Figures 15a and b)*; red-brown flakes of phlogopite *(Figure 16)*, yellowish tablets of feldspar and black grains of 'thorianite-uraninite' with tension haloes. In contrast to source A, the most abundant mineral inclusion in the samples from source C is green spinel *(Figure 17)*.

Below, new data about the properties of inclusions obtained by SEM-analyses will be discussed. Na-Ca-K-silicates, which could be scapolite or feldspars require XRD-analyses for identification. However, positive identification for meionite



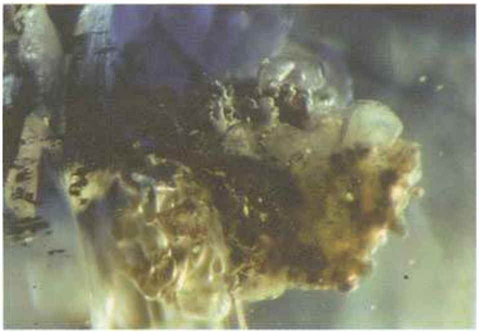


Figure 16: *Sapphire from Source A: botryoidal accumulation of F-phlogopite platelets accompanied by individual calcite crystals. 66x. An EDX spectrum indicates the major element peaks in the phlogopite.*

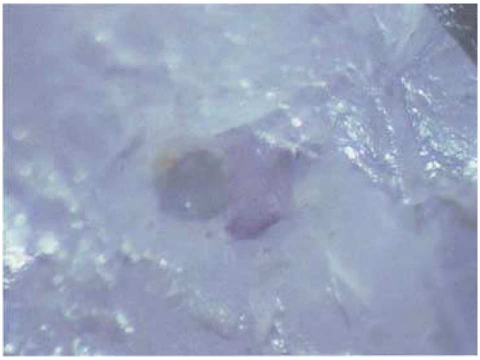


Figure 17: *Green spinel inclusion adjacent to lilac fluorite in a rough sapphire from Malagasy (Source C). Size of spinel is approx. 1 mm. Fluorite identification by SEM-EDX.*

inclusions is possible by combined SEM-analyses and acid testing (see *Figures 7 and 22*).

Baddeleyite (ZrO_2) from Source B

Baddeleyite inclusions were found with Mg–Al–spinel and Ca–Na–aluminosilicates (most probably scapolite and anorthite) in a rough sapphire *(Figure 18)* which had been heat-treated. Some silicate inclusions are transformed by heat treatment, but baddeleyite and Mg–Al–spinel are unchanged because of their very high melting points – above those of corundum.

Although baddeleyite has been discovered recently as an inclusion in a sapphire from a basaltic source, according to Guo *et al.* (1996), it was formed by alteration of zircon and is not considered to be a primary mineral inclusion.

Spinel group minerals from Sources A, B, and C

Spinel occurs in sapphires from each source. The chemical compositions range

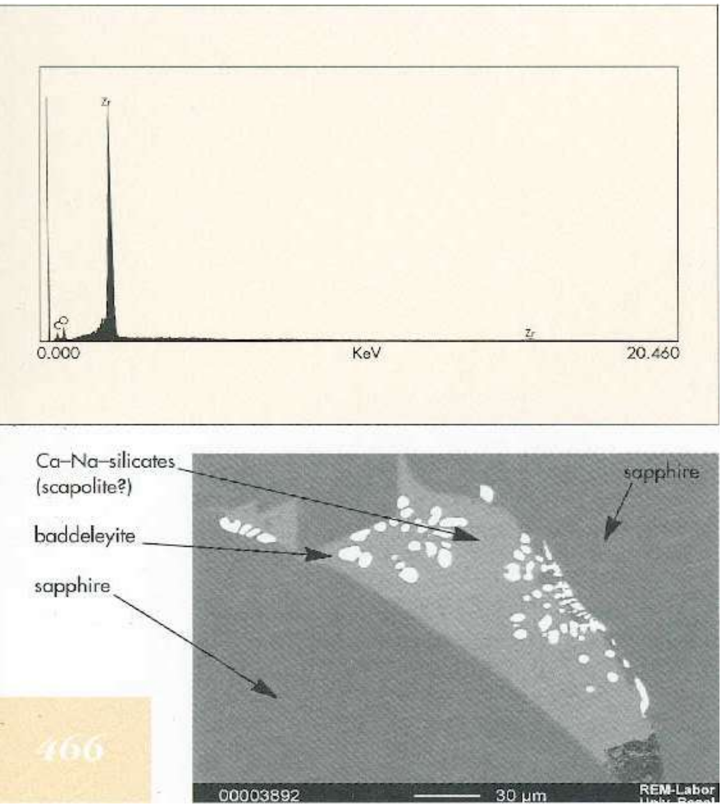


Figure 18: *Backscattered SEM image of baddeleyite inclusion (white) embedded in silicates (grey) in a matrix of a heat-treated rough sapphire (black) from Source A. Above is an SEM-EDX spectrum of baddeleyite (acceleration voltage 30 kV, carbon coated).*

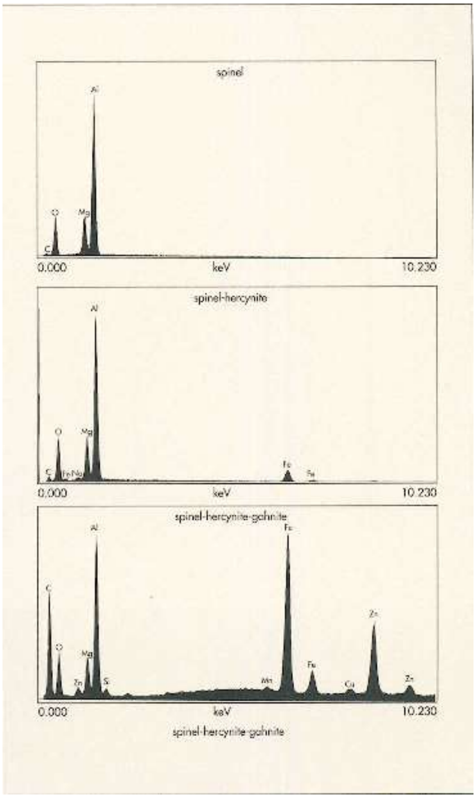


Figure 19: *A range of compositions of spinel group minerals which were found as inclusions in different rough sapphires (spinel, spinel-hercynite, spinel-hercynite-gahnite). SEM-EDX spectra from carbon-coated surfaces using an acceleration voltage of 20kV.*

from those of pure spinel ($MgAl_2O_4$) to green spinel with minor components of hercynite ($FeAl_2O_4$) and black spinel with a range of compositions in the gahnite ($ZnAl_2O_4$)–spinel–hercynite solid solution series *(Figure 19)*.

Thorianite (ThO_2) from Source C

This mineral was confirmed in sapphires only from Source C *(Figure 20)*. Its chemical composition is somewhat variable and results indicate that it lies in the thorianite-uraninite solid solution series in the region below 50 mol–% of the uraninite end-member. One example of a composition determined is: 65 wt% ThO_2, 30 wt% UO_2 and 3 wt% PbO with some traces of other elements.

Zirconolite [(Ca, Th, Ce)Zr(Ti, Nb)$_2$O$_7$] from Source C

'Zirconolite' was found as a minor constituent enclosed in the marginal part of a large rough sapphire from Source C *(Figure 21)*. It was intergrown with thorianite and surrounded by calcite and green spinel. These minerals were part of a minor piece of rock completely enclosed within the large pale-blue sapphire *(Figure 4)*. For details of the complex nomenclature and chemical composition of zirconolite, see Bayliss *et al.* (1989) and Williams and Gieré (1996). When comparing the chemical composition of Madagascan zirconolite included in sapphire to those published in the literature, the former show very

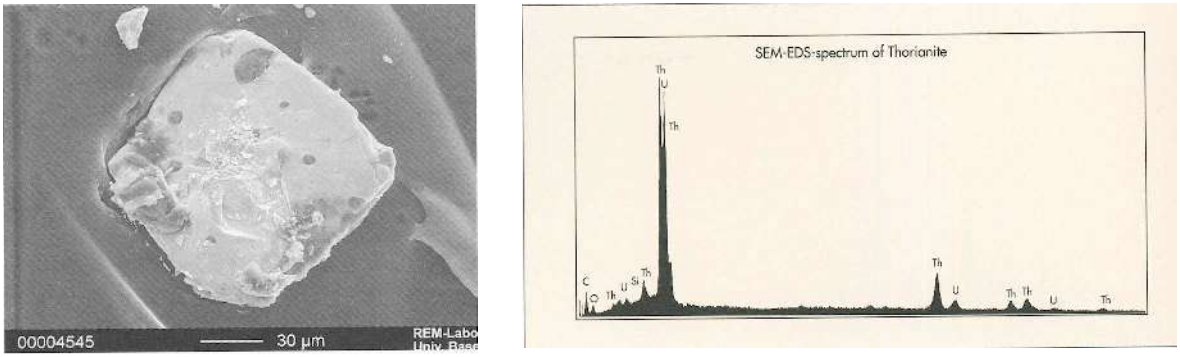


Figure 20: *Secondary electron SEM image of a separated thorianite-uraninite inclusion and its chemical composition (EDX spectrum, acceleration voltage 20kV, carbon coated). The sapphire host is from Source C.*

low Nb and rather high Th- and U-concentrations. They occur as inclusions associated with spinel, calcite and thorianite. Such associations occur in metasomatic skarn and other types of deposit (Purtscheller and Tessadri, 1985; Williams and Gieré, 1996), so this is consistent with the Madagascan assemblage also being of metasomatic skarn origin.

Fluorite (CaF$_2$) from Source C

Purplish fluorite inclusions were found in a rough sapphire from Source C. One of the fluorites was intergrown with spinel (*Figure 17*). Fluorite inclusions have also been found in a ruby from the Mong Hsu mining area in Myanmar (Burma) (Peretti *et al.*, 1996) where they were formed in hydrothermal veins within dolomite marbles at lower temperature and pressure than the Andranondambo sapphires.

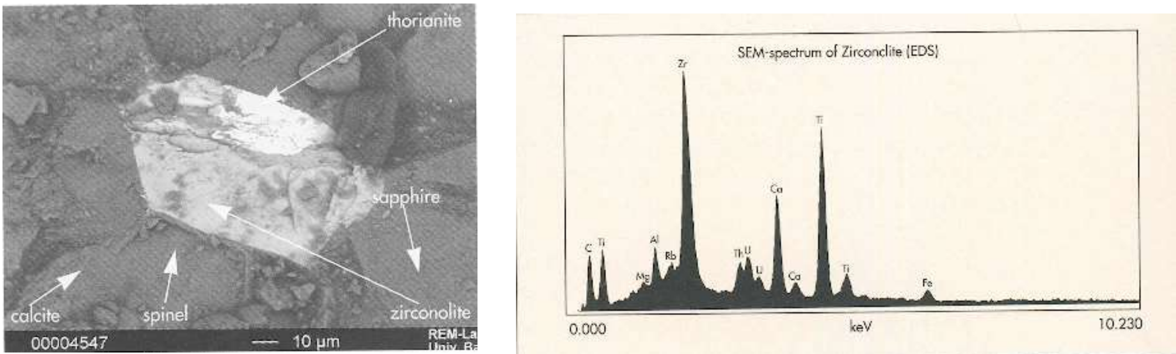
Fluor-apatite [$Ca_5(PO_4)_3(OH, F)$] from Source A

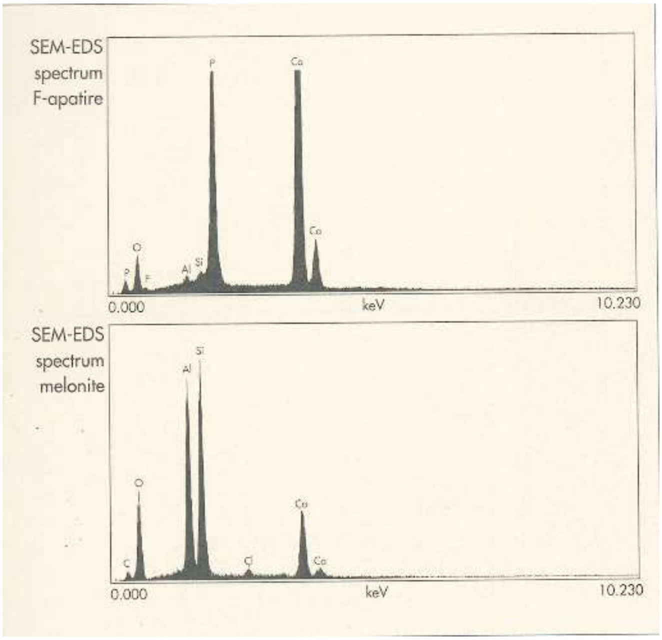
Minor concentrations of fluorine were found in a few of the apatites (*Figure 22*).

Fluor-phlogopite [$KMg_3(Al, Fe)Si_3O_{10}(F, OH)_2$] from Sources A and B

Analyses indicate that with a small content of iron, the mica inclusions lie in the phlogopite-annite [$KFe_3(Al, Fe)Si_3O_{10}(F, OH)_2$] solid solution series. Traces of F and Ti were

Figure 21: *Backscattered SEM image of 'zirconolite' inclusion in sapphire from Source C. Its chemical composition is indicated by the EDX-spectrum obtained with an acceleration voltage of 20kV (carbon coated).*





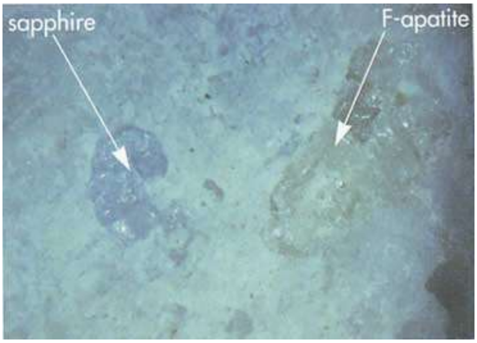


Figure 22: *Yellowish–green F-apatite next to a sapphire within a rock matrix consisting of anorthite and Cl-bearing meionite. EDX spectra of apatite and meionite are shown. Approximately the same F-contents were found in some apatite inclusions in the sapphires.*

also detected in the mica. Similar F-phlogopites were detected in a hand specimen from the Andranondambo mine *(Figures 7 and 16)*.

Calcite ($CaCO_3$) from Sources A, B and C

Calcite has been found in sapphires from each of the sources A, B and C. REE-elements above detection limits of 0.2–0.5 wt-% were not found during analysis.

Quartz from Source C

Although for chemical reasons one would not expect to find quartz inclusions in corundum, in one sapphire from Source C, a quartz inclusion was discovered alongside spinel. No other quartz inclusions have been seen in sapphires from Madagascan sources. It is worth noting that quartz inclusions have also been found in ruby from the mines of Luc Yen in Northern Vietnam (Delé-Dubois *et al.*, 1993), where the rubies occur in veins in marbles.

Summary

A review of the inclusions in sapphires from Madagascar (Andranondambo) which have been found to date is contained in *Table 1*. According to present knowledge, some have been found only in Madagascan (Andranondambo) sapphires, e.g. primary baddeleyite and zirconolite. On the other hand, some inclusions, which are often encountered in sapphires from other deposits, are uncommon in the Madagascan material examined in this study. This, for example, is the case with zircon. Although this mineral was described by Kiefert *et al.* (1996) as an inclusion in Madagascan (Andranondambo) sapphires, it is certainly extremely rare. It is much more common in the sapphires from other localities such as Kashmir, Sri Lanka and various basaltic deposits. Dolomite inclusions (except as listed in *Table 1*) were not found in this study, either in the mother rock or as inclusions in the sapphires. This demonstrates the distinctive genetic character of the skarn deposits at Andranondambo. Some inclusions, such as various types of Ca–Na–aluminosilicates, need further work to confirm their identities. In one sample, Ca-rich scapolite (meionite) could be identified by SEM-EDX analyses because of its high Cl-concentration and by its reaction to HCl *(Figures 7 and 22)*. Also, although hibonite occurs in some skarns *(Figure 7)*, it has not been reported as an inclusion in the Madagascan sapphires.

Conclusion

Mineral inclusions in the sapphires from the new mining area in southern Malagasy (Andranondambo) include carbonates (calcite), F-bearing minerals (F-apatite, F-phlogopite, fluorite), zirconium-bearing minerals (baddeleyite, zircon, zirconolite), Ti-bearing minerals (zirconolite, rutile, F-phlogopite), calcalkali silicate minerals (K-feldspar, plagioclase, scapolite), thorium and uranium phases (thorianite and zirconolite), hydrous minerals (Mg-hornblende, diaspore), phosphates (apatite) and various spinels in the system Mg–Al–Fe–Zn–O *(see Table I)*. This mineral association is typically found in rocks generally described as Th–U skarns. Therefore, these skarns are considered to be the most likely host rocks for sapphire formation which were produced by circulating fluids and mineral reactions within calcsilicate marbles.

Considering the different types of inclusions found in the sapphires and comparing them with the different generations of skarns (Rakotondrazafy *et al.*, 1996), the formation of sapphire can be more clearly defined. Mineral inclusions in sapphire can be related to at least two metasomatic events: the first event typically includes spinel and the second event is characterized by calcite, F-phlogopite and anorthite. Corundum (sapphire) therefore most probably formed during both phases of metasomatism. The published data on fluid inclusion analyses support this idea as different generations of CO_2-rich fluids are also present (see also Bruder, 1996). The variable formation conditions for the different corundum generations may be deduced from the data published by Bruder (1996) and Rakotondrazafy *et al.* (1996), ranging from approximately 850°C and 5 kbar (stage I) to lower temperatures and pressures of approximately 800°C and 3.5 kbar (stage II). The later metasomatic event is characterized by fluids rich in fluorine, titanium, and zirconium and mineral inclusions containing these elements (e.g. zirconolite and fluorite) are present in the sapphires.

Hibonite does not seem to have been formed with the first generation of sapphire but was formed during the later phase of the metasomatic event II from fluids rich in Ti, F, CO_2, and REE-elements. It has been demonstrated by Rakotondrazafy *et al.* (1996) that hibonite is formed from corundum by reaction with mineralizing fluids.

On the basis of this study of inclusions, metamorphic granulite facies metamorphism alone is not a likely model for the formation of the Andranondambo sapphires because at the time of formation of the sapphires, elements such as Th, U, K, Ca, Na, Mg, Al, Si, P, Fe, Mg, Zn, Zr as well as Cl, F and Ti must have been mobile. As suggested by Schwarz *et al.* (1996), sapphire formation seems to be best explained by metasomatic processes which are observed in the U–Th skarns within granulitic rocks (Rakotondrazafy *et al.*, 1996).

While most of the sapphires seem to have formed in a skarn environment, it is possible that other formation processes for sapphires may also have been active in other zones in the mines. Some indications of this are given by the presence of zircon as an inclusion (Kiefert *et al.*, 1996) and quartz (present work), which may have formed in later veins not equilibrated with the skarn rocks.

In conclusion, we have found no indication of formation of sapphires within a pegmatite-like vein environment as proposed by Kiefert *et al.* (1996), and the possible similarity between the Madagascan and Kashmir sapphires is now not thought to be significant. It is much more likely that the majority of Andranondambo sapphires were formed in a skarn environment.

Acknowledgements

We would like to thank Professor W. Stern (Geochemical Laboratory, University of Basel, Switzerland) for ED–XRF analyses, the SEM Laboratory (University of Basel, Switzerland) for scanning electron microscope analyses, Dr D. Schwarz (Gübelin Gemmological Laboratory, Switzerland) and Dr K. Schmetzer for providing specimens and stimulating discussions, and Fred Mouawad (Mouawad Jewellers, Geneva) for providing faceted gem materials.

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A unified system for classifying garnets

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ABSTRACT: Gem garnets are essentially solid solutions and compositions can be derived from refractive index data. Consequently, gemmological determinative tables can be greatly simplified by adopting a unified definition of a 'gem garnet species' as one containing 70 mole per cent or more of an end member. A simple new determinative table reflecting this concept is presented.

Garnet species classification

Although there will always be comments from mineralogists about nomenclature and the definition of a species, Stockton and Manson's (1985) paper put the matter on the line when they published their 'explicit gemmological definition' of species. It is now more than twelve years since publication of the 1985 definition and this author has yet to find any published disagreement with it. Silence gives consent (Goldsmith).

Whereas in the 1970s Webster dealt with five species of gem garnets, in 1985 Stockton and Manson introduced three more. In 1995, Johnson *et al.* added another. Simultaneously, a new generation of gemmologists has grown up familiar with that concept. Now it must be recognized that these 'new species' are a *fait accompli.*

Refractive index

The reason refractive index values are so useful is that, for practical purposes, most gem garnets can be considered as belonging to simple binary series. One great value of Stockton and Manson's study (1985) lies in its confirmation of this fact.

Previously, it had been believed by many that expensive elemental analyses were required to enable one to usefully classify a garnet. Consequently, arbitrarily set dividing lines were established in the different classifications to separate the different fields or categories occupied by each garnet species. Stockton and Manson (1985), after analyzing over 200 specimens, continued to use this approach for their new species.

Now it is recognized that useful compositional data can be derived from refractive index values. 'A good estimate of a given stone's composition can be made by measuring its refractive index and interpolating between [end-members]' (Johnson *et al.,* 1995). Of course, spectral properties and/or colour are first used for deciding which series is appropriate. This aspect has been adequately covered in the two previous references.

Defining limits of species

The problem to be dealt with in this paper is that of how one defines where an *end-member* species ends and a *mixed garnet species* begins. Granted, the initial decision is an arbitrary one. However, it is based on consistent proportions related to chemical

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composition, and its validity and utility should be readily apparent.

With any three-category series of a two-component system (i.e. end-member/mixture/end-member), two methods of dividing them come to mind: (a) divide the series into three equal parts of 33.33 per cent each; or (b) make the divisions at the 25 per cent and 75 per cent lines and have the mixture encompass the middle 50 per cent.

While the second alternative appears more attractive to this author, there is strong evidence that the trade, given the choice, prefers to deal with an 'end-member' over a 'mixture'. This is confirmed by the work of Stockton and Manson whose arbitrary boundaries reflect an acceptance of 70 mole per cent composition for their *end-member species*.

Therefore, it is proposed to 'draw the line' at 30 per cent and 70 per cent and adopt the following 'Rules':

1. if a garnet contains 70 per cent or more of the 'molecules' of one end-member, it shall be called that end-member;
2. if a garnet contains more than 30 per cent but less than 70 per cent of each of the 'molecules' of two different end-members, the names of the end-members will define the mixture.

Keeping with tradition, *mixed garnet species* will bear the following names: pyrope-almandine, pyrope-spessartine, almandine-spessartine and grossular-andradite. It is understood that the order of the names is an arbitrary one and does not necessarily reflect the ratio of the two components, as explained by Johnson *et al.* (1995).

Any three or more component garnets in which the end-member compositions are approximately equal shall be called by the three or more component name.

Benefits of unified system

Perhaps the greatest advantage for utilizing this unified approach is that it will, for the student, simplify the determinative tables for gem garnets. Given an unknown garnet, the investigator examines the colour, using the hand spectroscope if necessary, to determine the series to which it belongs. Then the refractive index is determined.

The following table defines the RI limits for the current *mixed garnet species* on the 70:30 basis:

Mixed garnet species	*Calculated refractive indices**
Pyrope-almandine	1.747–1.794
Pyrope-spessartine	1.740–1.780
Almandine-spessartine	1.816–1.824
Grossular-andradite	1.778–1.839

*see formula below

If the measured RI is below the limits of the mixture, the unknown is classified as the lower RI end-member. If the RI is higher, the unknown is classified as the higher RI end-member.

For example, both RI and end member composition data reported by Johnson *et al.* (1995) showed the lively greenish Mali garnets, which they classified as grossular-andradite, should be classified under this scheme as grossular. Their brown specimens, however, do cross the border into the grossular-andradite category.

Conversion of RI to composition or composition to RI can be done by means of the following formula using the appropriate end-member RI values:

End member garnets	*Refractive indices*
Pyrope	1.714
Almandine	1.830
Spessartine	1.800
Grossular	1.734
Andradite	1.887

Garnet refractive index = [0.01] {[(mole % of end-member A) (RI of end member A)] + (mole % of end-member B) (RI of end-member B)]}

If analytical results show the presence of more than two end-members, simply add additional terms. The total mole per cent should equal 100. Calculations can frequently be approximated for small (<10%) components by combining pyrope with grossular and/or almandine with spessartine.

Conclusion

This approach will help to make gemmological terminology more straightforward by defining the criteria for differentiating an *end-member species* from a *mixed garnet species*.

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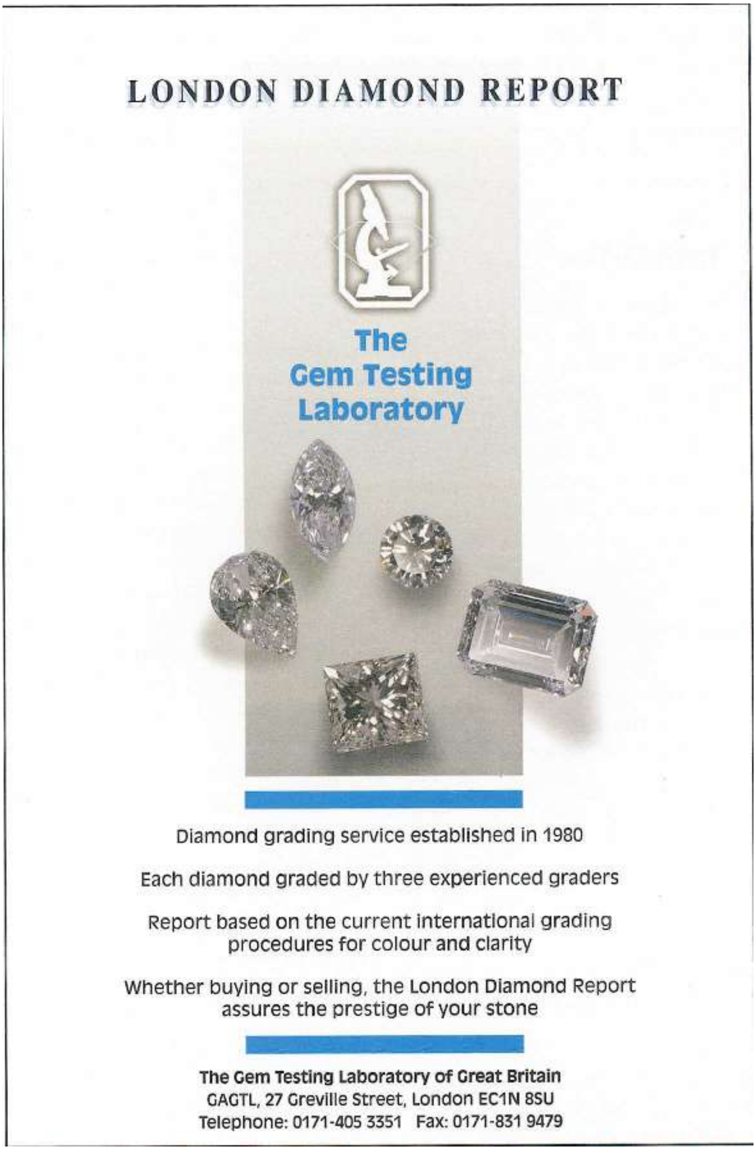

Gems of Sri Lanka: a list of cat's-eyes and stars

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ABSTRACT: Twenty-eight cat's-eye and star gemstone varieties from Sri Lanka are listed. In addition to the usual chatoyancy and asterism, they show twenty-six different but related effects, from multi-chatoyancy and asterism to complex networks of optical reflections.

Keywords: gemstones, Sri Lanka, chatoyancy, asterism, optical effects.

Introduction

From ancient times, local cat's-eyes (mainly chrysoberyls) and star stones (mainly corundums) have been successfully traded in the global gem and jewellery market. Unfortunately, lesser-known gems of other mineral species have been largely ignored, reducing them to near redundancy. This article reports on virtually all the known Sri Lankan cat's-eyes and stars, with the purpose of making the reader aware of their existence, and of allowing the dissemination of information to establish a market share for these stones.

The many effects of chatoyancy and asterism of the gemstones in the following list only permits a brief description for each stone. For the same reason, although unusual phenomena are listed, the causes or mechanisms of some unusual patterns of chatoyancy and asterism have not been discussed.

Unusual features of chatoyancy and asterism

In additional to the more regular appearance of the effects of chatoyancy and asterism *(Figure 1a, d and e)*, certain species can display additional rays to their usual six-ray reflection pattern; for example, in corundum the total number of rays in the star is a multiple of six and as the total increases beyond 24 the star merges into a spot of light. Other examples are known from spinel and quartz *(see Figure 1i and j)*.

A second kind of unusual feature concerning reflections within a gemstone is the occurrence of more than one independent star, visible simultaneously only within narrow angles of observation (see corundum, *Figure 1p, q, r and s*). Each star is of generally similar pattern.

There are also cat's-eyes or stars with rays which appear to be split into two or three parallel segments; for example, in corundum, *Figure 1l and m*, and other examples are: quartz, moonstone, kornerupine or scapolite.

Networks of stars may occur throughout a stone and naturally the star configurations vary with the species. Numerous bands may occur within these stones along different directions and may intersect to create two kinds of networks, one with exclusively four-ray stars and the other with both four-ray and six-ray stars; for example, chrysoberyl, spinel, garnet, quartz, hypersthene and scapolite.

Finally, some varieties also display chatoyancy in transmitted light and these include moonstone, kornerupine and iolite.

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Table 1. *List of cat's-eye and star gemstones*

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
Actinolite (amphibole group)	Cat's-eye	Dark greyish-brown, translucent to opaque	Rare	Strong chatoyancy
Almandine (garnet group)	Cat's-eye	Red, dark red, pink, brown colour shifts to red under tungsten light	Rarer than garnet stars	
	Four-ray star network	Deep wine red, orange red	Rare	Absorption lines attributable to almandine in the spectrum are stronger in deep red than in orange-red stones
	Four- and six-ray star networks[1]	Deep red, orange-red, brown colour shifts to reddish-brown under tungsten light, and may turn lemon-green under transmitted fluorescent light	Rare	One of the three bands in each six-ray star in the network is invariably weak. This is a characteristic feature
Apatite	Cat's-eye	Yellowish-green	Rare	
Aquamarine	Cat's-eye Six-ray star	Sea blue Sea blue	Rare Very rare	
Chrysoberyl	Cat's-eye	Yellow-green, honey-brown, green (including alexandrite), brown and black	Common	
	Four-ray star	Honey-brown, transparent to translucent; greenish-grey, opaque	Rare	Two bands of the star intersect at oblique angles
	Six-ray star	Pale yellow, translucent; greenish-grey, opaque	Very rare	Chrysoberyl is orthorhombic and a six-ray star may arise possibly from twinning (trilling) and appear hexagonal
	Four-ray star network	Yellow-green, honey-brown, lemon-yellow, green (alexandrite)	Rare	A common band is cut at right-angles and at regular intervals by a series of other bands
Corundum (including ruby and sapphire)	Narrow cat's-eye	Red (ruby), light blue, greyish-milky-white	Very rare	
	Broad cat's-eye	Light greenish-blue, light pink with a colour shift to medium pink in tungsten light	Rare	See six-ray star array below
	Six-ray star	Body colours – red, blue, pink, colourless, milky-grey, milky-white, yellow, orange, padparadscha, purple, lavender, green, black, blackish-copper-brown, other colours. With strong dichroism – blue-yellow, blue-yellowish green, other combinations. Parti-colours – red-blue, blue-pink, blue-yellow,	Common, greyish-blue is the commonest colour within the variety	There are three sets of parallel needle-like crystal inclusions (probably rutile) oriented at 60° to each other in the direction parallel to (0001) of the . corundum

Table 1. (Continued)

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
		yellow-green, blue-yellow-green, other colour combinations. Colour change between daylight and tungsten incandescent light – blue to pink, green to red, purple to pink, brown to red, respectively		
	Twelve-ray star	Body colours – red, blue, yellow, milky-white, black, blackish-copper-brown. Parti-colours – blue-yellow-green, other colour combinations. Colour change between daylight and tungsten light – blue to pink, purple to pink, green to red, respectively	Varies with the colour. Blackish-copper is the commonest. Colour change green to red type is the rarest	Close examination of the twelve-ray star reveals an overlap of two six-ray stars, which are generally of two different colours, sizes and intensities
	Eighteen-ray star	Blackish-copper-brown	Rarer than twelve-ray stars	
	Twenty-four ray star	Blackish-copper-brown	Rarer than eighteen-ray stars	
	Six-ray chaotic star	Blue, light-blue, milky-blue, grey	Rarer than single six-ray stars	Parts of rays appear in discontinuous patches in such a way that collectively they show a six-ray star
	Six-ray star twins	Blue, metallic-copper-brown, milky-white	Rare	Two independent six-ray stars, often with more or less similar qualities, are seen side by side in the same polished face of the stone. The boundary between the two stars is jagged; when the stone is tilted under an overhead light source, both stars move, and always one star disappears or reappears progressively at this boundary. Generally, corresponding rays of the two stars are parallel to each other
	Twelve-ray star twins	Metallic-copper-brown	Extremely rare	Structural details are similar to those commented on in six-ray star twins
	Six-ray star triplets	Light-blue	Rare	Structural details are similar to those commented on in six-ray star twins
	Six-ray star array	Metallic blackish-copper-brown	Rare	This is a series of six-ray stars located

Table 1. (Continued)

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
				close to each other with their centres forming a straight line. Where the stars are too close their identities are lost and they emerge as mere spots of light. Collectively they form a broad chatoyant band (see Broad cat's-eye above). Structural details are similar to those outlined for six-ray star twins above
	Twelve-ray star	Light blue	Very rare	This is the usual six-ray star, but each ray is split into two parallel segments
	Eighteen-ray star	Light blue	Rarer than twelve-ray star	This is the usual six-ray star, but each ray is split in to three parallel segments
	Eighteen-ray star	Pale greyish-green, translucent	Very rare	This is the usual six-ray star, but each ray is split into three segments which meet at the centre of the star
Diopside (pyroxene group)	Cat's-eye	Pale yellowish-green, brownish-brandy colour	Rare	There are characteristic spots of light on the chatoyant band apparently at regular intervals
	Four-ray star	Black-opaque, grass green — semi-transparent	Black type is common, green is rare	Black type found in abundance in India
	Eight-ray star	Black-opaque	Very rare	
Ekanite	Four-ray star			This mineral may exhibit a weak asterism.
	Six-ray star			The stones are black in reflected light and grass green in transmitted light.
	Eight-ray star			These stones are rare. There are four sets of linear, red-brown inclusions in four orientations, and they intersect in three dimensions at 45° to each other
Enstatite (pyroxene group)	Cat's-eye	Colourless, brown or light green	Rare	
	Four-ray star			
	Six-ray star			
	Eight-ray star			
Epidote	Cat's-eye	Deep brown, translucent	Very rare	

Table 1. *(Continued)*

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
Feldspar (alkali feldspar and plagioclase)	Four-ray star	Light-green, orange	Rare	
Hypersthene (pyroxene group)	Four- and six-ray network	Reddish-brown, translucent	Rare. The main source at Embilipitiya is now exhausted	The star configuration of the network is under study
Iolite (cordierite)	Cat's-eye	Greyish, translucent	Rare	Some stones exhibit strong chatoyancy under transmitted light also
	Four- and six-ray star network	Trichroic: deep purple-brownish yellow-yellow	Rare	Weak star net-work. The star configuration of the network is under investigation. Six-ray stars of the net-work are invariably oriented along the direction of the deep purple colour
Kornerupine	Cat's-eye	Black-opaque, honey-brown, yellow-green, greyish-brown. Stones other than black range from transparent to translucent	Rare	Rarely stones show a faint chromium absorption line in the red region of the spectrum
	Two-band cat's-eye	Honey-brown, translucent	Very rare	One chatoyant band is golden and the other is silver. Exhibits chatoyancy under transmitted light also
Monazite	Cat's-eye	Pinkish-brown with mottled appearance, translucent to opaque	Rare	Chatoyant band is of milky white colour
Moonstone (feldspar group)[2]	Two-band cat's-eye	Turbid white, semi-transparent	Rare	One band is golden and the other is silver. The two-band cat's-eye may be seen under transmitted light also
	Six-ray star	Turbid white, semi-transparent	Rare	This is the same two-band cat's-eye mentioned above, but the two bands are intersected at nearly 90° by a third silver band to form the star
	A star combination	Brownish-yellow, semi-transparent	Rare	Both eight- and four-ray stars mutually share a band. The same star combination is repeated on the other side of the stone *(Figure 2)*, but the positions of the two stars are changed along the common band. This common band and the two

Table 1. *(Continued)*

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
				bands perpendicular to it are of silver colour, whereas the other two inclined bands are golden *(Figure 1u)*
Phenakite	Cat's-eye and four-ray star	Colourless with brownish tint	Rare	
Quartz	Cat's-eye	Colourless, reddish-brown, blackish-green, pale green	Rare	Large specimens over 100 carats have been reported
	Cat's-eye aggregate	Brownish with milky white, translucent	Rare	Several cat's-eyes differently oriented within the stone arise from many crystal individuals in an aggregate
	Four- and six-ray star network	Colourless, milky white, milky pink	Rare	
	Discontinuous four- and six-ray star network	Colourless, milky white, milky pink	Rare	Rays of each star may or may not link with other stars of the network, and therefore the network does not maintain a continuous order as in the type above
	Eighteen-ray star	Milky pink	Rare	
	Eighteen-ray star	Milky white	Very rare	This is an ordinary six-ray star, but each ray is split into three parallel segments
Rutile	Cat's-eye and four-ray star	Stones are greyish-black and nearly opaque, with high metallic lustre. Some are strawberry-red under transmitted light.	Cat's-eyes are rare. Stars are very rare	
Scapolite	Cat's-eye	Colourless-transparent, light yellow-transparent to translucent, black-opaque	Rare	
	Two-band cat's-eye	Greyish, transparent	Rare	Displays a two-band cat's-eye in transmitted light also
	Four- and six-ray star network	Black to grey, semi-transparent	Rare	
Scheelite	Cat's-eye and four-ray star	Turbid material. Colourless with yellowish or brownish tint, translucent.	Rare	
Sillimanite (gem variety known as fibrolite)	Cat's-eye	Colourless, greyish, reddish-brown, green	Rare	Very strong chatoyancy. Abundant supply of cat's-eye fibrolites from Orissa (India)
Sinhalite	Cat's-eye	Golden brown, transparent	Very rare	Silver chatoyant band caused by rutile needles *(Figure 3)*

Table 1. (Continued)

Species	Optical feature	Colour	Degree of abundance or rarity	Comments
Spinel	Cat's-eye	Light blue, pink-mauve, transparent; deep blue, translucent	Very rare	*(Figure 4)*
	Four- and six-ray star network	Blue, green, mauve, milky grey, transparent to translucent		Rare
	Twelve-ray star	Greyish-brown, translucent	Extremely rare	Observations were made on the single fine specimen recorded so far *(Figure 5)*
Taaffeite	Six-ray star	Brownish mauve	Very rare	Weak asterism
Topaz	Cat's-eye	Colourless with a tint of yellow, transparent	Rare	The cat's-eye effect is caused by long, parallel, blade-like, sillimanite inclusions along the length of the prismatic topaz crystal with a slight inclination of about 7° to the crystallographic axis. There is an absorption band in the blue-green region of the spectrum of the stone
Tourmaline (Uvite)	Cat's-eye	Deep brown, brownish-green, transparent to translucent	Rare	Cat's-eye is caused by needle-like parallel inclusions oriented parallel to the c-axis of the host crystal
Zircon	Cat's-eye	Colourless, flame orange, green. Heat-treated: colourless, grey, brownish-yellow, and greenish-yellow	Rare. Production of cat's-eyes by heat treatment has affected rarity	Similar to diopside cat's-eye; there are characteristic spots of light on the chatoyant band at more or less regular intervals

[1] Colour change garnets found in Ethiliwawe, Theliulla, Wellawaya deposit (1995-1997) rarely produced stones with this star network. Dark blackish greyish green colour of these stones changes to purplish-red under tungsten light.

[2] In addition to these three effects, other kinds of chatoyancy and asterism are displayed by moonstone which are either: Type A. an extension of the 'sheen effect', which naturally occurs along the same direction of sheen (the rays are silver, broad, diffused, and not well defined; the body colour of the stone is whitish, translucent; the stones are rare); or Type B. occur along a direction at nearly 90° to the direction of the sheen effect (the rays are golden, very sharp, intense and well defined; the body colour of the stone is brownish-grey, with bluish sheen, and semi-transparent; the stones are rare)

Cat's-eye: Types A and B

Four-ray star: Types A and B

Six-ray star: Type B

Eight-ray star: Type B

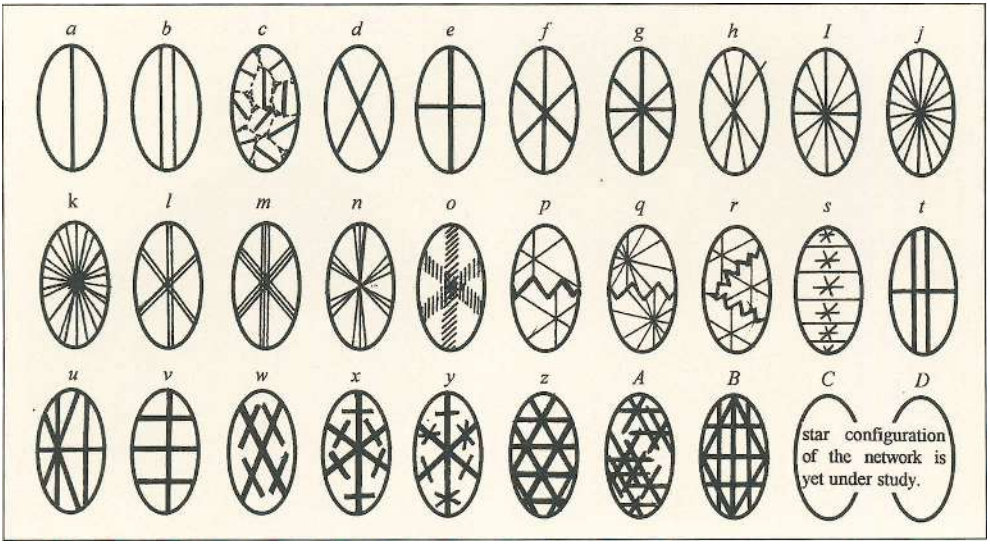

Figure 1: *A compilation of optical effects including chatoyancy and asterism observed in gemstones from Sri Lanka. Actinolite (amphibole group) a; almandine (garnet group) a, w, B; apatite a; aquamarine (variety of beryl) a, f; chrysoberyl a, d, f, v; corundum (including ruby and sapphire) a, f, i, j, k, l, m, n, o, p, q, r, s (Type A), s (Type B); diopside a, e, h; ekanite e ,f, g; enstatite (pyroxene group) a, e, f, h; enstatite, gem variety of hypersthene (pyroxene group) C; epidote a; feldspar (alkali feldspar and plagioclase) d; iolite (cordierite) a, D; kornerupine a, b; monazite a; moonstone (feldspar group) a (Type A), a (Type B), b, e (Type A), e (Type B), f, g, t, u; phenakite a, d; quartz a, c, j, m, z, A; rutile a, d; scapolite a, b, x; scheelite a, d; sillimanite (gem variety of fibrolite) a; sinhalite a; spinel a, i, y; taaffeite f; topaz a; tourmaline (uvite) a; zircon a.*

Figure 2: *Moonstone star combination.*

Figure 3: *Sinhalite cat's-eye. Only specimen recorded up to mid-1997.*

Figure 4: Spinel cat's-eye.

Figure 5: Twelve-ray star spinel. Single fine specimen recorded so far.

Concluding remarks

Patchy chatoyancy and asterism caused by parallel needle-like rutile inclusions have also been observed in Sri Lankan danburite, andalusite, sapphirine, vesuvianite and cassiterite. Therefore, it is likely that these gem species with well developed cat's-eye and star effects will be discovered in due course.

A recent study of topaz has revealed two sets of long, parallel, blade-like sillimanite crystal inclusions inclined at about 20° to each other. Consequently, it could be predicted that topaz with a four-ray star and a similar angle between the two bands may be found.

Fibrolites with very strong six-ray stars have been reported from Orissa, India *(Figure 6)*. Therefore, it is highly probable that similar stones may be found in Sri Lanka.

Chatoyancy and asterism are not mere accidental effects, they are ordered phenomena related to the crystallography of the host stone. Therefore, no natural amorphous material should show these effects with the possible exception of the metamict, ekanite and zircon. The occurrence of asterism in ekanite and the metamict zircons is the strongest evidence that the original materials were crystalline.

Figure 6: Six-ray star fibrolite from Orissa, India.

Acknowledgement

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The chronology of synthetic gemstones

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ABSTRACT: A detailed chronology of the various stages leading from initial experimental work to industrial production is presented for all of the gemstones that have been synthesized to date. Such information can be important for appraisal and authentication purposes.

Introduction

A chronology of synthetic gemstones is presented. Included are, for example, the first experimental growth of: emerald by J.J. Ebelmen (France, 1848); quartz by H. de Senarmont (France, 1851) and G. Spezia (Italy, 1898, *see Figure 1*); and ruby by E. Fremy and A.V.L.Verneuil (France, 1891, *see Figure 2*). Early commercial producers of ruby included the 'Geneva' product (Switzerland?, 1885; *see Figure 3*) and A.V.L. Verneuil and the Société Hellerite

Figure 1: *A natural quartz crystal, 25 mm long (above) and the same crystal after a five months' growth experiment (below) by G. Spezia in 1908 in Italy. Photo courtesy of E.A. Wood.*

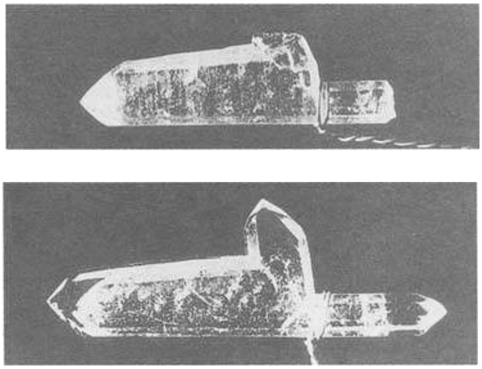

Figure 2: *An illustration from Fremy's 1891 hand-coloured book showing synthetic rubies in a crucible and experimental jewellery made from the product. The rubies grew only as small thin platelets up to 3 mm across and 0.33 carat in weight.*

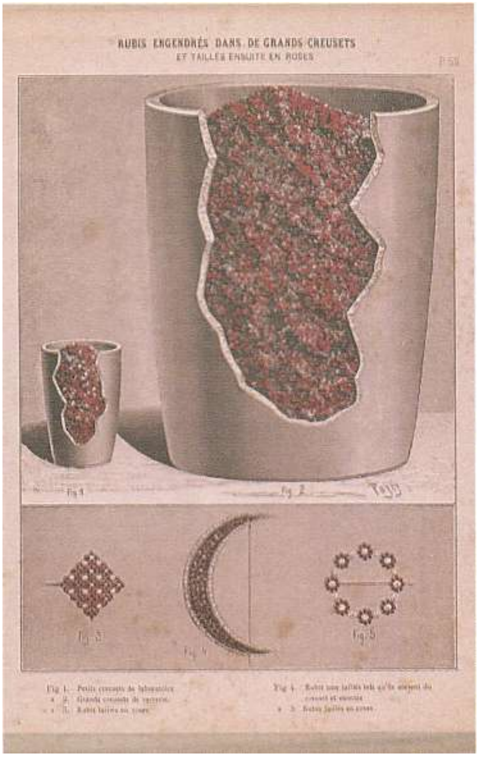

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Figure 3: *'Geneva' synthetic ruby produced about 1885 and sold as natural at that time. Photo copyright Kurt Nassau.*

FABRICATION DU RUBIS SYNTHETIQUE
Devant le Chalumeau

Figure 4a: *Professor A.V.L. Verneuil, the discoverer of the flame fusion process (left) and Spec-Torski (right) in front of a Verneuil torch in the laboratory of the Société Hellerite in Paris, France, about 1910.*

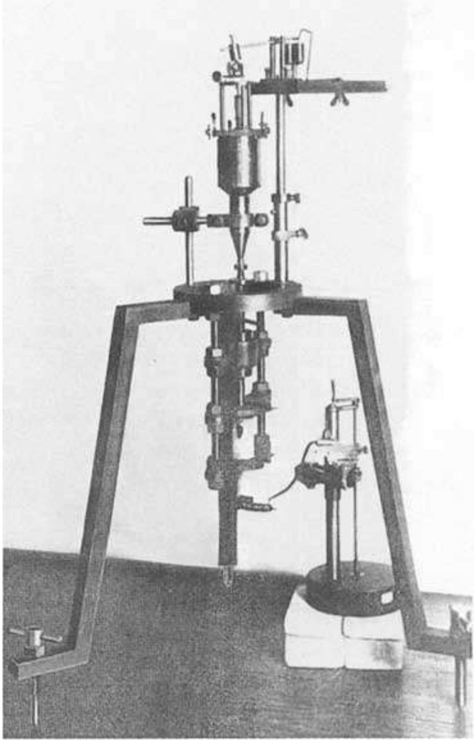

Figure 4b: *Verneuil's original flame fusion torch, about 1902, presently in the Museum of Art and Sciences, Paris.*

Figure 5a: *A rare photo of the De Beers synthetic diamond factory in the Rand, South Africa. Photo courtesy of De Beers.*

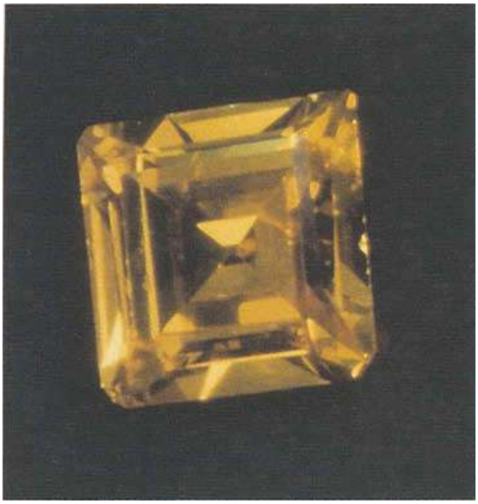

Figure 5b: *A yellow faceted De Beers synthetic diamond (0.24 ct), produced commercially for industrial use. Photo copyright Tino Hamid.*

Figure 6: *A synthetic moissanite, the most recent diamond substitute (1.68 ct, colour about G on the GIA diamond scale). Photo courtesy of C3 Inc. of Raleigh, NC, USA, which is introducing this material in 1997.*

(France, 1902, *see Figure 4*). The first commercial synthetic diamond production in size suitable for gemstone use was the yellow De Beers' material produced for semiconductor use in 1985 *(see Figure 5a and b)*. The most recent product, entering the market only this year, is synthetic moissanite, the latest diamond substitute *(see Figure 6)*.

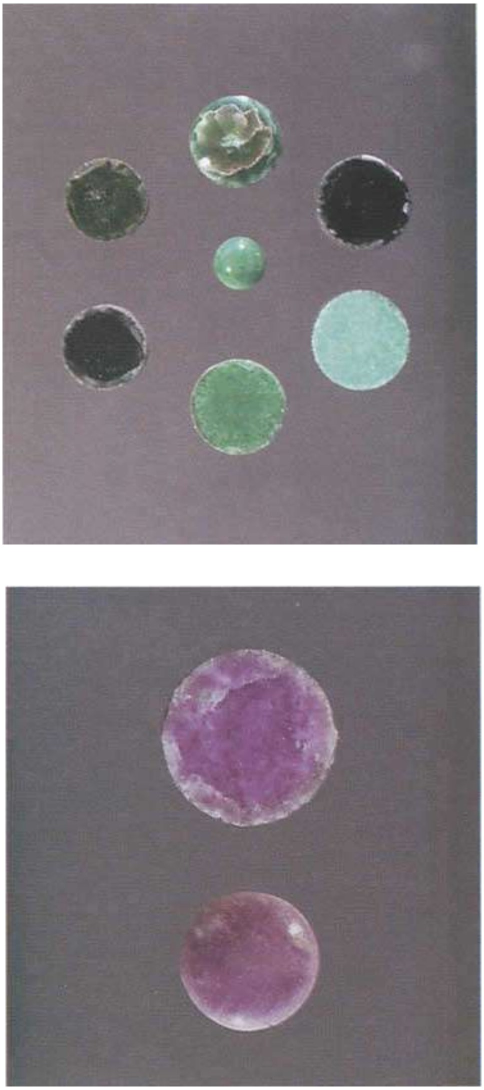

Figure 7a and b: *Synthetic jadeites produced on an experimental basis by the General Electric Co. in 1979. The largest disc is 12 mm diameter, 3 mm thick and weighs 2.46 ct. Photo copyright Kurt Nassau.*

Discussion

The question is often asked: When was a certain synthetic gemstone material first produced? There may be several answers to this question depending on which stage of the process leading from discovery to full-scale production is required. When was the first experimental success of any size or quality?

Table 1: *The chronology of synthetic gemstones*

Year	*Synthetic material*	*Inventor/trade name/manufacturer/ country*	*Growth method*	*Reference*
	Beryl, including emerald, aquamarine and red beryl			
	Flux method:			
1848	Emerald (IS, NC)	JJ Ebelmen/France	FlS	N80, 128
1888	Emerald (IS, NC)	P Hautefeuille & H Perrey/France	FlS	N80, 129
1925	Emerald (IS, NC)	R Nacken/Germany	FlS	N80, 131
1934	Emerald (IS, NC)	H Espig/IG-Farben/Germany	FlS	N80, 129
1938	Emerald	CC Chatham/USA	FlS	N80, 141
1964	Emerald	Gilson/France	FlS	N80, 144
	Hydrothermal and other methods:			
1960	Emerald (IS, NC); emerald over-growth (SP)	J Lechleitner/Austria	HyS	N80, 149; G81, 98
1964	Emerald (SP)	W Zerfass/Germany	HyS	N80, 130
1965	Emerald	EM Flanigen/Quintessa/Linde/USA	HyS	N80,150
1979	Watermelon beryl (SP)	Adachi Shin/Japan	?	G86, 55
1981	Aquamarine, pink and red beryl (SP)	Regency/Vacuum Ventures/USA	HyS	N90, 50; G81, 57
1988	Aquamarine, red and other colours (NC)	AS Lebedev/USSR	HyS	G88, 252; G90, 206
1994	Emerald, red beryl	Tairus/Russia and others	HyS	G96, 32
	Corundum: ruby, blue sapphire and other colours			
	Verneuil flame fusion, Czochralski pulling and other melt methods.			
1885	Ruby (SP) *(see Figure 3)*	'Geneva'/(Switzerland?)	FlF	N80, 42
1902	Ruby *(see Figure 4)*	AVL Verneuil/Société Hellerite/France	VeF	N80, 27
1903	Ruby (SP)	Hoquiam/USA	VeF	N80, 54
1907	Blue sapphire	Verneuil/Baikovsky/France	VeF	N80, 63, 66
1942	Ruby	L Merker/Linde/USA	VeF	N80, 69
1947	Star corundum	Linde/USA	VeF	N80, 69
1960	Ruby discs (SP)	Linde/USA	VeD	N80, 69
1965	Ruby	FR Charvat/Linde/USA	CzP	N80, 84
1971	Sapphire, colourless tubes, etc.	H LaBelle/Tyco/USA	CzE	N80, 87
1983	Ruby, etc. (NC)	Bijoreve/Seiko/Japan	FZo	G84, 60
1990	Pink Ti-sapphire	Union Carbide/USA and others	CzP	G95, 188, 214; G92, 66
	Flux and vapour phase methods:			
1891	Ruby (IS, NC) *(see Figure 2)*	E Fremy and Verneuil/France	FlV	N80, 39
1958	Ruby	CC Chatham/USA	FlS	N80, 78; Pc
1958	Ruby (NC)	JP Remeika/AT&T Bell Labs/USA	FlS	N80, 78; Pc
1964	Ruby (IS,NC)	EAD White/England	VaR	N80, 91
1974	Blue sapphire	CC Chatham/USA	FlS	G82, 140; Pc
1980	Orange sapphire (padparadscha, SP)	CC Chatham/USA	FlS	G82, 140; Pc
1983	Ruby and sapphire; ruby overgrowth (NC)	J Lechleitner/Austria	FlS	N90, 53; J85, 557; G85, 35; J88, 95
	Hydrothermal method:			
1958	Ruby (PQ, NC)	AT&T Bell Labs/USA	HyS	N80, 91; Pc
1965	Ruby (PQ, NC)	R Belt/Airtron/USA	HyS	N80, 91; G92, 278

Key

Growth methods:

CzE	CzP with edge-defined film-fed modification
CzP	Czochralski pulling from the melt
Exp	Explosion reaction
FlF	Flame fusion, pre-Verneuil variant
FlS	Flux solution
FlV	Flux-vapour complex system
FZo	Floating zone
HPI	HPS followed by irradiation
HPS	High pressure solution
HyI	HyS followed by irradiation
HyS	Hydrothermal solution
SkS	Skull Solidification and equivalnt methods
SkH	SkS with yttrium oxide content higher than usual
SkI	SkS followed by irradiation
SkL	SkS with yttrium oxide content lower than usual
VaR	Vapour phase reaction, atmospheric or low pressure
VeD	VeF with disc modification
VeF	Verneuil flame fusion
VeT	VeF with tricone burner modification

Table 1: Continued

Year	Synthetic material	Inventor/trade name/manufacturer/ country	Growth method	Reference
Diamond, including film overgrowth and carbonado				
High pressure methods:				
1954	Diamond (IS)	T Hall/General Electric/USA	HPS	N80,174
1964	Carbonado	General Electric/USA	HPS	N80, 186
1970	Diamond: yellow, blue, colourless (NC)	RH Wentorf *et al.*/ General Electric/USA	HPS	N80, 186
1985	Diamond: yellow *(see Figure 5)*	De Beers/South Africa	HPS	N90, 58
1985	Diamond: yellow	Sumitomo/Japan	HPS	N90, 58
1993	Diamond: pink, red, purple (SP)	Many producers	HPI	G93, 38, 191; G94, 123; G96, 52, 128
1993	Diamond: blue, colourless (SP), yellow	Many producers	HPS	G93, 182; G95, 53; J95, 363
Other methods.				
1956	Diamond over-growth (IS, NC)	BV Derjaguin & BV Spitsyn/USSR	VaR	D93
1956	Diamond over-growth (IS, NC)	WG Eversole/USA	VaR	D93
1964	Diamond (IS, NC)	PS DeCarli and J Jamieson/USA	Exp	N80, 196
1966	Diamond (IS)	G.R. Cowan *et al.*/DuPont/USA	Exp	N80, 196
1991	Diamond over-growth, blue (NC) *(see Figure 9)*	A Phelps/USA	VaR	G91, 240
Diamond imitation – Cubic Zirconia *(CZ is stabilized zirconia ZrO_2, usually with yttrium oxide Y_2O_3 added)*				
1969	CZ (NC)	Y Roulin *et al.*/France	SkS	G81, 9
1976	CZ	VV Osiko/USSR	SkS	G81, 9
1976	CZ	JF Wenckus/Ceres/USA	SkS	G81, 9
1978	CZ: many colours	JF Wenckus/Ceres/USA	SkS	G81, 9; J81, 602
1982	CZ: blue, green	C-Ox/Lebedev Institute/USSR	SkH	N90, 50
1983	CZ: opaque white (NC)	JF Wenckus/Ceres/USA	SkL	G91, 240
1983	CZ: opaque pink, white, black (NC)	?/Russia	SkL, SkI	G91, 240
Diamond – other imitations				
–	Spinel	See under Spinel below		
1948	Rutile	L Merker/National Lead/USA	VeT	N80, 211
1952	Strontium titanate	L Merker/National Lead/USA	VeT	N80, 214
1959	Yttrium garnets (IS, NC)	JW Nielsen and JP Remeika/ AT&T Bell Labs/USA	FIS	N80, 223
1968	Yttrium aluminium garnet	Many producers	CzP	N80, 224
1975	Gadolinium gallium garnet	Many producers	CzP	N80, 225
–	Cubic zirconia	See under Cubic Zirconia above		
–	Moissanite	See under Moissanite below		

Key

Production is (or was) for commercial gemstone use unless otherwise indicated:

IS	inadequate size for gemstone use
NC	not commercial, also in the sense that significant quantities are (or were) not seen in the USA trade
PQ	poor quality, not suitable for gemstone use
SP	small-scale production only.

References (source and year, page number)

D93	Davis, R.F. (Ed.), 1993. *Diamond thin films and coatings.* Noyes Publications, Park Ridge, NJ, USA
G– –	*Gems and Gemology*
J– –	*Journal of Gemmology*
N80	Nassau, K., 1980. *Gems made by man.* Chilton. Reprinted by Gemological Institute of America, Carlsbad, CA, and references given therein
N90	Nassau, K., 1990. Synthetic gem materials in the 1980s. *Gems and Gemology,* **26** (1) p. 50, and references given therein
Pc	Personal communication

Table 1: *Continued*

Year	Synthetic material	Inventor/trade name/manufacturer/ country	Growth	Reference
Alexandrite and chrysoberyl				
1973	Alexandrite	Creative Crystals/USA	FlS	N80, 246
1978	Alexandrite (NC)	Bijoreve/Seiko/Japan	FZo	G84, 60
1980	Alexandrite (SP)	Allied Chemical/USA	CzP	N90, 50
1983	Chrysoberyl cat's-eye (NC)	Sumitomo/Japan	FZo	G83, 186; J88,232
Forsterite and peridot				
1963	Forsterite (IS, PQ, NC)	TJ Shankland and K Hemmenway/USA	CzP	G94, 102
1971	Forsterite (NC)	CB Finch and GW Clark/USA	CzP	G94, 102
1991	Peridot (NC)	DR Hanson *et al.*/USA	FZo	G94, 102
1992	Forsterite *(see Figure 8)*	K Yamagachi/Mitsui Mining and Smelting, Japan	CzP	G94, 102
Jadeite				
1953	Jadeite (IS, NC)	L Coes/Norton/USA	MPS	N90, 50
1979	Jadeite (NC) *(see Figure 7)*	RC DeVries and JF Fleischer/ General Electric/USA	MPS	N90, 50
Malachite				
1982	Malachite (NC)	VS Balitskii *et al.*/USSR	(HyS?)	N90, 50; G87, 152
Moissanite				
1970	Moissanite: yellow, brown, green, blue (IS, NC)	Many carborundum producers	VaR	Pc
1997	Moissanite *(see Figure 6)*	C3 Inc./USA	Sub	G96, 52; Pc
Opal				
1972	White opal	P Gilson/France	ChR	N80, 259; N90, 50
1974	Black opal	P Gilson, France	ChR	N80, 259; N90, 50
1975	Fire opal (NC)	P Gilson/France	ChR	N90, 50; J84, 43; G85, 110
Phenakite				
1988	Phenakite (IS, PQ, NC)	P Hautefeuille and H Perrey/France	FlS	N80, 129
1957	Phenakite (IS, PQ, NC)	CC Chatham/USA	FlS	Pc
1965	Phenakite (IS, PQ, NC)	A Ballman/AT&T Bell Labs/USA	FlS	Pc
1994	Phenakite (NC)	?/Russia	FlS	G94, 199
Quartz: including citrine, amethyst, smoky and rose quartz				
1851	Quartz (IS, NC)	H de Senarmont/France	HyS	N80, 100
1898	Quartz (NC) *(see Figure 1)*	G Spezia/Italy	HyS	N80, 100; J84, 240
1898	Quartz (NC)	R Nacken/Germany	HyS	N80, 101
1940	Quartz	AT&T Bell Labs/USA	HyS	N80, 102
1940	Quartz	Clevite/USA	HyS	N80, 102
1942	Smoky quartz (NC)	AT&T Bell Labs/USA and others	HyS	N80, 114
1958	Citrine (NC)	LI Tsinober/USSR	HyS	N90, 50
1959	Amethyst (NC)	LI Tsinober/USSR	Hyr	N90, 50
1974	Citrine	Many producers	HyS	N80, 116
1975	Amethyst	Many producers	Hyl	N80, 117
1980	Amethyst/citrine (ametrine; NC)	K Nassau/AT&T Bell Labs/USA	Hyl	G81, 37
1985	Rose quartz (NC)	M Hosaka *et al.*/Japan	HyS	N90, 50
Sodalite				
1973	Sodalite, colourless (NC)	R Belt/Airtron/USA	HyS	Pc
1991	Sodalite: blue, colourless (NC)	Liu/China	HyS	G92, 240
Spinel: colourless, blue, red, etc., including gahnite spinel				
1848	Spinel (IS, NC)	JJ Ebelmen, France	FlS	N80, 210, 247
1907	Spinel (NC)	L Paris/France	VeF	N80, 210, 247
1908	Spinel	AVL Verneuil/Societe Hellerite/France	VeF	N80, 210, 247
1960	Spinel and gahnite, various colours (NC)	EAD White et al./England	FlS	Pc
1960	Spinel and gahnite, various colours (NC)	JP Remeika et al./AT&T Bell Labs/USA	FlS	Pc
1989	Spinel: red, blue (SP)	Lebedev Institute/USSR	FlS	G93, 81

Key

Growth methods:

ChR	Chemical reaction in solution, then settling and compaction
CzP	Czochralski pulling from the melt
FlS	Flux solution
FZo	Floating zone
HyI	HyS followed by irradiation?
HyS	Hydrothermal solution
MPS	Medium pressure solidification
Sub	Sublimation in the vapour phase
VaR	Vapour phase reaction, atmospheric or low pressure
VeF	Verneuil flame fusion

Production is (or was) for commercial gemstone use unless otherwise indicated:

IS	inadequate size for gemstone use
NC	not commercial, also in the sense that significant quantities are (or were) not seen in the USA trade
PQ	poor quality, not suitable for gemstone use
SP	small-scale production only.

References (source and year, page number):

G--	*Gems and Gemology*
J--	*Journal of Gemmology*
N80	Nassau, K., 1980. *Gems made by man.* Chilton. Reprinted by Institute of America, Carlsbad, CA, and references given therein
N90	Nassau, K., 1990. Synthetic gem materials in the 1980s. *Gems and Gemology,* **26** (1) p. 50, and references given therein
Pc	Personal communication

When did the size and quality first reach the needs of the gemstone trade in experimental work? When was the first actual commercial production? When were there any significant changes in the process or in the product? And so on. Such information can be important for appraisal and authentication purposes, among others.

I have assembled in *Table 1* data for synthetic gemstones used at present in the gemstone trade. Included are diamond imitations as well as some synthetic materials that have been announced but have never arrived in the trade, such as synthetic malachite. Also included are some synthetic materials that have been produced only experimentally so far but that could conceivably appear in the trade at any time, such as synthetic jadeite first made in adequate size and quality in 1979 *(see Figure 7).* Enhanced synthetics are included only when different colours are produced by irradiation, as with synthetic amethyst, red diamond and smoky quartz.

Excluded from *Table 1* are enhanced or reconstructed natural gemstones, as well as imitations such as ceramic products (e.g. imitation coral, lapis lazuli and turquoise) and glasses (e.g. 'emerald glass', goldstone, opalescence and fibre-optic imitation cat's-eyes). Also excluded are the many man-made technological crystals which are faceted only for specialist collectors.

The years given usually can be only approximate for several reasons. Production may have been announced before a significant quantity of a product was actually available; it may have taken several years between the achievement and the publication of a description or the issuing of a patent; and so on. As always, patent disclosures generally cannot be relied upon for several reasons; the patent claim may not have been followed up, the range of compositions claimed is frequently much wider than can be achieved in reality, and some patents actually do not work!

In fact, not everything published even in the refereed literature can be accepted at face value. As one example, success at diamond synthesis is occasionally attributed to Scottish scientist J.B. Hannay about 1902, yet subsequent investigation of his products have completely negated his claim *(see Reference N80, 164 of Table 1).* Even more curious is the occasional attribution to the AT&T Bell Telephone Laboratories (where diamond synthesis was never investigated) in 1955 of the Hannay claim (possibly because of confusion with Dr N.B. Hannay, who worked at AT&T).

Early work is included only if it represented a significant advance in the state of the art or unusual circumstances. Only the first commercial manufacturer for any combination of process and product is given, again except for significant developments or unusual circumstances. Today most synthetic products have several to many manufacturers, with Japan and Russia particularly active.

In deciding whether a product is (or ever was) in commercial production, I have ignored publicity releases and always tried to determine when the material was actually seen in significant quantities in the gemstone trade and by gemmologists, e.g. in the Gem Trade Laboratories of the Gemological Institute of America.

Some of these synthetic materials are or were initially investigated and manufactured for uses other than those of the gemstones trade. Examples include colourless synthetic quartz used for oscillators and filters in communications and for lenses and windows for special optics; Czochralski-grown synthetic alexandrite and forsterite (peridot) used as the active material for some lasers; synthetic diamond for abrasive grit and for semiconductor heat sinks; and so on. A current example is the latest diamond simulant, the synthetic moissanite listed in *Table 1* (as shown in *Figure 6*), important for semiconductor, light-emitting diode and blue laser uses.

To avoid a long and awkward citation list, the limited references given in simplified form will lead the interested reader mostly to books or review articles where detailed descriptions and sources (or reference to further compilations of sources) may be found.

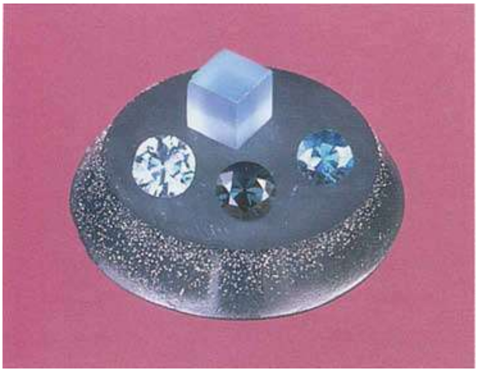

Figure 8: *Pure and chromium-doped synthetic forsterite grown by Mitsui Mining and Smelting Co., Japan, for laser use: a 27 mm diameter slice, a 50 mm cube and three faceted samples (1.18 ct, 1.07 ct and 0.83 ct). Photo by N. DelRe, courtesy of the GIA.*

Figure 9: *Originally near-colourless diamonds (0.33 ct, 1.15 ct and 0.36 ct) have been coated with a greyish-blue synthetic diamond film by A. Phelps at the University of Pennsylvania. Photo by R. Weldon, courtesy of GIA.*

LETTERS TO THE EDITOR

From Dr K. Nassau

Dear Sir,

A colour-change effect apparently never before reported in a gem or mineral has been described in chrome tourmaline from Umba Valley, Tanzania, by A. Halvorsen and B.B. Jensen (*J. Gemm.,* **25**(5), 1997, p. 325). The colour changed from green to red with an increase in thickness.

May I point out that this effect is well known in the field of organic dyes, in which field it is usually designated as 'dichroism'. The colour change is produced by an increase in the concentration of the dye, quite equivalent to an increase in the thickness of the tourmaline. An explanation is given on page 111 of my book *The physics and chemistry of color.*

A consideration of the mechanism involved makes one feel surprised that these effects have not been observed previously. Now that attention has been drawn to these effects, they will very likely be observed in other gem and mineral materials. So the question arises whether a name such as the 'Usambara effect' proposed by Halvorsen and Jensen is not tied too closely to the specific material they studied.

The simple designation 'dichroism' that already exists for these effects, however, conflicts with the orientation-dependent 'dichroism' of mineralogy and gemmology. Accordingly, I believe the simple and descriptive terms 'concentration dichroism' and 'thickness dichroism' would perhaps be more appropriate (and easier to remember as well!). One should note that the monumental *Oxford English Dictionary* does give both the orientation and concentration meanings under 'dichroism' and 'dichroic' on p. 327 in Vol. 3.

Yours, etc.
Kurt Nassau
Lebanon, New Jersey 08833, USA
25 January 1997

Reference

Nassau, K., 1983. *The physics and chemistry* of color. John Wiley & Sons Inc., New York.

From Asbjørn Halvorsen and Brenda Jensen

Dear Sir,

Reply to Dr Kurt Nassau

Dr Nassau raises three points to which we wish to reply:

1) *Lack of observations of colour change with thickness in the mineralogical literature.* We agree that it is surprising that such a colour change has not been reported in the mineralogical/gemmological literature earlier, but we conducted a careful search and failed to find any references. If we have missed something we would be glad to hear about it.
2) *Examples from solutions.* We did state in our paper that the same type of colour change was reported for solutions. Dr Nassau's example of organic dyes quotes only colour variation with concentration. If we had used it we would have had to explain the equivalence of concentration and thickness in modifying selective absorption patterns (with references to Beer's equation). Instead we quoted the Webster reference concerning chrome alum solutions, because the same chromophore was involved as in our tourmaline and because we could then refer to Webster's statement, that the effect is seen

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both with concentration and thickness change, without needing to make further explanation.

3) *Use of the term 'dichroism'.* We are aware of the disadvantages of introducing a locality name like 'Usambara effect', but we had problems in finding a suitable alternative 'scientific' term.

We considered 'dichroism' and Webster's 'dichromatism'. We must admit that we did not consult the *Oxford English Dictionary* in our search. We have, however, consulted many mineralogy and gemmology text books (American and English), *Glossary of geology, Concise Encyclopaedia of Science and Technology, Encyclopaedia of Mineralogy* and *Encyclopaedia Brittanica* and found only the pleochroic definition of dichroism in all of them. This would not, of course, prevent our introducing the term in another context if this were a logical extension of its use. However, 'dichroism' is synonymous with proof to a gemmologist that he is dealing with an optically anisotropic material; it seems therefore to us unnecessarily confusing to speak of 'thickness dichroism' in a case where the colour change can occur in any medium isotropic or anisotropic.

In a mineral, the point at which colour change occurs is determined by pathlength and chromophore concentration, possibly also modified by vibration direction, so 'thickness dichroism' (or pathlength colour change) does not tell the whole story, which was for us another reason for rejecting it in favour of the more neutral locality name.

Yours, etc.
A. Halvorsen and B. Jensen
Oslo, Norway

Abstracts

Diamonds

Instruments and Techiques

Gems and Minerals

Synthetics and Simulants

Diamonds

The typical gemmological characteristics of Argyle diamonds.

J. Chapman, G. Brown and B. Sechos. *Australian Gemmologist*, **19**(8), pp 339–46, 1 illus. in black-and-white, 2 maps, 1 table, 13 illus. in colour, 5 graphs, bibl.

Western Australia's Argyle lamproite pipe is located at the headwaters of Smoke Creek in a small valley near the eastern end of the Matsu range. The pipe's annual yield of brown, yellowish brown, colourless and red to pink diamonds rose to almost 40 million carats in 1995. In their paper, the authors make a valuable contribution to the information available on the characteristics of Argyle's diamonds. In addition to the text, there is a table listing gemmological characteristics ranging from Type classification through N aggregation status to UV and X-ray fluorescence/phosphorescence, and inclusions. Other characteristics are illustrated in the thirteen colour figures, four transmission spectra of colourless, champagne, cape and pink diamonds, and a typical IR absorption spectrum of brown diamond. P.G.R.

Gem trade lab notes.

C.W. Fryer. *Gems & Gemology*, **32**(3), 1996, pp 204–12.

Nitrogen impurities in diamond can be the cause of yellow to brown colours, but the nitrogen need not be evenly distributed within the diamond crystal. Hydrogen impurities may also lead to an uneven distribution of grey or brown colours. A rough diamond with uneven colour was sawn into two pieces with the larger half yielding a fancy brownish yellow and the smaller half yielded a G colour. Both stones showed similar inclusions, but they had substantially different infrared spectra, due to variations in impurity concentrations.

A 3.40 ct heart shaped diamond, graded as a Fancy Intense Pinkish Orange & Internally Flawless was examined. Infrared spectroscopy revealed the stone to be type IIa, due to a lack of measurable nitrogen. The absorption pattern showed a broad band centred at 550 nm.

A suite of six treated-colour pink-to-purple diamonds showed some unusual properties. Out of the six stones, four were type Ib showing three sharp bands at 575, 595 and 637 nm. One had some additional type Ia component and the sixth stone appeared to have a type IaA spectrum with an H1b peak, a feature commonly seen in treated yellow diamonds. It was the first time such a spectrum had been seen in a treated pink diamond. Although this stone might have been mistaken for an untreated diamond, the 637 nm line is rarely seen and the 537 nm is never seen in natural stones. J.J.

Gem trade lab notes.

C.W. Fryer. *Gems & Gemology*, **32**(4), 1996, pp 277–281, 16 illus. in colour.

Colour often appears unevenly distributed in cut diamonds as a result of the cutting style, e.g. the tips of a marquise may concentrate colour. Also, occasionally diamonds may be colour zoned. It has now been found that cleavage may also influence the colour distribution within a diamond. J.J.

Identification of diamonds from cubic zirconia (CZ).

N.B. Jashnani and S. Chudawala. *Indian Gemmologist*, **6**(4), 1997, pp 5–10, illus. in colour.

Summary of the properties of CZ and diamond with a review of the simpler means of identification. M.O'D.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **32**(3), 1996, pp 214–22.

A new cut of diamond is on the market called the 'Buddha Cut'. J.J.

Abstractors

A.F. Cooper	A.F.C.	R.A. Howie	R.A.H.	V. Jovic	V.J.	P.G. Read	P.G.R.
R.K. Harrison	R.K.H.	J. Johnson	J.J.	M. O'Donoghue	M.O'D.	R.E. Samson	R.E.S.

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

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Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology,* **32**(4), 1996, pp 282–292, 21 illus. in colour.

A summary of the types of diamond crystals is given from Kelsey Lake, Colorado. J.J.

Comments on the paper by G.M. Gonzaga *et al.* The origin of diamonds in western Minas Gerais, Brazil.

O.H. Leonardos, R.N. Thompson, R. Fleicher, S.A. Gibson, D.P. Svisero and R.K. Weska. *Mineralium Deposita,* **31**(4), 1996, pp 343–344.

A series of arguments was presented by Gonzaga *et al.* against a late Cretaceous kimberlitic diamond source in W Minas Gerais while giving geological evidence for glacial diamond transportation from a remote Precambrian source. It is considered that it failed on both counts. [Following abstract] R.E.S.

Reply to the comments by O.H. Leonardos *et al.*

G.M. Gonzaga, N.A. Teixeira and J.C. Gaspar. *Mineralium Deposita,* **31**(4), 1996, pp 345–347.

Although the comments [preceding abstract] do not stand up to critical analysis they provide the opportunity to continue the discussion. R.E.S.

Eclogitic inclusions in diamonds: evidence of complex mantle processes over time.

L.A. Taylor, G.A. Snyder, G. Crozaz, V.N. Sobolev, E.S. Yefimova and N.V. Sobolev. *Earth & Planetary Science Letters,* **142**(3–4), 1996, pp 535–551.

The first ion-probe trace element analyses of clinopyroxene-garnet pairs both included in diamonds and from the eclogite host xenoliths from the Udachnaya and Mir kimberlite pipes, Siberia, are reported. The most striking aspect of the chemical compositions of the diamond inclusions is the diversity of relationships with their eclogite hosts. Garnet and clinopyroxene inclusions in the diamonds from two Udachnaya samples have lower *mg*, lower Mg, higher Fe contents, and lower *REE* than those in the host eclogite; such variations are interpreted as due to metasomatism of the host eclogite after diamond formation. Clinopyroxene inclusions from the central (early) portions of Yakutian diamonds are lower in *mg* and Mg (by ≤ 25%) than those later inclusions at the rims of diamond. Diffusion rates in clinopyroxenes are much slower than in coexisting garnets, and therefore clinopyroxene may be the only useful mineral in determining the character of the ancient protoliths of these Yakutian eclogites. R.A.H.

Gems and Minerals

Die rubinminen im Ganesh Himal in Nepal.

A.M. Bassett. *Mineralien Welt,* **8**(3), 1997, pp 45–60, illus. in colour, 5 maps.

The geology and mineralogy of the Nepalese ruby deposits are discussed with notes on crystal morphology. Minerals accompanying corundum are listed and described. M.O'D.

Polished nephrite disc (refractive indices).

I. Campbell. *South African Gemmologist,* **11**(1), 1997, p 13, illus. in colour.

A dark-green nephrite disc gave RI 1.613–1.630 with an incomplete DR of 0.017 which figures compare with the published 1.62 usually obtainable. The disc was 38.90 mm in diameter and 4 mm thick. M.O'D.

L'huître aux lèvres noires, *pinctada margaritifera.* I. Dommages causés sur le bord des valves. Réconstruction-évaluartion des paramètres de croissance de la nacre coquillère.

J. Caseiro and J.-P. Gauthier. *Revue de Gemmologie,* **130**, 1997, pp 7–13.

First part of a study of black-lipped pearl-bearing oysters of *pinctada margaritifera*. Structure and growth are reviewed and the causes and effects of damage described. M.O'D.

Nephrite and metagabbro in the Haast Schist at Muddy Creek, northwest Otago, New Zealand.

A.F. Cooper. *Journal of Geology & Geophysics,* **38**(3), 1995, pp 323–332.

At Muddy Creek, NW Otago, a pod of gabbro, probably in a matrix of serpentinite, was tectonically emplaced into quartzofeldspathic sediments before the main metamorphism of the Haast schist. Metasomatic diffusion during pumpellyite-actinolite to greenschist-facies metamorphism produced talc-, tremolite-, chlorite- and muscovite-rich reaction zones at the margin of the pod. Subsequent shearing disrupted the metasomatic sequence and produced nephrite from the tremolite zone precursor. Relict magmatic hornblende and clinopyroxene from the metagabbro have compositions appropriate to a volcanic arc tectonic setting. In contrast, relict pyroxenes from four metabasaltic samples in the Greenstone mélange have compositions indicating generation of magmas in both ocean-floor and ocean-island environments. Ultramafic and mafic rocks at Muddy Creek and in the Greenstone mélange represent fragments of the ophiolitic basement to the Haast schist, the tectonic settings of which help constrain models for the evolution of the Rangitata orogen. A.F.C.

Les pierres gravées des portraits royaux. Un cas exceptionnel: Elisabeth I, reine d'Angleterre.

M. Duchamp. *Revue de gemmologie,* **130**, 1997, pp 3–6, illus. in colour.

Hardstone portraits of royalty are described with particular reference to representation of Queen Elizabeth I of England. Illustrated examples are taken from various museums. M.O'D.

Gem trade lab notes.

C.W. Fryer. *Gems & Gemology*, **32**(3), 1996, pp 204–12.

A large carved white translucent aragonite set as a pendant had a similar appearance to nephrite and a comparable SG of 2.84. A large (38.91 ct) faceted, pear-shaped stone, of transparent yellowish green, was found to be herderite. A carved jadeite hairpin reportedly from the Qing dynasty (1644–1912) showed chromium lines in the absorption spectrum and a compact intergrowth pattern, different from the 'honeycomb' structure associated with bleached and impregnated jadeite. A ring made by Tiffany & Co. was set with old English brilliant cut diamonds and an oval faceted green quartz.

Two natural sapphires of treated blue colour showed some interesting results. The first stone had an incised design on the back and contained fluid-filled 'fingerprints' and unidentified crystals that were altered in ways consistent with heat treatment. The blue was caused by a dye, which was evident when the stone was immersed in methylene iodide. The second stone was a diffusion-treated natural sapphire, which had been quench crackled, making it more difficult to identify. J.J.

Gem trade lab notes.

C.W. Fryer. *Gems & Gemology*, **32**(4), 1996, pp 277–81, 16 illus. in colour.

A red statuette Buddha was found to be an assemblage of natural corundum chips and plastic. Under long-wave UV the statuette appeared splotchy orange red. It was thought the Buddha had been made in a mould. A Biron hydrothermal synthetic emerald showed an inclusion similar to pyrite. Under high magnification it was found to be platy as seen before in Biron synthetics. Also detected was a two-phase 'nail head' spicule typical of hydrothermal synthetics. An imitation star ruby was composed of three distinct layers: the top was synthetic ruby with gas bubbles and curved straie; then an opaque layer, highly reflective, composed of engraved foil giving rise to the asterism; the bottom layer was not identified, as the stone was mounted. J.J.

Ambre de roumanie.

V. Ghiurca. *Revue de Gemmologie*, **130**, 1997, pp 14–17, illus. in colour, 2 maps.

Short study of Romanian amber with notes on chemistry, geology and occurrence, varieties and characteristics. Amber is found in the Department of Buzâo in the south-east of the country. M.O'D.

The Illinois-Kentucky fluorite district.

A. Goldstein. *Mineralogical Record*, **28**(1), 1997, pp 3–49, illus. in colour, 7 maps.

Fluorite from the Illinois-Kentucky area is one of the best-known United States minerals and has been collected for many years (with many specimens labelled 'Cave-in-Rock', in fact a small area in a much larger district). While some crystals have been fashioned the majority are displayed for their size, attractive form and colours which include magnificent purple, blue and yellow. The last fluorite-producing mine in the area has now closed. The paper describes the mineralogy of the area (fine calcite and other crystals are also notable), giving details of the history and contents of the various mines and full mineralogical descriptions of the species found. There is an extensive bibliography. M.O'D.

Zircon inclusions in corundum megacrysts: I. Trace element geochemistry and clues to the origin of corundum megacrysts in alkali basalts.

J. Guo, S.Y. O'Reilly and W.L. Griffin. *Geochimica et Cosmochimica Acta*, **60**(13), 1996, pp 2347–2363.

The morphology and geochemistry of zircon inclusions are described with examples from E Australia (King's Plains, New South Wales; Lava Plains, Queensland), and from E China (Wenchang, Hainan; Changle, Shandong). EPMA are presented of zircons and their pseudomorphs (sillimanite, siliceous mullite, baddeleyite). Zircon inclusions are syngenetic with their corundum hosts and show similar crystal habit, morphology and trace element contents despite their wide geographical origin. A common mechanism of the formation of the inclusions in basalt is indicated, with the zircon crystallizing from a reduced, peralkaline environment of a highly evolved syenitic or granitic melt. R.K.H.

Ethiopia: a new source for precious opal.

D.B. Hoover, T.Z. Yohannes and D.S. Collins. *Australian Gemmologist*, **19**(7), 1996, pp 303–7, 10 illus. in colour.

One of the authors (T.Z. Yohannes) was given a broken nodule of volcanic rock containing a fine crystal base precious opal while visiting his homeland, Ethiopia, in 1993. From a description of the location where it had been found he was able to discover an extensive deposit of opal-filled lithophysae near the village of Mezezo in Shewa province. Common opal that fills the nodules comes in a wide variety of colours. Precious opal is estimated to be present in about one per cent of the nodules.

Government regulations have limited opal production to the gathering of representative samples for testing and evaluation pending detailed mapping of the deposit. Owners of the deposit were hoping to complete government requirements during the summer of 1996 and to begin formal production soon after. P.G.R.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **32**(3), 1996, pp 214–22.

Natural green chrysoberyls lacking in colour change are now on the market, the first to be seen coloured by vanadium. Similar synthetic nonphenomenal chrysoberyls have been seen also coloured by vanadium. Two large faceted chrome diopsides from Inagly mine, Yakutsk, Siberia, north of Lake Baikal, were examined. This is not a new find and the stones could well have been mined some thirty years ago. Spessartine garnets from Pakistan, marketed as 'Kashmirine', are from Azad Kashmir in the NE of the country. The first garnets were found in 1993 in several pegmatites in a migmatite complex. J.J.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology*, **32**(4), 1996, pp 282–92, 21 illus. in colour.

A new source of gem blue to purple chalcedony was discovered in 1994 in Mount Airy, Nevada. It is believed there are significant reserves still to be worked. Chatoyant emerald is reported to come from Coscuez mine in the Muzo region of Colombia. The vein containing the cat's-eye emerald was depleted within a month of being discovered. The new locality for colour-change garnets is Athiliwewa in the south of Sri Lanka, where the garnets are found in alluvial gravels. Details of the garnet properties are listed. J.J.

Some gemological challenges in identifying black opaque gem materials.

M.L. Johnson, S.F. McLure and D.G. DeGhionno. *Gems & Gemology*, **32**(4), 1996, pp 252–261, 9 illus. in colour, 1 table.

The authors list the main problems with identifying many black opaque gem materials. Much of the information is laid out in table form with a useful list of references for further research. Optical tests include visual observations, e.g. the types of fractures especially around the girdle or on the backs of cabochons, together with reflected light which can help to indicate aggregate material by the presence of grain boundaries, differences in relief or differences in reflectivity.

Specific examples are given illustrating some of the problems that may be encountered when testing aggregate materials or minerals that belong to solid solution series. Positive identification is usually obtainable by X-ray powder diffraction and EDXRF spectroscopy. As with other gem identification, all information available should be used before coming to a conclusion. J.J.

Chrysoberyl from Visakhapatnam and East Godavari districts, Andhra Pradesh.

C. Kasipathi. *Journal of the Geological Society of India*, **48**(4), 1996, pp 463–465.

Chrysoberyl is recorded from 13 tracts in the northern coastal areas of Andhra Pradesh, E. India. The chrysoberyl occurs as tabular, columnar or short prismatic crystals with distinct prismatic striations; the crystals range from 5 to 30 mm in length and 2 to 35 mm in width; (110) cleavage is distinct, with (001) and (100) poor. It is transparent to translucent, yellow-green to yellow in colour; H. 8.2–8.5 SG 3.72–3.80; weakly pleochroic in thin section. Chrysoberyl occurs in pockets in acidic pegmatites intrusive into khondalite, especially where the pegmatitic vein transects a mafic/ultramafic intrusion. R.A.H.

Richterite: a new gem material from South Africa.

A. Kleyenstüber and I. Campbell. *South African Gemmologist*, **11**(1), 1997, pp 10–12, illus. in colour.

A richterite with K-content is reported from the Kalahari manganese field of South Africa. A member of the amphibole group, richterite is a sodium calcium magnesium iron silicate hydroxide: the described specimen is blue with RI 1.620, 1.632: the published SG for richterite is 2.97–3.45 and the hardness 5–6. The material occurs in a carbonate-rich environment in association with manganese ores and is accompanied by sugilite, calcite, pectolite and quartz with a sugary consistency. Specimens up to a few kg in weight have been recovered from sporadic occurrences. M.O'D.

Emerald mineralization and metasomatism of amphibolite, Khaltaro granite pegmatite-hydrothermal vein system, Haramosh Mountains, northern Pakistan.

B.M. Laurs, J.H. Dilles and L.W. Snee. *Canadian Mineralogist*, **34**, 1996, pp 1253–1286, illus. in colour, 4 maps.

In the Nanga Parbat massif of northern Pakistan hydrothermal veins ranging from 0.1–1 m in thickness have been found to host emerald which is also found within granite pegmatites cutting amphibolite which itself forms a sill-like body within garnet-mica schist. Crystals of emerald, pale blue and colourless beryl have been found, Cr and Fe being the cause of the green coloration. Details of the mineralization process and of associated minerals are given. M.O'D.

Hydrogen and oxygen isotope ratios in chrysoprase and prasopal.

N. Miljević, Z. Maksimović, J. Pezdič, D. Cole and W.A. Van Hook. *Bulletin de l'Académie Serbe des Sciences et des Arts CVIII, Sciences naturelles*, **35**, 1994, pp 19–27.

Hydrogen and oxygen isotopic compositions of prasopal (Ni-bearing opal-CGT) and chrysoprase (Ni-bearing chalcedony) from the weathering profiles of ultramafic rocks from Glavica (southern Serbia) were determined. The δD and $\delta^{18}O$ values are in the vicinity of the kaolinite line, and nearly parallel to the world meteoric line, suggesting that meteoric waters were involved in their formation. A wide variation of Ni content (≤2.8%) in analyzed samples causes a scattering of $\delta^{18}O$ values between 23.7 and 20.3‰. Estimation of the ^{18}O fractionation factor between silica (quartz) and water used for the geothermometer leads to the conclusion that prasopal and chrysoprase have been formed at similar *T* and have been exposed to similar weathering conditions. V.J.

Business and industry review: gemstones.

M. O'Donoghue. *Britannica book of the year*, 1997, pp 164–5.

Summary of developments in the gemstone and diamond trade with notes on new varieties of garnet, gemstones from the former USSR, notes on enhancement, on synthetic diamond production and its potential marketing arrangements. [Author's abstract] M.O'D.

Comparative study of corundum from various Indian occurrences – corundum from Jammu and Kashmir. Part 1.

J. Panjikar. *Indian gemmologist,* **6**(4), 1997, pp 36–47.

Corundum structure and properties are discussed before reference is made to corundum deposits in the Jammu and Kashmir areas of the northern part of the subcontinent. Gemmological properties are summarized: Kashmir sapphires have been examined with the electron microprobe and have been found to contain apatite, zircon and biotite. Tourmaline was found to be present when specimens were examined by X-ray power diffraction. Kashmir sapphires have also yielded inclusions of liquid and gaseous CO_2. M.O'D.

Fluid inclusion constraints on temperatures of petroleum migration from authigenic quartz in bitumen veins.

J. Parnell, P.F. Carey and B. Monson. *Chemical Geology,* **129**(3–4), 1996, pp 217–226.

Solid bitumens in fracture systems commonly contain microscopic crystals of authigenic quartz which were precipitated with the bitumen early in the paragenesis of the fracture fillings. The quartz contains primary fluid inclusions (aqueous and hydrocarbon) yielding homogenization *T* of mainly 95–130°C, indicating minimum *T* of entrapment during petroleum migration. Volumes of up to 50% entrained quartz, and a predominance of aqueous inclusions, suggest that the petroleum fluid had a substantial aqueous component. R.E.S.

What's new in minerals.

J. Polityka and M.P. Cooper. *Mineralogical record,* **28**(2), 1997, pp 131–139, illus. in colour.

Among the specimens seen at the Franklin, New Jersey, and Munich mineral shows were the Herkimer diamond variety of rock crystal, found at Fall Ridge, Little Falls, New York, where they occur in a weathered dolomite: non-gem ruby in a white massive quartz matrix, from Khit Ostrov island, northern Karelia, Russia: pink prisms of elbaite, up to 3 cm across, contained in a white albite matrix, from a new find at Paprock, Nuristan, Afghanistan: deep chestnut-red crystals of sphalerite ('ruby blende'), measuring approximately 1 cm and found in a matrix of small grey quartz crystals and colourless lenticular calcite: dark brown dravite crystals from Ganesh Himal, Dhading, Nepal: deep purple/green fluorite from Okaruso, Namibia: some milky lavender spinel crystals from Sri Lanka reached 8 cm on edge and one red spinel crystal from Myanmar was shown – this one an octahedron 1.2 cm on edge on a snow-white marble matrix. M.O'D.

Tasmania and Antarctica: a long association.

P.G. Quilty. *Australian Gemmologist,* **19**(9), 1997, pp 368–74, 7 diagrams, 3 illus. in black-and-white.

Tasmania and Antarctica were united as part of Gondwana from at least 600 million years ago until 55 million years ago when Australia separated and started moving northwards.

The author traces the movement of the landmass of Tasmania across eras of geological time and through climate zones, relating its present rock and soil composition to its long-term Antarctica partner. P.G.R.

The true story of White Cliffs.

G.R. Rowe. *Australian Gemmologist,* **19**(7), 1996, pp 296–300, 2 maps, 1 fig.

White Cliffs, Australia's first viable commercial opal field was discovered in the late 1880s. It was unique in that it represented the world's first seam opal deposit. Using abstracts from the literature, the author has documented the origins and problems associated with the mining of opal from this historic area in New South Wales. P.G.R.

Zoning in Sri Lankan zircons: chemically controlled?

M.S. Rupasinghe and A. Senaratne. *Australian Gemmologist,* **19**(7), 1996, pp 288–91, 1 illus. in black-and-white, 1 table, 5 graphs, bibl.

Zoned Sri Lankan zircon crystals of yellow and green colour were selected for electron microprobe analyses. Chemical data from at least three points in each crystal zone were obtained and some of the crystals were further studied under the scanning electron microscope. In each zircon crystal, a metamict zone was identified by the presence of high contents of trace elements including Th and U. In Sri Lankan zircons, iron migrates through pathways created by radiation damage. The clear coincidence of Fe peaks, and mid-points of zones, indicates a positive relationship between chemistry and zonation in these zircons. P.G.R.

Flammenachat aus Brasilen. Zur Entstehung ungewöhnlicher Chalcedon-Quarz-Geoden aus dem Paraná-Becken, Rio Grande do Sul, Brasilien.

R. Rykart. *Lapis,* **22**(5), 1997, pp 27–31, illus. in colour, 2 maps.

Agates with flame-like structure occur in the area of Paraná-Becken in the Soldedad region of Rio Grande do Sul, Brazil. Various examples are described and illustrated and there are notes on occurrence. M.O'D.

Kosmochlor from the Osayama ultramafic body in the Sangun metamorphic belt, southwest Japan.

S. Sakamoto and A. Takasu. *Journal of the Geological Society of Japan,* **102**(1), 1996, pp 49–52.

Kosmochlor occurs in actinolitic lenticular masses in serpentinized harzburgite; it is associated with uvarovite, Cr-bearing actinolite and minor chromite. EPMA results show that the pyroxenes contain Cr_2O_3 0–18.8 wt.%, Na_2O 0.3–7.9 wt.%; the uvarovite has Cr_2O_3 21.00 wt.% and the actinolite has $Cr_2O_3 < 4.3$ wt.%. The phase relations of this assemblage are tentatively discussed. R.A.H.

An update on Imperial Topaz from the Capao Mine, Minas Gerais, Brazil.

D.A. Sauer, A.S. Keller and S.F. McClure. *Gems & Gemology, 32*(4), 1996, pp 232–241, 15 illus. in colour.

The Ouro Preto Imperial Topaz district comprises two major active mining areas, Vermahao and Capao, the latter being the only completely mechanised, privately owned mine that also is currently in full production. The topaz is recovered from a single horizon of heavily weathered yellowish to dark-brown talc clay rock called 'brown terrain'. Details are given of the current mining operation and the recovery processes used.

All topaz from the Ouro Preto area is called Imperial Topaz and colours mined at the Capao mine range from yellows and oranges to pinks and reds, with the latter being the most sought after. Only 1%–2% of all the material recovered is of faceting quality. After heat treatment brownish-yellow and orange topaz may become peach to pink in colour. Most of the topaz is not suitable for heat treatment due to inclusions, especially liquid inclusions as these cause the stones to crack on heating.

It was found that the heat-treated stones showed a stronger fluorescence under short-wave UV than natural stones and this might prove to be an important diagnostic feature in the future but so far only a limited amount of stones have been tested. J.J.

Trapiche rubies.

K. Schmetzer, H.A. Hänni, H.-J. Bernhardt and D. Schwarz. *Gems & Gemology,* **32**(4), 1996, pp 242–50, 18 illus. in colour.

Trapiche rubies exhibit a fixed six-ray star effect, formed by six transparent ruby sections delineated by six non-transparent arms. The arms intersect at a small point in the centre of the crystal, or at an opaque yellow or black core. Most of the cores are tapered along the length of the crystal. The arms and boundaries of some of the cores are formed by a dense concentration of tubes, which under high magnification are found to be filled with a birefringent mineral, a liquid or a liquid and gas. The tubes are orientated perpendicular to the dominant dipyramidal faces ω $\{14\ 14\ \overline{28}\ 3\}$, which are inclined at 5° to the c-axis. By use of a Raman spectroscope and electron microprobe analysis the fillings were found to be calcite and dolomite. Excellent detailed coloured illustrations are included showing the various structures of the cores and arms. The authors thought the inclusions that gave rise to the core and the arms were primary structures. Myanmar, Vietnam and Mae Sai in N. Thailand are possible sources. Also discussed are the similarities and differences between trapiche emeralds and rubies, together with details of trapiche sapphires. J.J.

Achatführende Lithophysen aus dem Lierbachtal, Schwarzwald.

J. Schmidt. *Lapis,* **22**(5), 1997, pp 32–7, illus. in colour, 1 map.

Specimens of agate from the Lierbachtal in the German Schwarzwald show patterning attractive enough to make specimens worth collecting. Notes on their occurrence are given. M.O'D.

Mineralien aus dem Drammengranit, Norwegen.

M. Sendelbach. *Lapis,* **22**(4), 1997, pp 35–8, illus. in colour, 1 map.

Crystals of smoky quartz, light-blue topaz, colourless phenakite and blue-green beryl are described from the granites at Drammen in south-eastern Norway. M.O'D.

Amethyst aus den Colli Euganei, Monte Rusta, Fontanafredda, Padua/Italien.

S. Sovilla. *Mineralien Welt,* **8**(3), 1997, pp 36–8, Illus. in colour, 4 maps.

Though insufficiently large for ornamental use, amethyst crystals found at Colli Euganei, Monte Rusta, Fontanafredda, in north-east Italy, are finely-coloured and well-shaped: they are likely to attract collectors of gem mineral crystals. M.O'D.

Gem quality rhodochrosite: 'the Inca rose'.

M. Sutherland. *South African Gemmologist,* **11**(1), 1997, pp 14–15.

Account of the testing and identification of a mounted rhodochrosite during which the real/apparent depth method was used to obtain RI. M.O'D.

Gem spinels from Tunduru, southern Tanzania.

A.E. Thomas. *South African Gemmologist,* **11**(1), 1997, pp 24–35, illus. in colour.

Spinels recovered from a parcel of alluvial gem mineral concentrate from the Tunduru area of southern Tanzania proved to make up over 60% of the species included. The area of origin and the spinels are described: specimens were found as rounded pebbles and presented various shades of blue, with some lilac and light-pink examples. A few stones gave a colour change. Some inclusions were identified as calcite and others as högbomite. A full table of testing results is given, with a list of references. M.O'D.

[REE-rare-metal pegmatites of Madagascar.] (Russian with English abstract).

V.V. Zhdanov. *Proceedings of the Russian Mineralogical Society,* **125**(3), 1996, pp 1–8.

The data from many years of study of the gem-bearing and other economically important pegmatites of Madagascar are summarized. The principal stages in the geological history of Madagascar are outlined and the composition and structural settings of these pegmatites are discussed. R.A.H.

Enstatite, cordierite, kornerupine and scapolite with unusual properties from Embilipitiya, Sri Lanka.

P.C. Zwaan. *Gems & Gemology,* **32**(4), 1996, pp 262–9, 10 illus. in colour, 2 tables.

Gem stones with unusual properties have been found in the vicinity of Embilipitiya, southern Sri Lanka, in alluvial deposits. Some of the stones are Mg rich, especially the pale to colourless enstatite, cordierite and kornerupine, other gemstones include scapolite, almandine garnets and spinels. The enstatites are colourless to deep brown, with the colourless stones exhibiting exceptionally low RIs ($n_\alpha = 1.650$ and $n_\gamma = 1.658$) and SG (as low as 3.194). All were found to have an absorption band at 506 nm, which is diagnostic. Cordierites were colourless to pale blue. The diagnostic strong pleochroism was not to be seen in the paler stones. Kornerupine was one of the more common gemstones found in the area and varied from yellow to green to brown with the SG generally increasing with increased colour intensity; all exhibited pleochroism. Scapolite was colourless to yellow and showed a strong yellow fluorescence under long-wave UV. J.J.

Instruments and Techiques

Measurement of refractive index by the apparent depth method.

D. Bennett. *Australian Gemmologist,* **19**(7), 1996, pp 292–4, 2 illus. in black-and-white, 5 tables.

Experiments were carried out to determine the practicability and accuracy of the direct method of refractive index measurement of a faceted gemstone. The average was taken of five measurements of the actual depth and apparent depth of a range of stones having a refractive index above 1.79. A binocular Siewa microscope at 40x magnification, a uniocular Shimadzu microscope at 50x magnification, and a vernier gauge were used for the measurements. Chips on the culet made it difficult to locate the absolute bottom of a stone when focusing through the table of the stone. It was also found that results were closer to accepted standards if the vernier gauge, rather than the microscope, was used to measure the actual height of the stone. The experiments proved that the method produced credible results which would assist gemmologists to identify faceted gemstones and other man-made materials having refractive indices beyond the range of the standard critical angle refractometer. P.G.R.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology,* **32**(4), 1996, pp 282–92, 21 illus. in colour.

International conference on Raman spectroscopy and geology. The merits of Raman spectroscopy are outlined, especially for identifying inclusions and the fillings in fractures in gem stones. The problems to date have been the setting up of a data base and with the variations of the Raman peak intensities, which depend on the crystallographic orientation of the stone. J.J.

Synthetics and Simulants

Gem trade lab notes.

C.W. Fryer. *Gems & Gemology,* 32(3), 1996, pp 204–12.

Five imitation cubic zirconia shaped to look like diamond crystals, with diamond features such as triangular impressions, engraved parallel lines and frosted surfaces, were detected by the difference in 'heft', the SG of cubic zirconia being 5.80 compared to 3.52 for diamond. J.J.

EPR/ESR spectra of natural and synthetic opals.

D.R. Hutton, G.J. Troup and M. Young. *Australian Gemmologist,* **19**(9), 1997, pp 365–7, 4 graphs.

The late application of Electron Spin Resonance spectroscopy and Electron Paramagnetic Resonance spectroscopy to opal examination is explained by the authors as being due to the non-arrival of specimens of CSIRO's synthetic opal at the Physics Department, Monash University, in the mid-1960s. However, in retrospect, it is now thought that the sensitivity of the apparatus at that time would have been inadequate for research work into opal spectra.

Specimens of natural opal from various sources (Australian from Coober Pedy, Mintabie and Lightning Ridge, precious opal from Indonesia, Mexican fire opal and precious opal from Nevada, USA) and a sample of old production Gilson 'synthetic' opal were examined on a Varian E-12 9.1 GHz ESR spectrometer in the Physics Department of Monash University, and on an ESR spectrometer developed by members of that Department.

Observed differences between the spectra produced by the samples should allow discrimination between natural opals from Australia and those from other world-wide sources. Discrimination should also be possible between natural opals and 'synthetic' opal as represented by early production Gilson opal. P.G.R.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology,* **32**(3), 1996, pp 214–22.

Four chatham synthetic 'white' diamonds showed normal reaction of synthetic diamonds to UV, with the shortwave fluorescence being stronger than the longwave but no cross-shaped octagonal patterns were visible under UV. They were found to be type IIb and contained metallic inclusions which were magnetic.

Fibre-optic glass imitation of tiger's eye has been on the market since 1991 and marketed under the names of Catseyte, Cathaystone and Fiber Eye. It produces a sharp chatoyant band in white and brown. More recently yellow, pink, purple, black, blue and gun-metal grey reminiscent of hawk's-eye quartz, a bright green similar to some cat's-eye diopside are now coming from India. J.J.

Gem news.

M.L. Johnson and J.I. Koivula. *Gems & Gemology,* **32**(4), 1996, pp 282-292, 21 illus. in colour.

Imitations of ruby in a green-black-zoisite-matrix (imitation 'anyolite') have been moulded into plaques. The red grains were synthetic rubies, the yellow and colourless grains were not determined, and all were set in a polymer.

A grey metal pendant was thought to be a Tibetan Pendant consisting of meteorite iron. EDXRF spectroscopy found it to be a bronze or brass alloy.

Another tanzanite imitation consisted of a synthetic spinel triplet with a quartz centre. J.J.

Some tanzanite imitations.

L. Kiefert and S. Th. Schmidt. *Gems & Gemology*, **32**(4), 1996, pp 270–276, 11 illus. in colour, 2 tables.

The authors provide up-to-date identification criteria for some of the imitations of tanzanite that have recently appeared on the market. These are: doped heavy glass, trade name U.M. Tanzanic; YAG, trade name Purple Coranite; synthetic corundum, trade name Blue Coranite; and Ca phosphate glass. A table of the properties of tanzanite and the imitations is given. Most of the imitations are readily identifiable, as tanzanite is pleochroic, biaxial and inert under long- and short-wave UV. J.J.

Synthetic diamond: a challenge of the century.

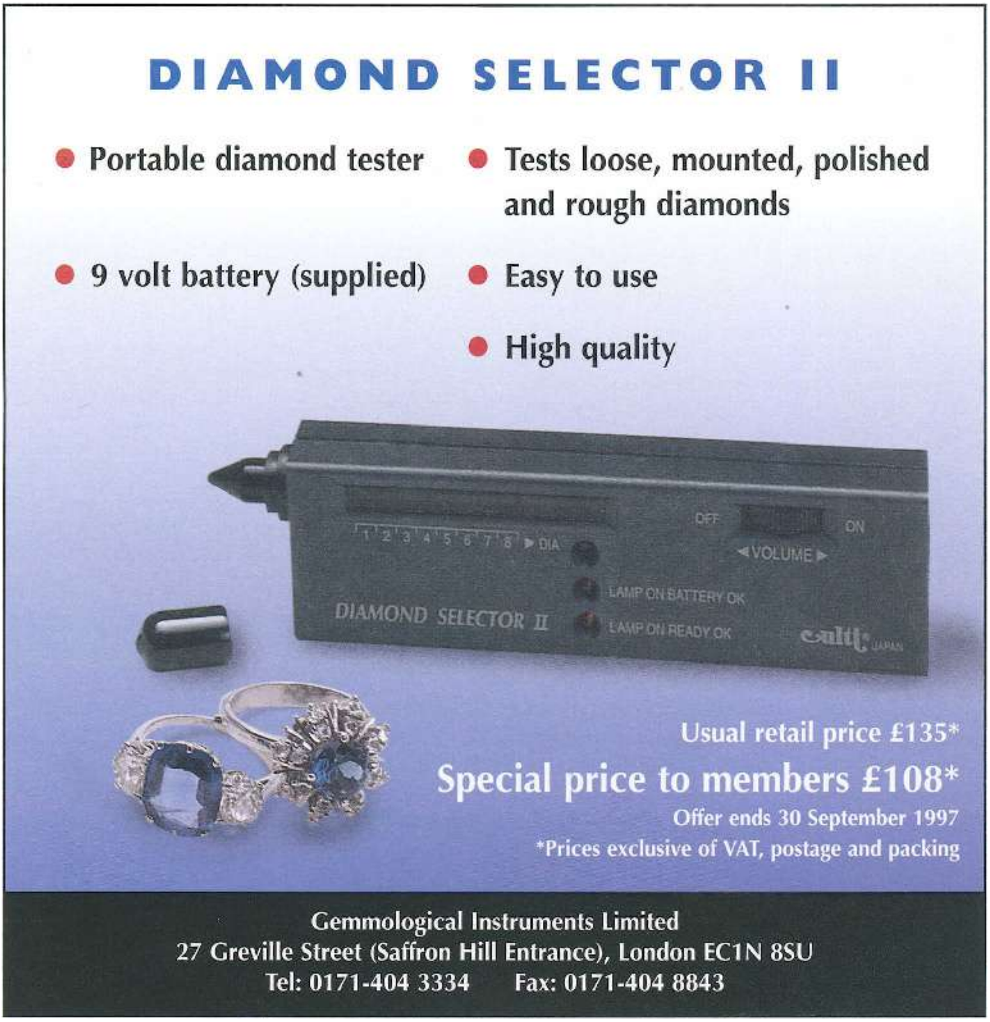
J. Panjikar and K.T. Ramchandran. *Indian Gemmologist*, **6**(4), 1997, pp 11–16, illus. in colour.

An outline of some of the methods for the manufacture of synthetic diamonds is given with notes on the tests so far made available to gemmologists. M.O'D.

Identifying characteristics of hydrothermal synthetics.

B. Sechos. *Australian Gemmologist*, **19**(9), 1997, pp 383–8, 13 illus. in colour, 3 tables.

Dealing with those hydrothermally produced synthetic gems that are presently common on the Australian market, the author tabulates the identifying properties and illustrates the identifying features and inclusions in Biron and Russian synthetic emerald, and Russian synthetic ruby. While the hydrothermally grown Russian emeralds and rubies are quite readily identifiable, the Biron synthetic emerald presents more of a challenge. However, the gemmologist with a well equipped laboratory of standard gemmological instruments, including a good microscope, should have no difficulty in identifying any of these hydrothermal synthetics. P.G.R.



BOOK REVIEWS

Gemme del Vicentino.

M. Boscardin and O.V. Tescari, 1996. Montecchio Maggiore: Museo Civico 'G. Zannato'. pp 114, illus. in colour, softcover. Price on application.

A number of mineral species with ornamental application have been found in the Vicenza area of north-eastern Italy. The present study describes the species in alphabetical order with notes on their occurrence and distinguishing features, together with their size and general appearance. Species selected for description are taken from the collections of the Museo Civico 'G. Zannato' at Montecchio Maggiore.

Gemmologists will be interested to know that while quartz in its various forms accounts for a high proportion of the specimens described, faceted examples of attractive orange-yellow-brown zircon and green peridot appear in the survey with cabochons of rhodonite and rhodochrosite. One faceted xonotlite is illustrated, here resembling white moonstone: this is a calcium silicate hydroxide with a hardness of 6.

Data are coherently assembled and there is an excellent bibliography. M.O'D.

Brazil

Companhia de Pesquisa de Recursos Minerais Principais depósitos minerais do Brasil. Vol. IV Parte A. Gemas e rochas ornamentais. Brazil, 1991. pp viii, 461, illus. in colour, softcover. No price given.

Published in association with the Departamento Nacional da Produção Mineral, the book forms one part of a survey of Brazil's major mineral deposits. This is the only current large-scale study of Brazilian gem occurrences written from the geological/mineralogical/mining standpoint and although English readers may have some slight difficulty with the Portuguese, this should not stand in the way of consulting the book where it can be found. The maps which seem to occur on almost every page are a vital source of information on their own. Each chapter has its own list of references, very many of them taken from the less easily obtained journals and forming a rich archive of information.

The first chapters deal with the definition of a gemstone, with nomenclature and classification and with the general 'gem province' of Brazil. The third chapter deals with the geology of Brazilian gemstone deposits and the book then continues with nine chapters (about 150 pages) on the geology, mineralogy and occurrence of diamond in Brazil. I cannot think of another such study apart from occasional papers. Emerald has three chapters (about 45 pages) and is followed by a survey of amethyst and agate in Rio Grande do Sul, Alto Bonito and Pau d'Arco (about 30 pages).

Similar coverage is given to topaz, aquamarine and opal, after which the book turns to a description of malachite, gemstones from pegmatite deposits and their properties, ornamental materials, granites and marbles from the state of Paraná and other states.

The book is in every way worthy of its subject and of one of the great gem-producing countries of the world. It has appeared quietly, as can be seen by this review written six years after publication. Interested readers should write to Departamento Nacional da Produção Mineral, SAN-Quadra 01-Bloco 'B', 70040 Brasília DF, Brazil. M.O'D.

Costume jewellery.

D.F. Cera, 1997. Antique Collectors' Club, 5 Church Street, Woodbridge. pp 256, illus. in colour, hardcover. £14.95. ISBN 1 85149 265 8.

For once there is a jewellery book of manageable size (20 x 12.5 cm) with high-quality illustrations! The text was first published by Arnoldo Mondadori Editore of Milan in 1995 and the English translation and captions read easily. The book is arranged chronologically, beginning with the Edwardian period and including the Arts & Crafts and Art Nouveau styles and continuing with Art Deco, the first costume jewels 1950-1959, the Hollywood years, the supremacy of Paris and the period from 1960 to 1969 when Italian costume jewellery held first place in fashion.

Illustrations are well chosen, the captions giving manufacturer, place and date, materials and techniques used, mark where relevant and provenance. Sizes are not given but this does not matter in most cases. Useful short biographies of major manufacturers and a glossary are given at the end of the book where there is also a very short bibliography. Small errors can be found in the glossary but they do not affect the general excellence of the book and its pleasing appearance. M.O'D.

Bernstein, Tränen der Gotter.

Michael Ganzelewski von Herausgegeben and Slotta Rainer, 1996. Katalog der Ausstellung des Deutschen Bergbau-Museums Bochum in Zusammenarbeit mit dem Ostpreussischen Landesmuseum Lüneburg und dem Siebenbürgischen Museum Gundelsheim. Deutsche Bergbau-Museum, Bochum. pp xiii, 585, illus. in colour, hardcover. Deutsche Bergbau-Museum, Am Bergbaumuseum 28, D-44791 Bochum, Germany. ISBN 3 921533 57 0. [Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum. Nr 64.] DM60.

This is the largest and most comprehensive study of amber to appear for many years and is published by the Bergbau-Museum with the co-operation of a number of German museums to accompany a loan exhibition shown during 1996. Any study by museum staff is expected to show a high level of scholarship and the book examines amber and its occurrence and recovery in such detail that it

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should remain the standard text for many years to come. At the outset I have to make the point that European amber is the main theme though deposits elsewhere are not omitted. The bibliographies that accompany each separate section reflect this very reasonable emphasis – European deposits and their working have been known for centuries and are well recorded.

The arrangement of the book is in major sections subdivided into smaller ones, some of which may be two or three pages only. To give an idea of the form, the first section is fully described as a model for the following sections. Though I have used the word chapter for convenience, there are no chapters and neither the major sections nor the smaller ones are numbered.

The first section opens with a short account of references to amber in Classical texts and especially to Ovid's *Metamorphoses* and to references in Lucian. The text then turns to the major task of introducing the finding and discovery of Baltic amber: a useful map shows the position of sea and land during the Eocene period. The formation and structure of amber are discussed with short notes on inclusions and notes on the wider use of the name amber. The next chapter surveys world deposits and includes maps.

Inclusions are dealt with in the next part which contains several photographs of the highest quality and which is followed by a short note on amber chemistry and origin. Methods of amber recovery are described next in a section covering contemporary resins as well as amber. By now we have covered over 60 of the 585 pages and completed the first major section.

The next major areas to be discussed are in Germany as understood today. Taken in order they are the south-eastern part of Lower Saxony (the area of Helmstedt), central Germany (Bitterfeld and its environs), Lausitz and Mecklenburg. Notes on amber finds in Jutland and south Sweden are also here.

Another major section now begins with reports on amber deposits and working in the former east Prussia. These are deposits well-known to all connoisseurs of amber and their history is minutely detailed with biographical notes on some of the major figures involved. Many mines are illustrated and the photographs show workings and techniques that I have not seen published before. Amber mining in Poland, the Ukraine, western Russia, the Alps, Romania, Italy and the Dominican Republic are also described in detail, completing another major section.

The book now deals with amber in history and in artefacts, taking a number of major works and examining them as well as describing the medicinal uses of amber. Imitations of amber are covered in this section.

The final section lists and describes the 437 items forming the exhibition. A double-page spread of 24 colour photographs of insect inclusions in amber, with the insects classified, is included in the exhibition.

The review can give only a glimpse of the very large amount of information contained in the book. The very large number of references include mostly papers in German or published in Germany: they are especially welcome as amber has not previously had a serious scholarly treatment on this scale and much published information has hitherto been very hard to trace. The production is excellent with good paper and clear printing: though the book is heavy it is bound in boards and seems firm. This is a major book in every way and needs to be in major libraries. M.O'D.

Otamatea Kauri and Pioneer Museum. [A guide to the Museum. Fifth printing]

Otamatea Kauri and Pioneer Museum Board, 1995. Matakohe, Northland, New Zealand. Unpaginated, 1 map. Price on application.

The Museum contains artefacts pertaining to the Kauri tree, source of the Kauri gum resin whose nature and processing are also described and illustrated. It is clear from the black-and-white photographs that the Museum should be visited by all with an interest in this type of material which is often not well understood by gemmologists. Matakohe is 142 km from Auckland and its position is shown on a useful map which also includes locations of forests and other notable places.

The literature of natural ornamental and workable resins is not large and gemmologists should try to obtain this excellent modern example. M.O'D.

Mani-málá, a treatise on gems.

TAGORE, RAJA SOURINDRO MOHUN, SIR ALSO KNOWN AS SAURÍNDRAMOHANA THÁKURA, 1996. Dr Nandkishor R. Barot, PO Box 47928, Nairobi. 2 vol., pp 1046, illus. in colour, hardcover. Price £120.00.

This welcome addition to the eastern lore and language of gemstones is published as a facsimile reprint of the now very rare Calcutta edition of 1879. Copies of the original often lack one or other of the parts which were usually bound together although the paper used was quite durable.

The purpose of the author was to bring together as a corpus some at least of the vast body of Indian reports, legends, stories, medical hints, accounts taken from the gemstone lore of other literatures including European ones, and notes on how gemstones were priced. Students needing to begin a search on any aspect of Indian gemstones must begin with this book: it provides a starting-point for many of the tales still current and repeated today from book to book and gives accounts of locations, however vague, for a number of important gem species.

The first volume comprises part 1 of the work and starts with an account of a mystical jewel with magical properties. This separate work, the *History of Syamantaka*, occupies 60 pages and tells of the Syamantaka, a gem of unstated species, which played a part in the activities of some of the deities of the Hindu pantheon. The author then turns to diamond after a brief note, with anecdotes, of other well-known species: he recounts in 95 pages how diamonds occur in different colours (including red) and how eight sources are known (all on the Indian sub-continent). While some of the properties are now known to be inaccurate (some stones are said to float on water), others are recognizable today. References are made to the diamond crystal rather than to fashioned stones. The chapter ends with a sudden jump to the nineteenth century and includes details of properties still used in gem testing and short accounts of named diamonds known by that time.

Ruby, which follows, is treated in the same way although no legend is transcribed. Sri Lankan stones are given pride of place: some rubies are compared to the interior of the half-blown red water lily while others are compared to cochineal. The best rubies are given the name *padmarága* and the author states that 'the authorities mention sixteen kinds of shade, four good and eight bad properties of rubies' – these are described. As with diamond, this account is then followed by an up-to-date description of rubies and their simulants and notes on famous specimens.

This way of ordering material is followed with the species cat's-eye [chrysoberyl is meant], pearl, zircon, coral, emerald, topaz, sapphire, chrysoberyl, garnet, carnelian, quartz and rock crystal. The first volume ends at this point.

The second volume, like the first giving English and the original text on opposing pages, deals with 'minor gems': these are aquamarine, chrysoprase, onyx, bloodstone, jade and tourmaline. After remarks on the genesis of gemstones and the division of diamonds into cast, particular properties of the major gem species are given – these are simple medicinal hints taken from Sanskrit rather than identification criteria. Sanskrit thoughts and legends pertaining to gemstones take up approximately the next 200 pages.

The remainder of the book is given to appendices in which a number of different topics are covered. They include details of some European regalia, further notes on the properties of gemstones, selling prices past and present, and notes on the Peacock Throne of Shah Jehan. This miscellaneous section is followed by gemstone descriptions taken from Arabic and Persian writers. Even now the book is not complete since the last hundred pages contain further descriptions and a most useful bibliography. A few black-and-white reproductions of various items of regalia and two coloured photographs (of a group of unnamed faceted stones and of the Imperial State Crown) bring the two volumes to an end.

We can see from this account that the book is an essential source for all kinds of information that would not have been brought together before its original publication. It is both informative and charming to read: the touch of the present editor is very light and serious students of gemstones should try to get a copy: the print run cannot be large and this is an opportunity to obtain one of the rarest and greatest gemmological texts. M.O'D.

The complete? polygon.

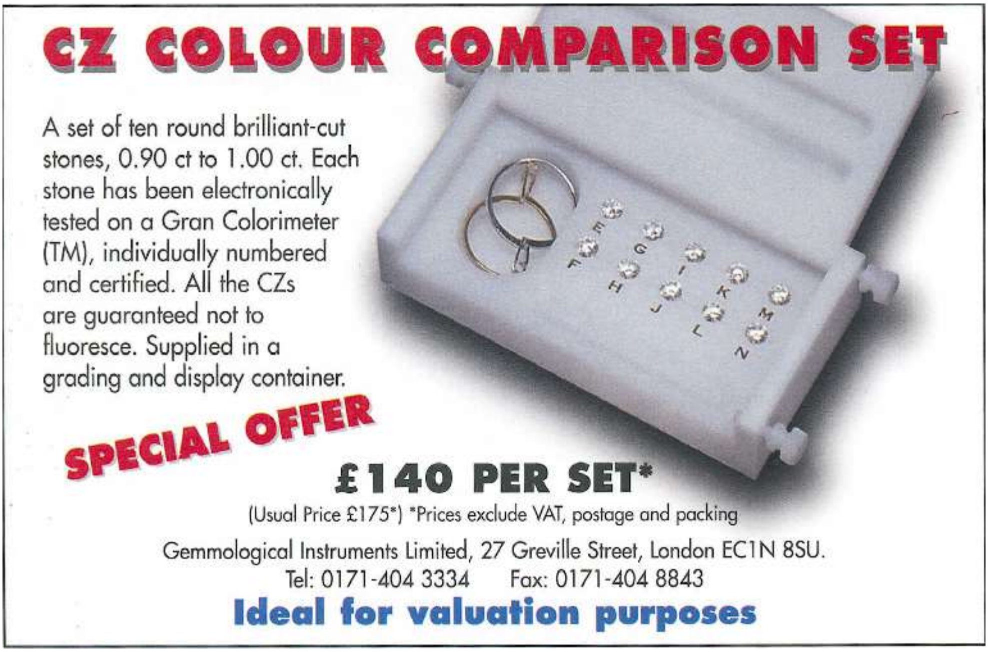
P. Taylor, 1997. Nattygrafix, 277 Cavendish St., Ipswich, IP3 8BQ. pp 60. Price on application.

This study will be of interest to readers specializing in crystal morphology and forms a part of an intended survey to be entitled *The complete? polyhedra.* The printing and layout are very well handled and though the text needs a good deal of concentration by the reader it is a useful and provocative essay. M.O'D.

Tiaras. One hundred tiaras: an evolution of style 1800-1990.

1997. Wartski, London. pp 38, illus. in colour. £5.00.

A short but informative and well illustrated catalogue raisonné of an exhibition of tiaras held at Wartski of London with descriptions, provenances and notes of present owners. The exhibition itself was very well arranged and lit. Studies of particular items of jewellery are not too common and readers should ensure that they obtain a copy. M.O'D.



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

PHOTOGRAPHIC COMPETITION

The 1997 Photographic Competition on the theme 'Collectors' Gems' produced an interesting and varied selection of fascinating illustrations. After careful deliberation by the judges, the prizes have been awarded as follows:

First Prize

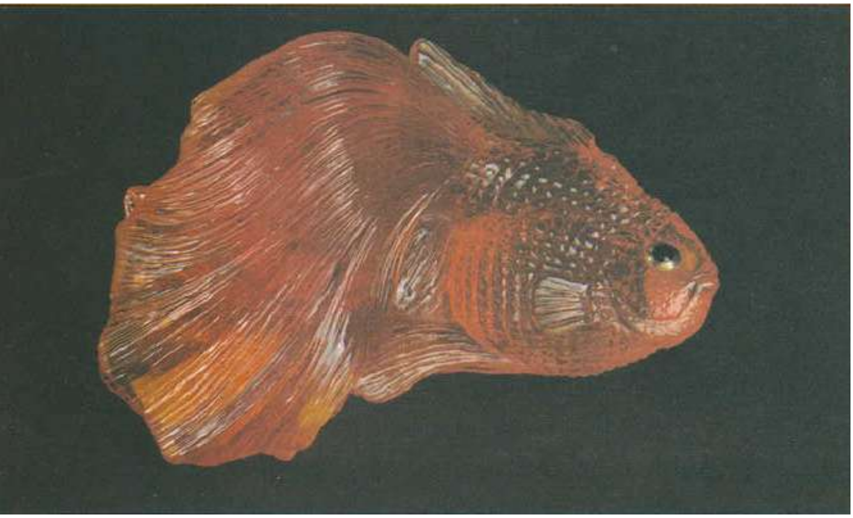
Patrick Daly, BSc, FGA, Windsor
A hopper crystal of diamond **(see front cover)**

Second Prize

Robert J. Maurer, FGA, DGA, Redhill
A fish carved in fire opal

Third Prize

Victoria A. John, London
Pietersite



We are pleased to announce that the prizes were sponsored by Quadrant Offset Ltd, and the GAGTL is most grateful to them for their generosity. The prizes were presented and the winning entries exhibited at the Reunion of Members held on 30 June.

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OBITUARY

Eunice Miles (Hon. FGA), Naples, Fla, USA, died 31 March 1997. A full obituary will be published in the October issue of the *Journal*.

GIFTS TO THE ASSOCIATION

The Association is most grateful to the following for their gifts for research and teaching purposes, and for contributions towards the gemstone loan collection being set up by the Education Department:

Tom Banker, Bangkok, Thailand, for 67 pieces of rough including amethyst, apatite (various colours), iolite, Mexican opal, topaz and tourmaline (various colours).

René Brus, Rijswyk, The Netherlands, for a copy of his new book *De Juwelen van het Huis Orange-Nassau*.

Eddie S.K. Fan, FGA, Kowloon, Hong, for 22 samples comprising treated jadeite, serpentine, saussurite and maw-sit-sit.

Mrs Ameena Kaleel, FGA, Mount Lavinia, Sri Lanka, for a collection of crystals including colour-change garnets, tourmaline and corundum and an unusual garnet crystal.

David Kent, FGA, a Vice-President of the GAGTL, for 193 small crystals and cut gemstones.

Çigdem Lüle, Ankara, Turkey, for crystals of diaspore from Milas, south of Izmir, Turkey, and *A catalogue of a collection of minerals of Turkey*.

Ms C.M. Ou Yang, Hong Kong, for an owl carved in hydrogrossular.

Michael Parsons, FGA., Bath, for 28 assorted stones.

Pierre Vuillet à Ciles, FGA, Villards d'Heria, France, for specimens of cut and rough garnet-topped doublets, slices of almandine garnet for GTDs, preformed soudé emerald, imitation emerald, 'roughs' of spinel/spinel soudé, glass and glass-coated samples, synthetic rubies, various cabochons and *L'industrie lapidaire* by G. Burdet.

Bernard Worth, FGA, Stow-on-the-Wold, for 192 stones including turquoise, opal, garnet, topaz and paste.

The Education Department would like to thank all those who responded to the request for gem materials for training and demonstration purposes, published in the April issue of the *Journal*.

NEWS OF FELLOWS

Michael O'Donoghue and **Tony French** gave a presentation on rare stones to the Wessex Branch of the National Association of Goldsmiths on Wednesday, 23 April 1997.

MEMBERS' MEETINGS

London

On 16 April at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8SU, Ian Freestone gave an illustrated lecture entitled 'Make paste! Imitating precious and semi-precious stones over 5000 years'.

On 7 May at the Gem Tutorial Centre, Terry Davidson, FGA, gave an illustrated talk on '150 years of Cartier'.

The Annual General Meeting was held on Monday, 30 June, followed by the Reunion of Members and a Bring and Buy Sale. A full report will appear in the October issue of the Journal.

Midlands Branch

On 21 March at the Discovery Centre, 77 Vyse Street, Birmingham, Blane Price of the London Pearl Company gave a talk on pearls.

On 25 April at the Discovery Centre the Annual General Meeting of the Branch was held at which David Larcher was elected President, and Gwyn Green and Elizabeth Gosling were re-elected Chairman and Secretary respectively. The AGM was followed by a talk by John Bugg entitled 'Gems from the Law'.

At Gem Clubs held at Barnt Green on 20 April and 18 May, David Proudlove gave a demonstration of diamond-cutting techniques and Gwyn Green gave a practical session on diamond grading. Examination seminars for Preliminary and Diploma students were held on 27 April and 4 May.

North West Branch

On 21 May at Church House, Hanover Street, Liverpool 1, Doug Garrod gave an illustrated talk entitled 'The ins and outs of gemstones'.

On 18 June at Church House a social evening and Bring and Buy was held.

Scottish Branch

The Annual General Meeting and Conference of the Scottish Branch was held from 18 to 20 April in Peebles. At the AGM, Brian Jackson, Joanna

GAGTL CONFERENCE

Collectors' Gems

The 1997 Annual Conference is to be held on Sunday, 9 November, at the Barbican Centre, Silk Street, London EC2Y 8DS.

Gems are collected for a variety of reasons – perhaps for their rarity, or for an unusual feature compared with others of the species or for their historical associations. Our Conference will give an in-depth view of gems from important collections and speakers will include the following:

Gabriel (Gabi) S. Tolkowsky - Antwerp, Belgium	Forgotten terminologies
David Thomas - London	The Royal Jewels
Ludek Hubrt - Prague, Czech Republic	Crown Jewels of the Czech Kings
Monica Price - Oxford	An educational collection of gems
Lisbet Thoresen - Malibu, California, U.S.A.	Some thoughts on the origin and uses of gemstones in Classical Antiquity
Dr Eleni Vassilika - Cambridge	An historical setting: engraved gems in the Fitzwilliam Museum

As well as a full programme of lectures, delegates will be able to enjoy displays and demonstrations. Arrangements are being made for delegates to view museum collections in London on Monday, 10 November.

Full details of the Conference and an application form are enclosed with this issue of the *Journal.*

Thomson and Gillian O'Brien were re-elected Chairman, Secretary and Treasurer respectively. The Gordon Ness Trophy, for the student who achieves the highest marks in the Diploma Examination in Scotland, was awarded to Catriona McInnes of Edinburgh. A full report of the Conference was published in the June issue of *Gem and Jewellery News.*

A lapidary day was held on 1 June at the West Granton Research Centre, Edinburgh.

ANNUAL REPORT

The following is the report of the Council of Management of the Gemmological Association and Gem Testing Laboratory of Great Britain for 1996

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. Professor R.A. Howie was elected President at the AGM in June and E.M. Bruton resumed his vice-presidency together with A.E. Farn, D.G. Kent and R.K. Mitchell. The company benefits greatly from the contributions of the Members' Council, the trade and education committees and meetings. Dr G. Harrison Jones continued as Chairman of the Board of Examiners and Miss C.M. Woodward was elected Vice-Chairman. C. Winter continued as Chairman of the Members' Council; G. Monnickendam retired at the AGM and J. Greatwood and J Monnickendam were elected to the Members' Council. D. Gann continued as Chairman of the Trade Liaison Committee.

It has been a good year for education, pearl testing and Gemmological Instruments Ltd which showed significant growth, but overall in GAGTL 1996 saw a slightly reduced turnover, with considerable investment in updating the education courses and reduced activity in diamond grading. At the Gem Tutorial Centre in Greville Street, the short course programme was expanded and an additional staff member was recruited to maintain this growth. Allied Teaching Centres (ATCs) were opened in four more cities in China during the year and more are under discussion. The second successful gemmological tour to Idar Oberstein took place in March and both this tour and other ventures are planned for 1997.

FORTHCOMING EVENTS

9, 10 and 11 August	**Scottish Branch.** Field trips.
17 September	**North West Branch.** Mrs Irene Knight will give a talk on jewellery, relating to her visit to Beijing, and Stanley Hill will speak on cloisonnè enamel work.
18 September	**Scottish Branch.** *A stone buyer abroad.* John Levy.
24 September	**London.** *Rock-forming minerals – the writing of a classic.* Professor R.A. Howie.
26 September	**Midlands Branch.** *Famous diamonds I have known.* Howard Vaughan.
13 October	**Scottish Branch.** *Gems – a valuer's heaven or hell?* Brian Dunn.
15 October	**London.** *From sparks to sparkle – a brief history of the use of marcasite/pyrites.* Lynne Bartlett.
15 October	**North West Branch.** A talk by Dr Jack Ogden.
25 and 26 October	**Midlands Branch.** Gemmology workshop.
31 October	**Midlands Branch.** *The sapphires of Scotland.* Brian Jackson.
9 November	**London.** Annual Conference – Collector's gems (full details given on p.506).
10 November	**London.** Visit to the Natural History Museum.
16 November	**Midlands Branch.** Practical gemmology training day.
20 November	**Scottish Branch.** *Scottish river pearls.* Fred Woodward.
28 November	**Midlands Branch.** *Opals.* David Callaghan.
3 December	**London.** *Fluid inclusions: solutions for mineral genesis and gem identification.* Andrew Rankin.
6 December	**Midlands Branch.** 45th Anniversary Dinner.

For further information on the above events contact:

London:	Mary Burland on 0171 404 3334
Midlands Branch:	Gwyn Green on 0121 445 5359
North West Branch:	Joe Azzopardi on 01270 628251
Scottish Branch:	Joanna Thomson on 01721 722936

GAGTL WEB SITE

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

Students taking our examinations improved both their grades and their pass rate over 1995 performances. The Tully Medal was won by Miss Qian Ding of Shanghai, who also won the Diploma Trade Prize; the Anderson-Bank Prize was won by Mr Liu Xu of Wuhan; the Anderson Medal was awarded to Mrs Unni Mitteregger of London; and the Preliminary Trade Prize was won by Miss Victoria Forbes of London.

At the Presentation of Awards, again held at the Goldsmiths' Hall, David Callaghan handed over the diplomas and prizes to the successful students, and also presented a framed Honorary Diploma in Gemmology to Professor R.A. Howie. The new Bruton Medal, named in honour of the immediate past-president, Eric Bruton, was on display and will, in future, be awarded to students for excellence in the Gem Diamond Examination.

Over the past five years GAGTL has participated in developing the Federation of European Education in Gemmology (FEEG), and in August the Federation was legally registered in The Netherlands. Examinations for the Federation's European qualification in gemmology are planned for July in each of the Federation's member countries.

Laboratory staff continued to provide a highly professional service in gem identification and pearl testing. Although total coloured stone testing was slightly down on last year, issuing country of origin opinions and heat treatment opinions for ruby and sapphire continues to be in demand. Pearl testing in 1996 was higher and the benefits of the new X-ray machine installed in 1995 were apparent. In diamond grading, international advertising of the London Diamond Report continued and a new marketing initiative aimed at UK retailers commenced in the summer. Growth in requests for the London Report is steady and the marketing will be continued. CIBJO reports are also an important service offered by the laboratory and staff attended the annual CIBJO conference to participate in discussions on nomenclature and standards concerning diamonds, pearls and coloured stones. The laboratory was pleased to participate in the evaluation of the DiamondSure and DiamondView instruments developed by De Beers DTC Research Centre to distinguish synthetic diamonds from natural diamonds. In June, N.P.G. Sturman resigned from the GAGTL to take up a post with the Bahrain Government. The Council of Management would like to thank him for his contributions to the work of the laboratory – always of a high calibre – and wish him well in his future career.

This year the Trade Luncheon was held in June at the Langham Hilton Hotel and the guest of honour was Mr Naim Attallah, until recently Group Chief Executive of Aspreys. He addressed more than 60 members and guests with a very humorous and perceptive review of the industry today.

During the year staff from the Education section visited China, Hong Kong, Norway and the USA as well as a number of UK locations to give lectures, short courses and to liaise with the growing number of Allied Teaching Centres (ATCs). GAGTL had a stand with the UK group at the Basel Trade Fair, and laboratory staff exhibited at the Institute of Trading Standards Association Fair held in Bournemouth.

The theme of the annual conference held in October was 'Exceptional gems' and Professor Dr Hermann Bank presented the keynote lecture – a kaleidoscope of gem rarities from his exceptional resources in Idar-Oberstein. In sessions chaired by the President, Professor Howie, and by Vivian Watson, Howard Vaughan, Brian Jackson, Peter Zaltsman, Jonathan Condrup and Ben Gaskell presented a varied and fascinating programme of lectures to an audience of 150 from 14 countries.

The evening lecture programme for members in London was augmented by three overseas visitors – Grahame Brown from Australia, Shigeru Akamatsu from Japan and David Minster from South Africa. Several of the events were oversubscribed and accentuated the markedly higher attendances at all the members' lectures during the year. For members outside London, the Midlands Branch again provided a stimulating programme of lectures, club nights, courses and an annual dinner, and there were programmes of lectures and practical sessions at the North West and Scottish Branches – the latter mounting a field trip to hunt for agates.

The 1996 *Journal of Gemmology* issues contained 324 pages exceeding the totals of previous years and sufficient to clear much of the backlog of papers. A constant pressure is maintained to keep costs down, but even though production costs were reduced, mailing costs rose. The same is true for *Gem and Jewellery News,* our joint production with the Society of Jewellery Historians. During the year we welcomed Corinna Pike to the editorial board and she brings current first-hand experience of a top-class jeweller to coverage of a wide range of topics.

Response in the members' photographic competition with the theme 'Images in gems' was the best yet. The winner was S.J.A. Currie of New Zealand, and his rather abstract image of an owl on a branch together with a selection of other exceptional pictures were reproduced in the 1997 calendar, sent free to all members.

Gem Tutorial Centre
Autumn 1997

27 August	**A DAY TO STRING YOUR OWN BEADS** Learn to string with an expert stringer, step-by-step instruction, tips and hints on techniques. *Price £95 + VAT (£111.63) – includes sandwich lunch and a pack of beads and stringing material.* ***Early booking is advised as there is limited space on this course***
2 September	**SHADES OF GREEN** An opportunity to see a variety of green gemstones; not just emerald and synthetic emeralds but tourmaline, diopside, quartz, peridot, green sapphire and zircon, to name but a few. How do you tell them apart? How are they treated? Which man-made products look like them? *Price £99 + VAT (£116.33) – includes sandwich lunch.*
17 September	**INTRODUCTION TO GEMSTONES** A day to look into the beautiful world of gemstones. Hold the gems in your hands and discover the individual qualities and characteristics that make them so prized. *Price £44 + VAT (£51.70) – includes sandwich lunch.*
1 October	**PRELIMINARY WORKSHOP** A day of practical tuition for Preliminary students and anyone exploring the world of gemstones and crystals. You can learn to use the 10x lens at maximum efficiency, to observe the effects and results from the main gem testing instruments and to understand important aspects of crystals in gemmology. *Price £44 + VAT (£51.70) – includes sandwich lunch* *GAGTL student price £32 + VAT (£37.60)*
14 October	**INTO THE BLUE** An opportunity to see a variety of blue gemstones. Handle and examine sapphire, tanzanite, iolite, tourmaline, aquamarine, topaz and zircon, to name but a few. How do you tell them apart? How are they treated? Which man-made products look like them? *Price £99 + VAT (£116.33) – includes sandwich lunch.*
28 October	**DIAMONDS TODAY** An up-to-date review of all aspects of diamonds; rough and cut stones, and treated (laser-drilled and filled), synthetic and imitation materials. *Price £104 + VAT (£122.20) – includes sandwich lunch.*
4 November	**REVIEW OF DIPLOMA THEORY** A day for Gemmology Diploma students to review their theory work and to prepare for the Diploma theory examinations. Tips on the consolidation and revision of facts, figures, principles, practical techniques and instruments. Let us help you to review your examination technique with the help of past questions. *Price £44 + VAT (£51.70) – includes sandwich lunch* *GAGTL student price £32 + VAT (£37.60)*
4 and 5 November	**SYNTHETICS AND ENHANCEMENTS TODAY** Are you aware of the various treated and synthetic materials that are likely to be masquerading amongst the stones you are buying and selling? Whether you are valuing, repairing or dealing, can you afford to miss these two days of investigation? *Price £198 + VAT (£232.65) – includes sandwich lunches.*
11 November	**JADE – THE INSIDE STORY** A panel of jade experts including Roger Keverne, Bob Frey and Rosamond Clayton will cover the history and carving, geology and make-up, simulants and factors affecting the price of jade. *Price £99 + VAT (£116.33) – includes sandwich lunch*

Contact the Education Office on 0171 404 3334 for further information

In common with many other professional associations and learned societies it is a challenge to increase membership of the organization, and totals have varied by only 150 in the last six years. But 1996 did see an increase and the total is 3669. Efforts to gain more members and to retain those we have are bearing some fruit and we will continue the drive to expand the membership.

Gemmological Instruments Ltd can report a successful year in a very competitive market. Turnover rose by over 8 per cent, reflecting increases in both books and instruments. At the end of 1996, the London dichroscope, a low-cost dichroscope for trade and student use, was introduced, having been developed jointly by staff from the Education section and GI Ltd. This reflects the GI Ltd philosophy of supplying good value equipment for practical gemmological use.

In the demanding economic conditions, the Council of Management would like to thank all who have willingly supported and made effective the wide range of gemmological activities undertaken – including staff, those involved in developing and tutoring the courses, and those who have contributed their expertise through committee or personal contact. Their contributions have been crucial to the successes particularly of the education programme and of GI Ltd.

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8SU, on 19 March 1997, the business transacted included the election of the following:

Diamond Membership (DGA)

Lawrence, George, Hove, Sussex. 1997

Tse Yiu Yu Stephen, Hong Kong. 1997

Fellowship and Diamond Membership (FGA/DGA)

Scott, Doreen M., Liverpool, Lancs. 1987/1997

Fellowship (FGA)

Ball Edwards, Chantal, Cheltenham, Glos. 1991
Dupuy, David John, London. 1997
Friedberg, Guy, London. 1997
Kasliwal, Ritika, Jaipur, India. 1996
Nang Mo Kham, Yangon, Myanmar. 1997
Zhang Xueyun, Jiansu, P.R. China. 1996

Ordinary Membership

Arsenikakis, Helena, Blackwood, SA, Australia
Bappoo, Reenabai, London
Breisach, Gabriela, Vienna, Austria
Brunstrom, Isabella, Stockholm, Sweden
Chong, Yuen Kwan, Kowloon, Hong Kong
Costola, Nicola, Grisignano di Zocco, Italy
Dennis, Damon Siegfried, Little Bytham, near Grantham, Lincs
Nyan Hlaing, Yangon, Myanmar
Sharples, James, Bolton, Lancs
Shen, Andy Hsi-Tien, Cambridge
Smith, Robert Jonathan, Birmingham, Warwicks
Stewart, Rosemary June, Sandwich, Kent
Wang Shu-Hui, Taipei, Taiwan, R.O.C.

Laboratory Membership

Russell Lane Antiques, 2–4 High Street, Warwick.

Transfers from Fellowship to Fellowship and Diamond Membership (FGA/DGA)

Chow Chun Hung William, Hong Kong. 1997
Fowle, Michael J., London. 1997
Richardson, Cathryn, Silsden, near Keighley, West Yorks. 1997
Torrent, Denise, Geneva, Switzerland. 1997
Tsang Wai Yi Rita, London. 1997

Transfer from Diamond Membership to Fellowship and Diamond Membership (FGA/DGA)

Liping Li, Wuhan, P.R. China. 1997

Transfers from Ordinary Membership to Diamond Membership (DGA)

Kenny, Sark, Hong Kong. 1997
Kepel, Arthur Mvuta, London. 1997
Lemessiou, Maria A., Nicosia, Cyprus. 1997
Lodge, Tim, London. 1997
Battiscombe, Brigid, London. 1997
Davies, Paul B., Great Missenden Bucks. 1997
Jackson, Stephen D., Perranporth, Cornwall. 1997
Johnston, Dale, Dundonald, Co. Down, N. Ireland. 1997
McInnes, Catriona O., Edinburgh. 1997
McInnes, John L., Edinburgh. 1997
Mao Lingyun, Beijing, P.R. China. 1997
Starreveld, Francis M. M., Hilversum, The Netherlands. 1997

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8SU on 17 April 1997 the business transacted included the election of the following:

Diamond Membership (DGA)

Buxani, Reena Haresh, Kowloon, Hong Kong. 1997
Zhang Yindi, Xia Men, Fujian, P.R. China. 1996

Fellowship (FGA)

Chang, Morley Seng-Hong, Taichung, Taiwan, R.O.C. 1997
Chong Sylvia Yung Yung, Thornhill, Ont., Canada. 1997
Courage, Bruce Crandall, Mahwah, NJ, U.S.A. 1997
Dougherty, William C., Alexandria, VA, U.S.A. 1982
Duncan, Kenneth Greg, Reston, VA, U.S.A. 1997
Hunter, Rachel Suzanne, Clapham, London. 1997
Kearton, Michael James, Eastbourne, East Sussex. 1997
LeungYuen Fan Janice, Hong Kong. 1997
Li Ki Wing Alison, Hong Kong. 1997
Li Qingnian, Xia Men, Fujian, P.R. China. 1996
Made, Lollo, Hong Kong. 1997
Pöntynen, Raija Kaarina, Helsinki, Finland. 1996
Qiu Zhili Zhongshan, Guangzhou, P.R. China.1996
Tang Deping,Fuzhou, Fujian, P.R. China. 1996
Triantafillos, Spiridon, Corfu, Greece. 1997
Tsang Shiu King, Kowloon, Hong Kong. 1997
Uriben, Awr, Bellflower, CA, U.S.A. 1997
Wang Hsiao-Fei, Taipei, Taiwan, R.O.C. 1997

Ordinary Membership

Adan, Abdikarim Abdi, Cardiff, Glamorgan
Aldred, Alison Jane, Wellington, New Zealand
Cheong-Iy, Karine, London
Churchley, Chris M., Windsor Forest, Berks
Ebbs, Heather Alexandra, Winsley, Bradford-on-Avon, Wilts
Frediani, G., London
Fullwood, Garry, Bishops Wood, Stafford
Griffin, Donald John, London
Kitazawa, Yoko, Shibuya-ku, Tokyo, Japan
Lüle, Çigdem, Ankara, Turkey
Maehara, Tamao, London
Razvi, Ahsan, Pimlico, London

At a meeting of the Council of Management held at 27 Greville Street, London EC1N 8SU, on 14 May 1997, the business transacted included the election of the following

Fellowship (FGA)

Chen Liang-Hsuan, Toronto, Ont., Canada. 1997
Chu Li-Ju, Sanchung, Taipei, Taiwan, R.O.C. 1997
Hotung-Lamb, Mara Tegwen, Hong Kong 1997
Kafetsis, George, Athens, Greece. 1997
Lin Shwu-Jiun, San-Chorng City, Taipei, Taiwan, R.O.C. 1997
Marolla, Marianna, Athens, Greece. 1997
Ng, Shuk Hing Jonas, Kowloon, Hong Kong. 1996
Wijesuriya, Guthila, Nittambuwa, Sri Lanka. 1980

Ordinary Membership

Bhargan, Deepak Prakash, Bearwood, West Midlands
Dalaa, Zine Labidine, Oran, Algeria
De Reus, Leonardus Adrianus, Oisterwijk, The Netherlands
Hogg, Ronald, Crieff, Perthshire
Jones-Bateman, Peter, Cardiff
Kleiner, Peter Howard, London
Pagan, Sabine, Berne, Switzerland
Phillips, Andrew Thomas, Pulau Pinang, West Malaysia
Photiou, Maria, Berkeley, CA, USA
Slavin, Nathan, Cockfosters, Barnet, Herts
Thomas, Caan Marcus, Northwood, Middx

Transfer from Ordinary Membership to Fellowship (FGA)

Alessandro, Guastoni, Milan, Italy. 1997

Laboratory Membership

Lucie Campbell, Suite 203, 100 Hatton Garden, London EC1N 8NX
I.M.K. Ltd, 88-90 Hatton Garden, London EC1N 8DN

Corrigenda

On p. 318 above, second column, for 'Moore, Rown Duggan' read 'Moore, Rowan Duggan'
On p. 402 above, in the final line of the caption to Figure 6a and in the Raman spectra shown in Figure 6b, for 'datolite' read 'danburite'

ADVERTISING IN THE JOURNAL OF GEMMOLOGY

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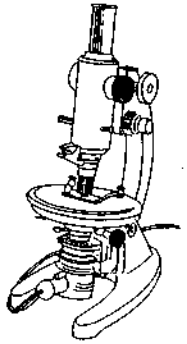

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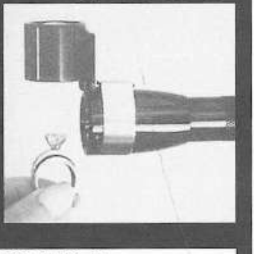

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Collector's gems
A hopper crystal of diamond. Photograph by Patrick Daly, B.Sc., FGA, Windsor (see Photographic Competition pp. 504)

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