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Hte long sein

Gemstones of Peru

Gem quality clinohumite

Colour of diamonds

The Gemmological Association and Gem Testing Laboratory of Great Britain

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Hte long sein – a new variety of chrome jadeite jade

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ABSTRACT: A new variety of chrome-jadeite jade called 'hte long sein' is described. The origin of the name is given and the gemmological properties, chemical composition and IR spectrum described. Its main features compared with traditional jadeite jade are evenness of colour, relative coarseness of grain and opacity.

Introduction

At the 27th Rough Auction held at the end of March 1999 in Yangon, Myanmar, the participants did not expect to see nearly a hundred piles of jadeite rough ranging from full green to bright medium emerald green (*Figures 1 and 2*). It was classified in two grades: Grade A material was pure in colour and fine-grained with few fractures; Grade B was more coarsely textured and contained more fractures. The quality can be classified into five grades according to the colour, transparency, texture and clarity. All the grades are generally called hte long sein.

Hitherto, a few private dealers had sold hte long sein for quite high prices, but the floor prices for the lots at this auction were much lower and prompted the feeling that they were very good value – with comments such as 'glad tidings' and 'Gospel from Heaven' being heard! Consequently, bidding was fierce and ran from one afternoon until 4:00 a.m. the next morning, with some bids ten times the floor price for a particular lot.

In April 1999, several tonnes of full green hte long sein were shipped to Hong Kong, where it became the major topic of conversation – especially around the Canton Road where the dealers have long been involved with 'traditional' jadeite. Initially, some doubted that it was jadeite jade and some gem laboratories declined to issue identification certificates. The influx of such a large quantity of jadeite also raised fears of a slump in the jade market – so far, groundless.

Figure 1: *Hte long sein jadeite jade in Yangon auction in 1999.*

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Figure 2: A lens-shaped specimen of hte long sein jadeite jade.

The Hong Kong market soon saw a wide variety of hte long sein full green products including carved butterflies, autumn leaves, carved beadwork and bangles – all thin-based pieces to demonstrate the richness of the colours (*Figures 3 and 4*). Despite the misgivings of a few people, many welcomed the hte long sein to stir up a jade market they likened to a pond of stagnant water!

Figure 3: A polished slice of hte long sein jadeite jade.

Origin of the name 'hte long sein'

In 1994 a primary deposit of jadeite was discovered at Longkin worksite, north of Pharkant mining district, northern Myanmar. This jadeite had a full green colour and differed from the more familiar green vein or white jadeite with green spots or patches. This difference led to it being called 'hte long sein' – which means 'full green' in the local language. Later, the Chinese transliterated the name to 'tie long shen' or 'tian long sheng' which sounds close to the original Burmese.

Characteristics of rough hte long sein

Large-scale exploitation of the jade at Longkin started in 1997 and was jointly conducted by the Myanmar Government and private enterprise. However, production could only go to auction under the auspices of the government.

The hte long sein jadeite occurs in veins or lens-shaped masses up to 1 m across enclosed in amphibolite and the occurrences

***Figure 4:** Jewellery fashioned in hte long sein jade: (a) dragonfly; (b) flower; (c) beads; (d) butterflies.*

commonly display the following pattern of zoning:

1. core of homogeneous, fine-grained pure green jadeite;
2. each margin consists of jadeite with a glistening mineral resembling hornblende; some veins have margins of white jadeite;
3. country rock of black amphibole and white plagioclase feldspar.

In general, hte long sein has a lovely bright green colour but is poor in transparency.

With this new knowledge about the primary deposit, it is now apparent that similar jadeite has been recovered from secondary deposits for many years, but only in very small amounts.

Gemmological characteristics

Many Hong Kong merchants with more than 20 years experience in the jade trade

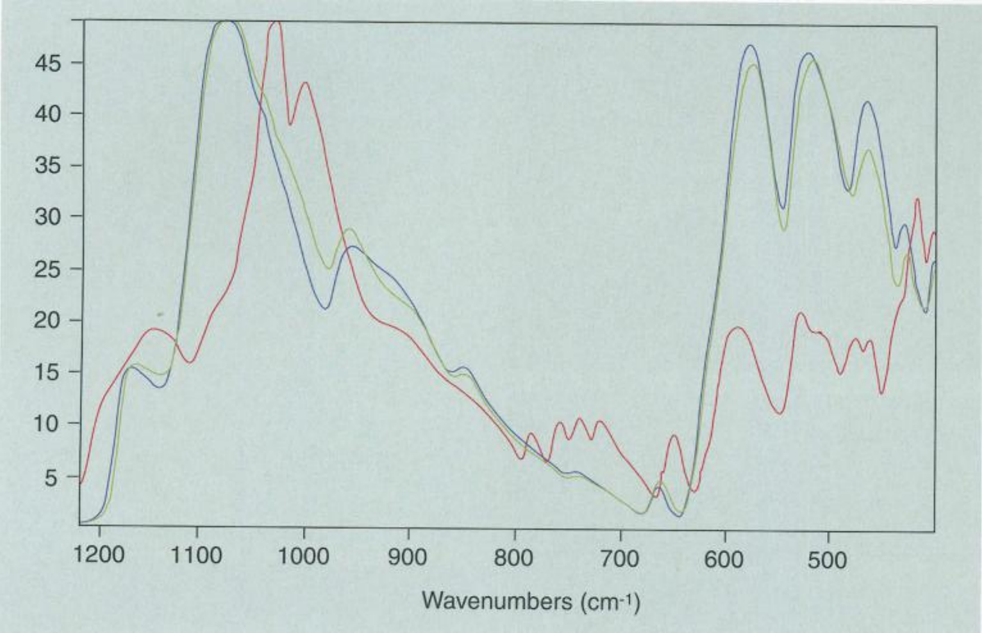

***Figure 5:** Infrared spectra of jadeite jade (blue), hte long sein jade (green), and kosmochlor jade (red).*

consider hte long sein to differ significantly from their traditional material, the principal visible differences being the full green colour and 'looser' coarser texture. Its gemmological features are summarized thus:

Appearance: Bright medium green in different shades; some white spots, poor transparency; coarse to medium grained granular texture; the crystals have no preferred directional orientation but some specimens do contain crystals with some degree of preferred orientation. Because hte long sein is relatively opaque, its appearance can be made most attractive in pieces whose thickness is about 1 mm.

Specific gravity: Most specimens measured by the hydrostatic method had SGs of 3.30-3.31, floating in di-iodomethane, but there is some variation due to the coarse textures and variable contents of fine cracks. If the jadeite contains any of the glistening hornblende-like minerals, SGs are lower.

Refractive index: the average RI is 1.66 by the distant vision method.

Chelsea Colour Filter: Appears green under the filter.

Ultra violet radiation: inert under both long and short wave UV.

Infrared spectrum: reflectance infrared spectral measurements were made on ten samples and a typical spectrum is shown in *Figure 5*, green trace. Pure jadeite and kosmochlor spectra (blue and red traces) are shown for comparison, and the similarity of the hte long sein and jadeite traces is evident.

Laser Raman spectrum: laser Raman spectrum measurements were made on ten samples and a typical spectrum is shown in *Figure 6*, trace 2. Pure jadeite and kosmochlor spectra (traces 1 and 3) are shown for comparison, and the similarity of the hte long sein and jadeite traces is evident.

The petrology

In thin section (*Figures 7 and 8*), the hte long sein can be seen to consist of 80-98% jadeite. Some grains are colourless, others are pale green with distinct pleochroism from

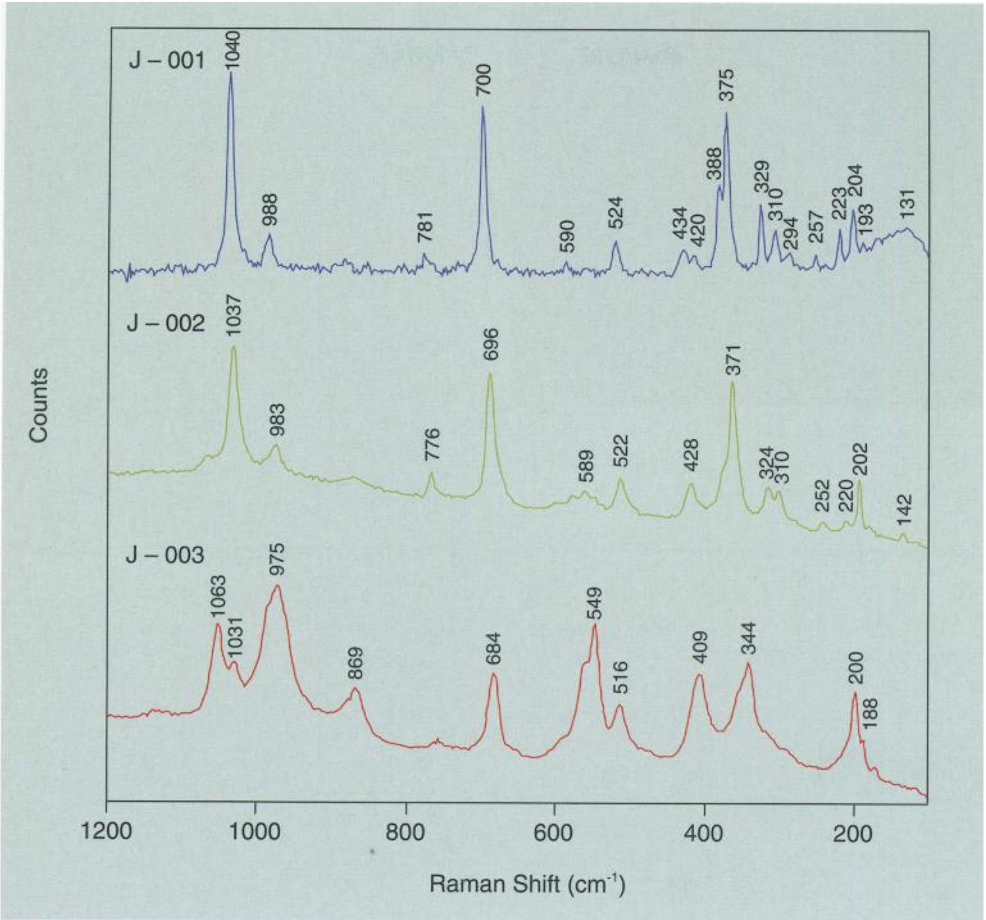

***Figure 6:** Laser Raman spectrum of pyroxene jade: J-001 jadeite jade; J-002 hte long sein; J-003 kosmochlor jade.*

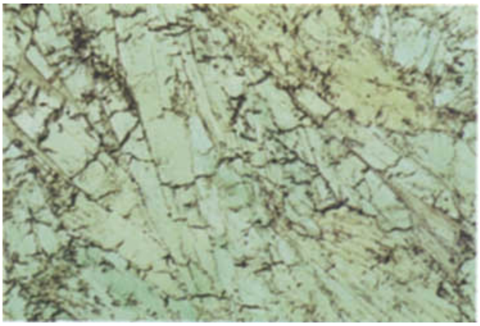

***Figure 7:** Prismatic chrome-rich jadeite in hte long sein jade displays bluish-green / light yellow pleochroism. Field of view 4.25 mm. Plane polarized light.*

***Figure 8:** Fine sub-parallel cracks are visible crossing the c-axis of prismatic crystals of chrome-rich jadeite in hte long sein jadeite jade. Field of view 4.26 mm across. Cross polarized light.*

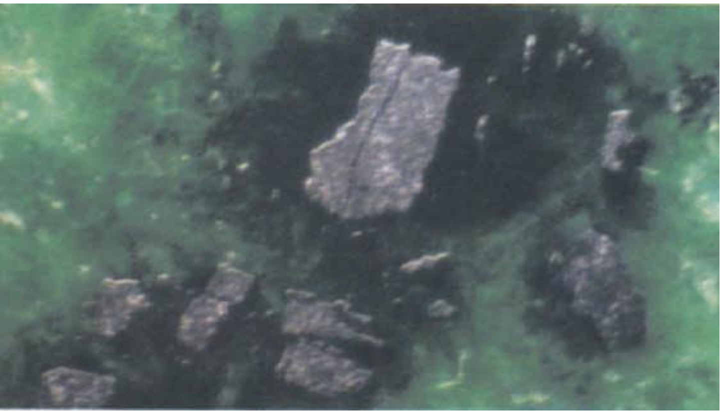

Figure 9: Chromite (black) residual crystal in hte long sein jadeite jade. Field of view 4.8 mm across. Plane polarized light.

light bluish-green to light yellow, and all have the typical pyroxene cleavages. Under crossed polarizers, the maximum angle of extinction from the *c* direction is 36°. In the hte long sein specimens containing chromite, the chromite crystals are residual (*Figure 9*), but the kosmochlor grains and the hornblende grains are holocrystalline, ranging from isogranular to prismatic crystalloblastic, mostly medium coarse grained but ranging from fine to coarse. Many crystals contain closely spaced cleavage cracks parallel to *c* but not continuous along the length of the crystal. Many also have fine cracks across the cleavages.

Chemical composition

The major and minor element contents of ten samples of hte long sein were determined by electron microprobe analyses and are summarized in *Table I*.

The analyses indicate small contents of Fe, Mg, Ca and Cr but the composition is essentially that of jadeite. In some specimens Cr content exceeds Fe. In others, the reverse is true. Technically, it should be classified as a chrome-jadeite jade.

Table I: Composition of hte long sein: range and mean of major and minor elements in ten samples.

wt %	Range	Mean
SiO_2	55-60 - 59.42	57.99
TiO_2	0.05 - 0.70	0.23
Al_2O_3	18.81 - 22.14	20.73
FeO	0.31 - 1.76	1.14
MnO	0.00 - 0.13	0.04
MgO	1.12 - 3.78	2.33
CaO	1.15 - 5.08	2.79
Na_2O	12.70 - 14.87	13.71
K_2O	0.00 - 0.10	0.03
Cr_2O_3	0.33 - 2.61	1.20
NiO	0.00 - 0.03	0.00
Total		100.19

NB: Seven electron microprobe analyses were made by the Mineral Deposit Research Institute (China Academy of Geological Science) and three were made by the Testing Centre of China University of Geosciences, Wuhan.

Conclusion

Hte long sein is jadeite jade with between 0.33-2.61% Cr_2O_3, which provides a lovely bright green colour to the stone. It shows wide differences in gem quality, from high quality (fine grain, good transparency and more or less crack-free), to poor quality (very coarse grain, opaque and loose texture). However, most hte long sein on the market is of medium quality with medium grain and a patchy loose texture. Its rather poor transparency is due to abundant fine internal fractures which are probably also responsible for a slightly lower SG than expected for traditional jadeite. Some specimens are more fragile as a result of their loose texture. Such jadeite can be injected with epoxy resin to increase the transparency and enhance the colour to a more vivid emerald green. Such treatment may increase the apparent market value of the jadeite by enhancing its physical appearance towards top quality jadeite jade, but can easily be detected by measurements of infrared spectra.

Further reading

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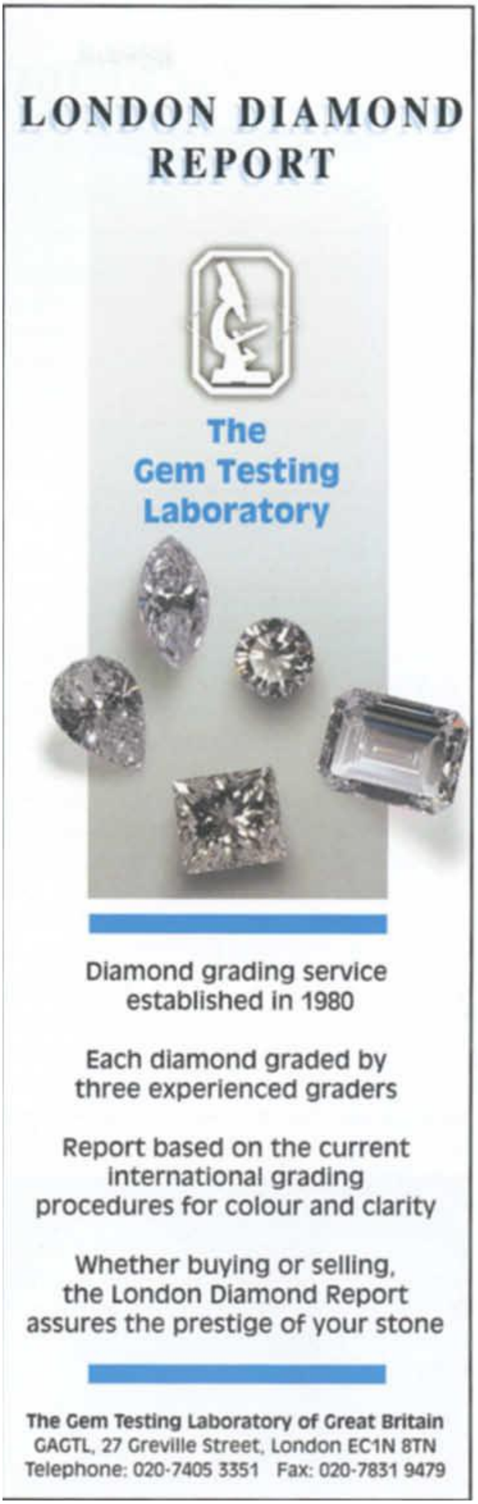

Gemstones of Peru

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ABSTRACT: Gem and ornamental stones from Peru are described. The most economically important gems are blue and pink opal, chrysocolla and silicified chrysocolla. Properties of various types of opalised or silicified chrysocolla are discussed. Massive rhodochrosite, aragonite, dumortierite and some rare stones are also described.

Keywords: blue opal, chrysocolla, gemstones, Peru, pink opal

Introduction

Although it has a long history of gemstone use, Peru is a country almost unknown in modern gemmology. Recently, however, there has been a notable production of ore mineral specimens (Crowley *et al.*, 1997). In the past, ancient Indians used many local decorative stones as well as sodalite from Bolivia, and the first Colombian emeralds, used by Incas and imported to Europe by Spaniards, were described as Peruvian by mistake.

This brief survey will deal with two main kinds of opal, stones under the general heading chrysocolla, rhodochrosite and then rare gems including more carbonates, a sulphate, sulphide, fluoride, tungstates and a glass. Finally, ornamental stones will be summarized.

Figure 1: *Blue opal from Acari, cut stones 8.09 and 2.50 ct.*

During preparation of this article, it proved very difficult to establish exact localities of some materials. Peruvians are very secretive about origins of minerals and even more so where gemstones are involved. For this reason, some localities could probably be localized more correctly in future.

Opal

Blue opal

The most interesting recent gemstone produced in Peru and used in local jewellery for at least 25 years, is a greenish-blue opal called 'Andean opal', which is recovered from veins with a thickness between 1 and 5 cm. It is usually translucent and inhomogenous with common black and brown dendrites, but rarely it can be almost transparent and yield very nice faceted stones. Unfortunately, some (but not all) stones turn milky after some time, perhaps a few weeks to months (*Figure 1*). Their transparency can be restored after immersion in water, but for a limited time only. The onset and development of milkiness is probably strongly influenced by humidity of the air surrounding the stone.

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The bluish colour is attributed to the presence of bivalent Cu (Koivula and Kammerling, 1991a), and in a recent study Fritsch *et al.* (1999) found inclusions of chrysocolla in this opal. The RI of the blue opal lies between 1.430 and 1.452 and some (but not all) cut stones may show a birefringence up to 0.005. The SG lies between 2.01 and 2.08, hardness is 5 and it is inert to UV light. Blue opal is collected in a copper mining area called Acari near Nazca in Arequipa department (see map *Figure* 2), where a variety of colourless dendritic opal is also found (Koivula and Kammerling, 1991b). The Czech mineralogist, V. Bouska, collected almost identical bluish opal with black dendrites in 1981 from a vein in Lower Pleistocene andesite volcanic rocks. These belong to the Barroso formation and occur on the SE slope of Misti volcano (5,822 m) near Arequipa; the recent production of blue opal is probably from the same geological position.

Pink opal

Reputedly the locality that produces blue opal also produces a pink translucent to opaque variety of opal in veins which are said to be very close to the chrysocolla mine (see p.330). The RI of the pink opal is 1.45 - 1.49, the SG is 2.16 - 2.22 and hardness is 6. Pink opal has a pinkish-white luminescence in LW UV and adjoining veinlets of colourless opal are bright green in SW UV. Very nice cabochons can be cut and strongly resemble pink coral (*Figure* 3); their size can exceed 5 cm.

Figure 2: *Map of Peru showing the major gem-bearing areas.*

Figure 3: *Pink palygorskite opal from Acari; the rough is 4 cm wide.*

Berdesinski *et al.* (1977) studied very similar pink 'opal' from unknown localities in Peru and Mexico, and found them to be composed of the rare clay mineral palygorskite. Their material from Peru had an RI of approximately 1.55 (higher than the new material) and SG of 2.18, and was accompanied by quartz with minor plagioclase, sericite, sanidine, apatite and ore minerals.

In the present investigation, several specimens of Peruvian blue opal, and pink opal from both Peru and Mexico, were subject to X-ray analysis and the results follow. Blue opal has two very broad peaks (*d*-spacing/intensities of 4.07/100 and 2.50/30) and both peaks are also prominent in pink opal from Peru and Mexico. However, the pink opal has additional broad palygorskite peaks (at 10.3, 4.28, 3.17 and 2.54Å).

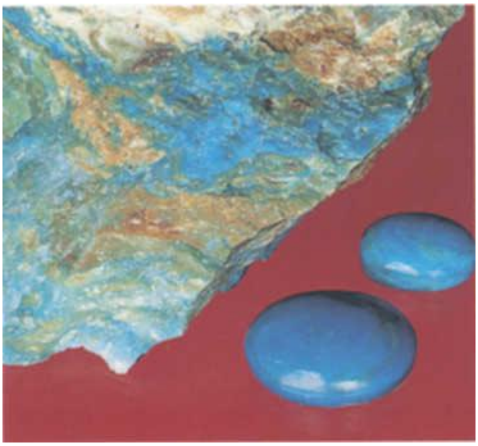

Figure 4: Blue chrysocolla from Acari, rough is 6 cm wide.

The Peruvian pink opal also has sharp quartz lines, which indicates that pink opal from Peru is a mixture of palygorskite, opal and chalcedony, whereas the Mexican material is a simple palygorskite-opal mixture. This also explains the difference in hardness, 6 for the Peruvian and 5 for the Mexican pink opal. There are also differences in associated minerals – Mexican pink opal grows with calcite and white felt-like palygorskite, whereas the vein of Peruvian pink opal is embedded in creamy-white massive rock, which is a mixture of opal and chalcedony (confirmed by X-ray diffraction studies). The cause of the pink colour in the opal is not known.

Figure 5: Bluish-green 'gem silica' from Lily; the rough on the left is 4 cm wide.

Chrysocolla

The Acari copper mine near Nazca in Arequipa department (close to the locality of blue and pink opals), produces a large volume of chrysocolla, a material much used in modern Peruvian jewellery, and known in Peru as 'turquesa' (turquoise), although true turquoise is still unknown in Peru. It is blue-green and very often mixed with green malachite. It does not occur with blue azurite. It is very similar to chrysocolla from Arizona as well as to the famous 'Eilat stone' from Israel (Kammerling *et al.*, 1995). A lot of this material was shipped to Israel in the past to be sold to tourists. The same ore district also produces massive blue covellite with pyrite veinlets, which is sometimes used for cabochons. Very probably from the same area comes the most important recent find in Peru – greenish-blue silicified chrysocolla, called locally 'gem silica' or 'silicia'. There are several types of this material. Blue-green opaque cabochons (*Figure 4*) have RIs 1.49 – 1.51, SGs of 2.27 – 2.30, hardness 4.5 and show a blue streak. The material is probably a mixture of chrysocolla with a small amount of opal. Better for use in jewellery is a greenish-blue opaque homogenous material with a bluish-green streak, with RI 1.54 – 1.57, SG 2.67 – 2.75, and hardness slightly more than 6. The best translucent material, with a hardness of almost 7, is very rare and is reported to be similar to the material from Morenci and other places in Arizona. Chrysocolla specimens with cavities covered by tiny quartz crystals have been used for special pieces of jewellery by some artists.

Another bluish-green to green translucent material (*Figure 5*), comes probably from Lily, a copper mine near Pisco (Hyršl and Rosales, 2000). It has an RI of 1.55, SG 2.61 – 2.65 and hardness 6.5. With magnification, a moss-like structure can be seen, some parts appearing more bluish and homogenous. Clusters of small, irregular quartz crystals and dark green flakes are typical inclusions (*Figure 6*). It is silica, probably chalcedony, and may be stained by traces of chrysocolla or other Cu-minerals (but not by Ni as in chrysoprase). The Lily mine was developed in about 1998

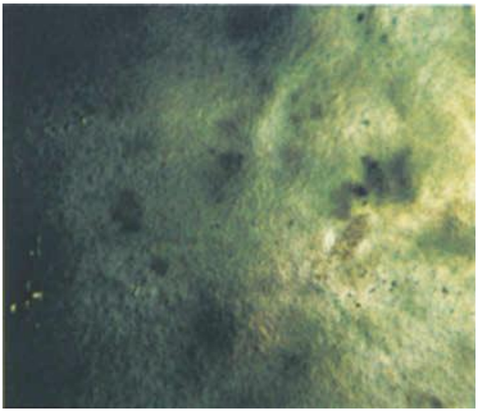

Figure 6: Small quartz crystals and yellowish-green flakes in 'gem silica' from Lily, magnified 10x.

and produces very beautiful specimens of colourless gypsum crystals with perfectly developed green atacamite and malachite inclusions (*Figure 7*), and quartz with rare embedded malachite crystals.

The most recent (spring 2000) source of various types of chrysocolla is another still unnamed but very promising prospect in mountains near Pisco, probably not far away from the Lily mine. This chrysocolla is usually porous, but some parts are hard enough to cut into cabochons. It is light blue to blue-green and some types strongly resemble turquoise. Nevertheless, their X-ray patterns show only two opal lines, comparable with the pattern shown by blue opal. The stones are too soft and porous to be cut, but after treatment (possibly with resin) they could be very appropriate for inexpensive jewellery. The locality has already produced small veinlets of top-quality 'gem silica', which is bright greenish-blue and homogenous. It has RI 1.54 and hardness 6.5, indicating that it is chalcedony stained by copper. All the chrysocolla types described above are inert in UV-light. X-ray diffraction data from opals and all types of 'silica' have been compared. These indicate that green-blue chrysocolla from Acari is silicified by opal, whereas blue-green and green silica from Lily, and from a new prospect, show only well-crystallized quartz lines indicating that they are chalcedony.

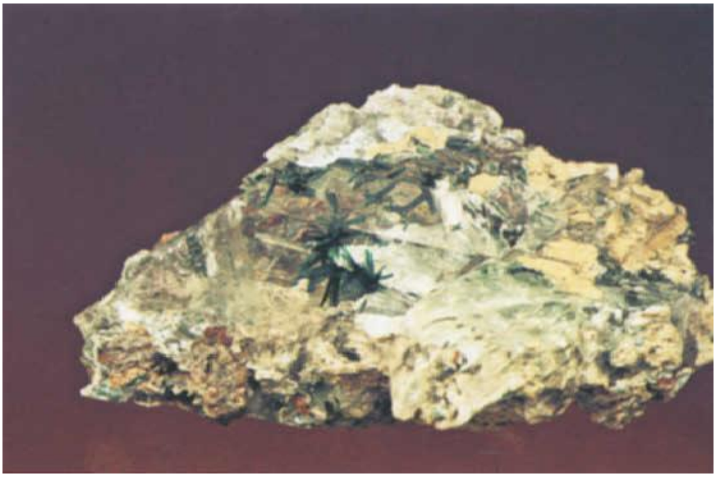

Figure 7: Atacamite crystals in gypsum from Lily, 50 x 25 mm.

Rhodochrosite

Other classic gemstones have not been found in Peru, but several rare minerals have been cut for collectors. The most famous is rhodochrosite, common in many Peruvian ore deposits. The best known of these are the most beautiful raspberry-red crystals growing on quartz druses associated with the tungsten deposit at Pasto Bueno. They are only rarely transparent and have a rhombohedral form. A large silver deposit at Uchucchacua, north of Lima, still produces red transparent crystals of mostly scalenohedral habit (*Figure 8*). The crystals are 2 cm or more long and are very similar to those already known from South Africa. Cut stones

Figure 8: Rhodochrosite crystals from Uchucchacua, width 6 cm.

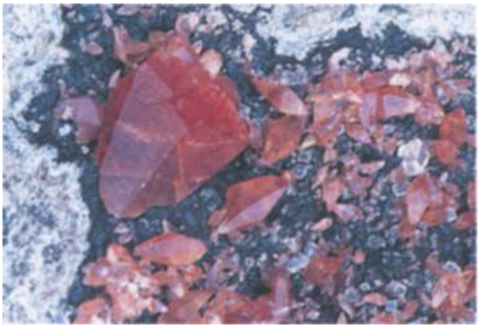

***Figure 9:** Rhodochrosite from Manuelita; the largest piece is 50 x 35 mm.*

can exceed 3 ct. Massive rhodochrosite, useful for tumbling, has recently been recovered from veins at the Manuelita mine in the Morochata ore district. Some specimens have a layered structure similar to Argentinian rhodochrosite (*Figure 9*).

Rare gemstones

Koivula *et al.* (1992) described greenish-blue massive aragonite from a copper mine in Moquegua department. It was marketed under the name 'Victorite' and strongly resembles the better-known 'Larimar', which is pectolite from the Dominican Republic. Aragonite is semi-translucent, with RIs of 1.52 – 1.66, a high birefringence and SG of 2.75. Its colour is probably due to a small copper content.

New bluish-grey material called 'Angelite' was confirmed by X-ray diffraction as a massive variety of anhydrite. It forms concretions with a white crust (*Figure 10*), and probably comes from sedimentary rocks at an unspecified locality.

Silver-bearing veins in the San Genaro mine, Uchucchacua, and in some other mines have produced large transparent red pyrargyrite and proustite crystals. The largest faceted proustite weighs more than 55 ct. In the summer of 2000, an unspecified mine in Huancavelica department produced loose realgar crystals, up to about 2 cm, which are transparent enough for faceting.

***Figure 10:** Blue anhydrite; the rough is 6 cm wide.*

***Figure 11:** Polished calcite crystals from Ica, each crystal is 45 mm long.*

Transparent fluorite is known from several Peruvian mines, the most interesting (and valuable) being nice pink octahedrons, found in 1981 and 1982 in the Huanzala mine. Faceted stones up to 187.65 ct are known. Transparent light green fluorite is common in Pasto Bueno, and the Huaron mine recently produced colourless clean fluorite octahedrons up to 5 cm across. Over the years a number of mines have produced transparent sphalerite in various shades of yellow, pale green and reddish-brown (e.g. Casapalca, Morococha, Manuelita and Carmen Lira). An occurrence of epidote crystals near Ica is accompanied by brown ferroaxinite crystals up to several centimetres in length, some of which have small cuttable areas. Honey-coloured transparent calcite up to more than 5 cm in length may well come from the same place as the epidote and axinite. The scalenohedral crystals are strongly weathered on the surface and are sold with polished facets (*Figure 11*).

Pasto Bueno has produced the world's best hubnerite crystals (Mn end-member of the wolframite series). They are usually brownish-black with a high metallic lustre but some deep red crystals are transparent enough to be cut. The same locality also produces large crystals of quartz, most of which are very clean but some contain interesting macro-inclusions of hubnerite, several kinds of sulphides and green chlorite.

In 1998, a few large orange transparent scheelite crystals appeared at the Tucson show. They are said to come from the Turmalina mine in Piura department, and the largest known faceted scheelite from this find weighs 266.68 ct! They are very similar to scheelites from China.

Makusani near Lake Titicaca is the source of an obsidian glass called 'makusanite'. It is brown and contains rod-like inclusions possibly of andalusite (Henn, 1995), or again they could be sillimanite, as was found in similar obsidian from Chile (Hyršl and Zacek, 1999). An unspecified locality in southern Peru has recently produced brown obsidian with black spots. Cabochons with a high lustre can be manufactured and they are used in Lima for inexpensive jewellery.

Figure 12: *Dumortierite from Canta; the cabochon measures 35 x 27 mm.*

Ornamental stones

Peru is rich in various types of ornamental rock. Massive rhodonite is known from the Pachapaqui ore district. Veins of massive blue dumortierite (*Figure 12*) occur near Canta in Lima department. They contain white patches of fine-grained quartz and muscovite mica as well as dark blue spherulites of pure dumortierite. The Huanzala mine is the world's most abundant source of large pyrite crystals up to about 20 cm across. The production of mineral specimens is estimated to be many thousands of tonnes, the best qualities being faceted in Thailand for 'marcasite' jewellery, while poorer qualities are tumble-polished. Bird and animal carvings made in pink opal, chrysocolla, rhodochrosite, yellowish-green serpentine, pale blue quartzite, blue massive anhydrite and other rocks are exported in thousands from Peru every year. These carvings are not exclusively of Peruvian materials and may also contain foreign materials such as sodalite and ametrine from Bolivia, rock crystal and amethyst from Brazil, or malachite from central Africa.

In Lima, one can also buy nice cabochons made from sea shells (*Figure 13*). They have an attractive orange or purple colour with white or yellow spots and can be easily identified by their low SG and by their structure which may be described as a flame-like layering.

Figure 13: *Sea shell cabochons; the largest measures 20 x 12 mm.*

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Gem-quality clinohumite from Tajikistan and the Taymyr region, northern Siberia

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ABSTRACT: The rare collectors' stone clinohumite has been available on the gemstone market for about 20 years. Bright yellow to orange and brownish-orange specimens have come from the Pamir mountains of Tajikistan. A new occurrence has been discovered in the Kugda massif in Northern Siberia which produces dark red-brown clinohumite of gem quality. This article presents the gemmological and other properties of clinohumite from both localities.

Keywords: clinohumite, Pamir mountains, Siberia, physico-chemical properties, internal characteristics

Introduction

Clinohumite is a very rare silicate material and has been sporadically available on the international gemstone market for about 20 years. Because of its fine colour it is an interesting stone for collectors. Clinohumite in gem quality is known from an occurrence in the Pamir mountains of Tajikistan, former Soviet Union (Anderson, 1983; Bank, 1983; Koivula *et al.*, 1988). The colour of the transparent, facetable stones ranges from yellow to yellow-brown and brownish-orange. A new type of clinohumite has been discovered in Siberia, Russia, which is relatively dark reddish-brown.

Clinohumite belongs to the humite group together with norbergite, chondrodite and humite. These orthosilicates have orthorhombic or monoclinic symmetry. The general formula is $A_n(SiO_4)_m$ (F,OH)$_2$ where A = Mg, Ca, Mn, Fe^{2+}; n = 3, 5, 7 or 9; m = 1, 2, 3, 4. The chemical formula of monoclinic clinohumite is $Mg_9(SiO_4)_4(F,OH)_2$ and the structure is described as a hexagonal close-packed arrangement of anions. Iron and titanium commonly substitute for some of the magnesium. Half of the octahedral and one-ninth of the tetrahedral sites are occupied. The octahedrons are arranged in zig-zag chains producing the monoclinic cell. Five distinct octahedra exist, three types of MO_6, and one type each of $MO_5(OH,F)$ and $MO_4(OH,F)_2$. Mg and Fe are ordered in distorted MO_6 octahedra, Ti in $MO_4(OH,F)_2$ sites.

Clinohumite has a hardness of 6 on the Mohs scale and basal (001) cleavage is poor. According to Deer *et al.* (1982) the RIs are $n_x = 1.629 - 1.638$, $n_y = 1.641 - 1.643$, $n_z = 1.662 - 1.674$. The birefringence varies between 0.028 and 0.041. SG ranges from 3.21 to 3.35.

Pamir mountains

Hitherto, the best known clinohumite occurrence has been Kukhi-lal in the eastern part of the Pamir mountain range of Tajikistan, bordering Afghanistan and China.

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Figure 1: *Clinohumite crystal on matrix from the Kukhi-lal area, Pamir mountains (width of view about 2 cm).*

This area is especially known for magnificent pink spinels (Koivula and Kammerling, 1989; Kammerling *et al.*, 1995). Geologically, the Kukhi-lal area is composed of marbles with skarn bodies, and clinohumite occurs together with spinel in both these rocks (*Figure 1*). In the same region (Tura-Kuloma; Spiridonov, 1998) gem-quality rubies are recovered from marbles (Henn *et al.*, 1990; Smith, 1998) as well as gem-quality pale purple scapolite (Kammerling *et al.*, 1995, p.211) and near-colourless forsterite. Several pegmatitic minerals such as tourmaline (mostly red elbaite), yellow and blue topaz, aquamarine and morganite, hambergite, orange danburite and jeremejevite are found in the Rangkul pegmatite field near Kukurt east of Murgap (Skrigitil, 1996).

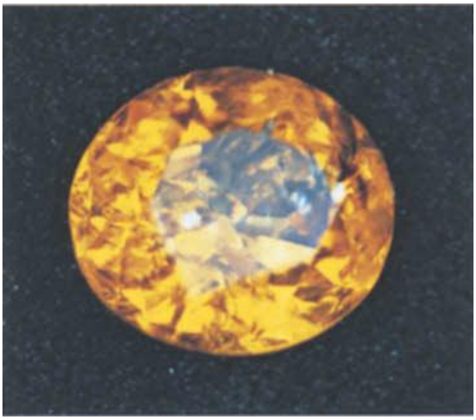

Figure 2: *Faceted yellowish-orange clinohumite of 0.79 ct from the Pamir mountains.*

For about 20 years, the Kukhi-lal occurrence of clinohumite has only produced relatively small specimens up to 3 ct in weight. However, in the last few years some larger stones weighing more than 10 ct have been found, and the largest known specimens weigh 15.25 ct (eye-clean) and 17.87 ct (slightly included) respectively.

The Pamir clinohumites are bright yellow to orange (*Figure 2*) or brownish-orange. RIs were determined as $n_x = 1.630$, $n_y = 1.648$, $n_z = 1.669$, birefringence $\Delta n = 0.039$ and SG = 3.19. As summarized in *Table I*, the refractive indices are comparable to the clinohumite data from Pamir as published by Koivula

***Table I:** Physical properties of gem-quality clinohumite from Pamir, Tajikistan and Northern Siberia.*

	Pamir mountains			Siberia
	1	2	3	4
n_x	1.630	1.631	1.625	1.640
n_y	1.648	1.642	1.636	1.654
n_z	1.669	1.668	1.659	1.671
Δn	0.039	0.037	0.024	0.031
SG	3.19	3.18	3.18	3.35

NB: 1 and 4: this work
2: Koivula et al.*, 1988*
3: Bank, 1983

et al. (1998), but are higher than those given by Bank (1983).

Clinohumite from Pamir is inert under long wave ultraviolet radiation, but displays moderate to strong chalky-orange fluorescence under short wave UV.

***Table II:** Electron probe microanalyses of clinohumite from Pamir and Siberia.*

Wt %	Pamir	Siberia
SiO_2	37.47	37.05
TiO_2	2.54	0.77
MgO	57.12	53.19
FeO	0.25	5.48
MnO	0.02	0.49
CaO	0.01	0.03
F	2.25	2.18
Number of ions on the basis of 18 (O,OH,F)		
Si	3.94	4.01
Ti	0.02	0.06
Mg	8.95	8.57
Fe	0.02	0.50
Mn	<0.01	0.04
Ca	<0.01	<0.01

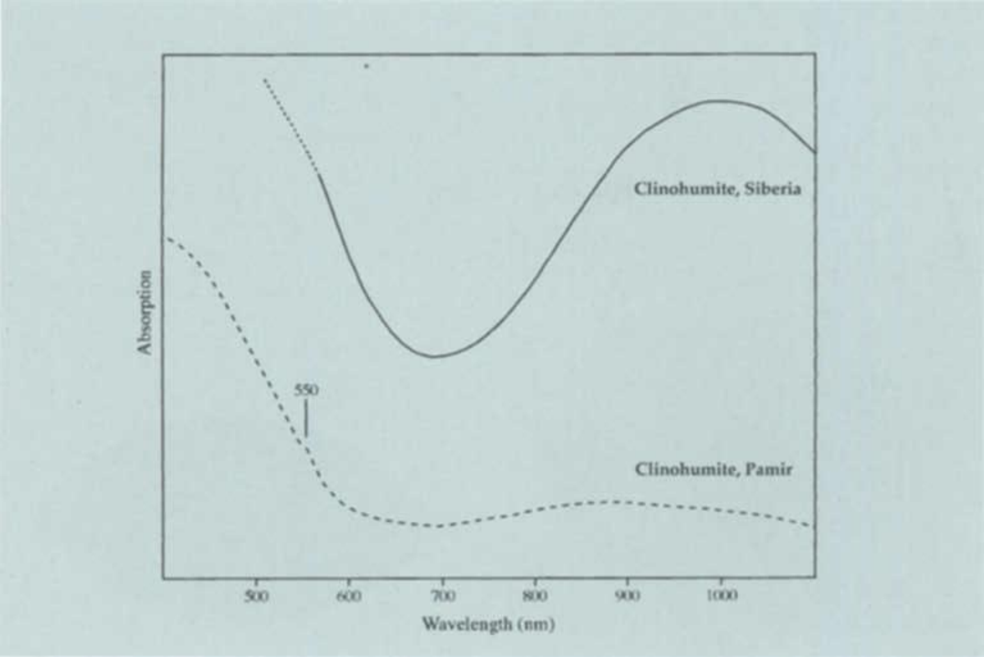

***Figure 3:** Non-polarized absorption spectra of two clinohumites; an orange one from Pamir and a red-brown specimen from Siberia.*

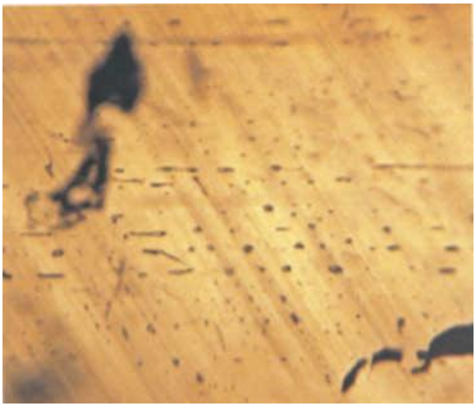

Figure 4: *Fluid inclusions and growth zoning in a gem-quality clinohumite from the Pamir mountains. Immersion, magnified 20x.*

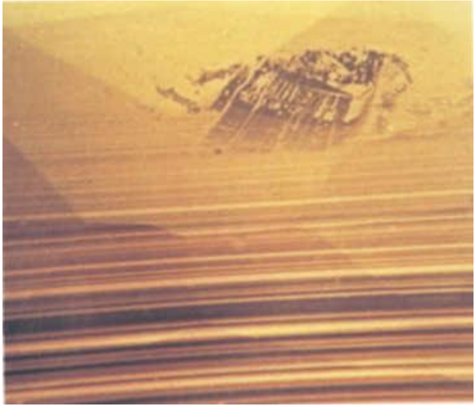

Figure 5: *Lamellar twinning in a gem-quality clinohumite from the Pamir mountains. Immersion, magnified 20x.*

The chemical analyses are presented in *Table II*. In addition to the major constituents SiO_2 and MgO, the Pamir clinohumite contains significant TiO_2 and minor concentrations of FeO, which both substitute for magnesium. Contents of manganese and calcium are not significant.

The absorption spectrum of an orange clinohumite from Pamir (*Figure 3*) shows a weak but broad band in the near infrared spectral range which is caused by Fe^{2+}. From approximately 600 nm, absorption continuously increases towards shorter wavelengths, with a band at 550 nm, which is also due to Fe^{2+}.

Fluid inclusions, growth-zoning (*Figure 4*) and lamellar twinning (*Figure 5*) in the (100) direction were observed under the microscope.

Figure 6: *Red-brown clinohumite crystals from Taymyr peninsula in northern Siberia (width of view about 5 cm).*

Siberia

One of the authors (J.H.) obtained a new variety of clinohumite from Russian dealers in 1998, which came from an occurrence in a basin of the Kotui river on the Taymyr peninsula, northern Siberia. Geologically it is located in the Kugda massif where olivine, clinohumite and vermiculite are found in large crystals along with melilite, monticellite, pectolite and perovskite (Evseev, 1994). Clinohumite from that locality forms well-developed red-brown crystals (*Figure 6*) which are up to 2 cm in size and sometimes twinned. Only small parts of the crystals are transparent and a few red–brown stones up to 2 ct in weight have been faceted (*Figure 7*). RI values are

Figure 7: *Faceted red-brown clinohumite of 1.33 ct from Taymyr peninsula in northern Siberia.*

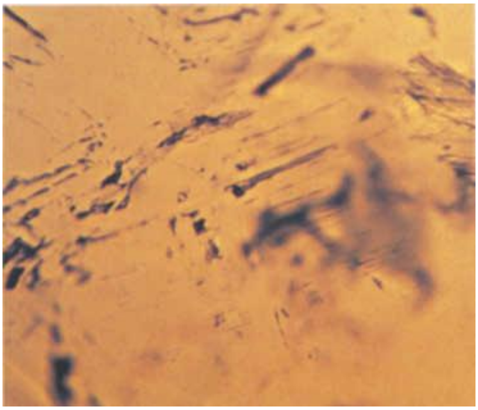

Figure 8: Fluid inclusions in a gem-quality clinohumite from Taymyr peninsula in northern Siberia. Immersion, magnified 20x.

Figure 9: Parallel hollow tubes in a gem-quality clinohumite from Taymyr peninsula in northern Siberia, magnified 10x.

$n_x = 1.640$, $n_y = 1.654$, $n_z = 1.671$, birefringence $\Delta n = 0.031$ and SG = 3.35. These are distinctly higher than the data for the Pamir clinohumites. Consideration of the chemical analyses in *Table II* indicates that this can be attributed to the significantly higher FeO concentrations of 5.48 %wt compared to 0.25 wt% in the specimen from Pamir. The inert behaviour under short wave ultraviolet radiation is due to the high iron content. Manganese is also higher in the Siberian clinohumite, whereas the TiO_2 contents are distinctly lower.

The absorption spectrum shown in *Figure 3* is characterized by a strong spin-allowed band in the infrared part of the spectrum, with a maximum at approximately 1000 nm. From approximately 670 nm, there is continuously increasing absorption towards shorter wavelengths. Notable fluid inclusions of the Siberian clinohumites are primary and secondary two-phase inclusions *(Figure 8)*. In addition, growth zoning may be visible under a microscope, and some stones contain parallel hollow tubes *(Figure 9)*.

Conclusions

The Kugda massif in northern Siberia, Russia, is a probable new source of gem-quality clinohumite. The stones are red-brown and have higher optical and SG values than the gem-quality yellow to orange specimens from the well known source in the Pamir mountains in Tajikistan. These differences are predominantly due to higher iron and lower titanium contents.

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The colour of diamond and how it may be changed

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WC2R 2LS

ABSTRACT: The optical centres responsible for many of the naturally-occurring colours in diamond are reviewed. Although there is a good scientific understanding of some of the colour centres, those responsible for orange, brown and pink diamonds remain a puzzle. Chameleon diamonds, and the violet and blue colours that seem characteristic of diamonds with a high hydrogen concentration, are also poorly understood. Methods of adding colour to diamond, using radiation and, if appropriate, annealing, are described, and the high-pressure, high-temperature treatment of natural brown diamonds – to reduce the brown coloration or produce vivid yellow and yellow/green specimens – is discussed in detail. Finally, methods for detecting colour-enhanced diamonds of all varieties are considered.

Introduction

The colour of a gem diamond is one of the four important parameters which determine the value of a cut and polished stone. Until relatively recently a completely colourless diamond would command the highest price, but in the last few years there has been considerable interest in 'fancy coloured' diamonds (Harris, 1994; Hofer, 1998) and some pink diamonds have sold for extraordinary sums. The majority of gem quality diamonds have less attractive colours than those at either the colourless or fancy extremes of the distribution, and many techniques have been used, (see, for example, Bruton, 1978; Harris, 1994), to disguise the slight yellow colour of a diamond or, for more strongly coloured (and therefore less attractive) specimens, to increase the coloration so that the diamond acquires a fancy colour.

In March 1999 the diamond gem trade was staggered by an announcement from Pegasus Overseas Ltd. of Antwerp, Belgium, a subsidiary of Lazare Kaplan International (LKI), that they had begun marketing colour-enhanced diamonds (Rapaport, 1999). The diamonds had been processed by General Electric (GE) and it was generally assumed, and subsequently confirmed (Woodburn, 1999), that the process involved treatment at high pressure and high temperature (HPHT). Information circulating in the trade (Johnson *et al.*, 1999; Moses *et al.*, 1999) indicated that the starting material was brown type IIa diamond (diamond types will be discussed in sections 1.1 to 1.3) and that the GE process substantially reduced the brown colour.

More recently Novatek, which manufactures high-pressure presses used in diamond synthesis, has announced that they are also processing natural brown diamonds (Templeman, 2000). A subsidiary company, NovaDiamond Inc., has been set up to produce and market these diamonds. They are not pre-selecting the diamond type, and many of the stones they process change from brown to yellow/green. Similar colour changes are being produced by research laboratories in Russia, and may have been for some time (Van Bockstael, 1998; Henn *et al.*, 1999).

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Until these recent developments, it had generally been thought that permanent colour changes to natural diamonds (by, for example, radiation and annealing, see sections 1.6 to 1.7) can only add to the pre-existing colour (Bruton, 1978). Clearly, this is no longer the case.

In this article I shall summarize the current understanding of the major colour centres in diamond, and show how this leads to an explanation of the processes currently being used by GE/LKI, NovaDiamond and others to enhance the colour of natural diamonds. I shall assume that the reader is familiar with an earlier review on colour centres in diamond published in this journal (Collins, 1982); some of the important points will be reiterated here and can also be found in Wilks and Wilks (1991). More recent publications by Fritsch (1998), Harris (1994) and Hofer (1998) also provide many important insights.

Absorption spectroscopy

If a diamond is coloured it must be absorbing visible light in the wavelength range 400 nm (violet) to 700 nm (red), and it is convenient to present this information graphically. To assess the visual appearance of a given diamond it may be appropriate to plot a graph of the percentage transmission as a function of the wavelength. For more detailed analysis it is preferable to plot absorption coefficient as a function of wavelength. This has the advantage that the absorption coefficient is proportional to the concentration of defects producing the absorption, and it is often important to be able to estimate the concentration of defects. Most of the spectra in this article will be plotted to show absorption coefficient. Details of vibronic bands (Collins, 1982) become better defined when the diamond is cooled to liquid nitrogen temperature (77 K) and the vibronic spectra shown here have been recorded at that temperature.

Perfect diamond

Figure 1 illustrates the absorption spectrum of a perfect diamond. Because of the wide spectral range covered, wavelengths are shown in mm (1 μm = 1000 nm) and a compressed (logarithmic) wavelength scale has been used. At short wavelengths (around 0.23 μm) the ultraviolet light has sufficient energy to remove electrons from the electron-pair bonds between each carbon atom, and at wavelengths shorter than this the diamond absorbs strongly, giving rise to the so-called 'absorption edge'. In the infrared part of the spectrum there are characteristic absorption bands at wavelengths where the infrared radiation can set the carbon atoms into vibration. To analyse the interaction with the infrared radiation, the vibrational waves can be represented as particles called 'phonons' which have characteristic frequencies (or energies). In a pure diamond it is not possible for the infrared radiation to generate just one phonon, but it is possible to produce two or three phonons. The peaks between 2.5 and 7.5 μm are referred to as the 'two-phonon' and 'three-phonon' bands, and are identical for all diamonds. It is clear from *Figure 1* that there is no absorption in the visible region, and a perfect diamond is therefore completely colourless.

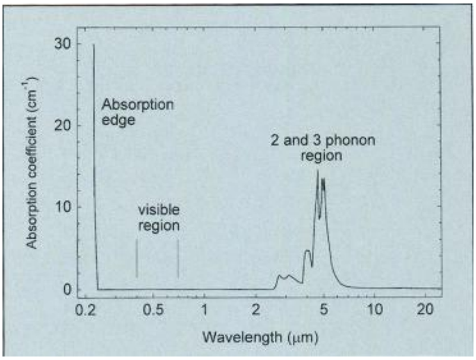

***Figure 1:** Absorption spectrum of pure diamond.*

1. Defects in diamond

Diamonds which absorb in the visible region, and are therefore coloured, do so because they contain defects. These may be 'point defects' which have dimensions comparable with the distance between the carbon atoms in the diamond, or they may be 'extended defects', some of which can be sufficiently large to see with an optical microscope. The scientific understanding of point defects is more advanced than that for extended defects but, even so, is far from comprehensive. What is clear, however, is that nitrogen, which is a very common impurity in diamond, is involved in many of the point defects. Nitrogen can exist in several different forms in diamond and a brief summary is given in the next section.

There is a further important point which emerges from *Figure 1*. With a perfect diamond there is no absorption in the 'one-phonon' region at wavelengths longer than 7.5 mm. However, when a diamond contains defects, the perfectly regular array of carbon atoms is perturbed and absorption then becomes allowed in the one-phonon region; consequently, that region of the spectrum is frequently referred to as the 'defect-induced one-phonon region'. Each defect produces a uniquely shaped spectrum, and the absorption coefficient is proportional to the concentration of the corresponding defect. Nowadays infrared spectra are normally measured using a Fourier Transform Infrared (FTIR) spectrometer, and the spectra are plotted with the wavenumber in cm^{-1} as the horizontal axis. This is simply the reciprocal of the wavelength expressed in cm and, to retain an appearance which is similar to historical spectra, it is conventional to show the spectra with the wavenumber decreasing from left to right. A wavenumber scale is convenient, because it is proportional to frequency (or energy). The one-phonon region in diamond lies at frequencies less than 1332 cm^{-1} and consists of several broad peaks. Some defects also produce one or more sharp lines at wavenumbers slightly higher than 1332 cm^{-1}; these lines are said to arise from 'localized vibrational modes'. This description is used, since the vibration cannot propagate through the diamond (because the frequency is above the cut-off value of 1332 cm^{-1}), and so is localized at the defect.

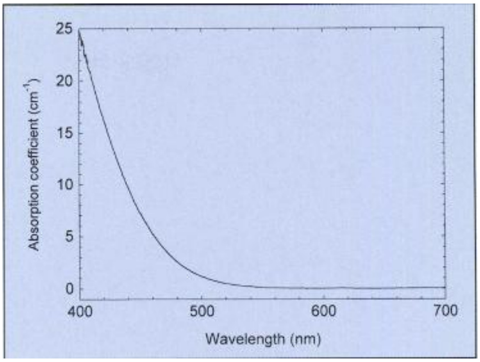

Figure 2: *Absorption spectrum of a type Ib diamond in the visible region, recorded with the specimen at 77 K.*

Diamonds which contain sufficient nitrogen to produce easily measurable nitrogen-related absorption in the defect-induced one-phonon region are generically known as 'type I.' Other diamonds are generically known as 'type II' and it is important to realise that diamonds classified as type II may, nevertheless, contain small concentrations of nitrogen.

1.1 Nitrogen

It is believed that nitrogen is initially incorporated into natural diamonds on isolated substitutional sites. Very few natural diamonds are found with nitrogen in this form, but almost all manufactured diamond produced commercially by HPHT synthesis has most of the nitrogen in the isolated substitutional form. This sort of diamond is referred to as 'type Ib' and *Figure 2* shows the absorption spectrum in the visible region for a typical specimen. The presence of the nitrogen causes an absorption starting at approximately 500 nm and increasing towards shorter wavelengths. Diamonds like this therefore have a distinctive yellow colour; at higher nitrogen concentrations, or in larger diamonds, the colour is yellow/brown.

Nitrogen in this form, frequently referred to as the 'C form', also produces a characteristic absorption in the one-phonon region, shown in *Figure 3*. The major features are the broad band with a maximum at about 1130 cm^{-1} and a sharp line at 1344 cm^{-1} associated with a localized vibrational mode. By measuring the absorption coefficient at either of these locations the concentration of

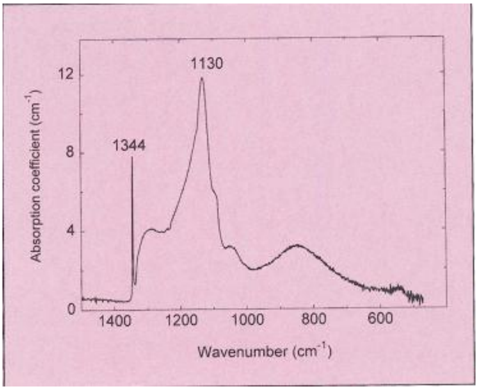

***Figure 3:** Absorption spectrum of a type Ib diamond in the defect-induced one-phonon region, recorded with the specimen at room temperature.*

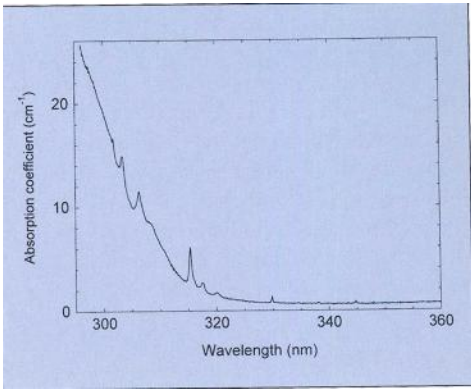

***Figure 4:** Absorption spectrum of a type IaA diamond in the ultraviolet region, recorded with the specimen at 77 K.*

isolated substitutional nitrogen can be determined.

For type Ib diamonds with a low concentration of nitrogen (a few ppm) the absorption spectrum shown in *Figure 2* can be extended into the ultraviolet region right up to the absorption edge, and shows a well-defined broad peak at 270 nm (Dyer *et al.*, 1965; Chrenko *et al.*, 1971). This peak can be used to estimate the concentration of the C-form of nitrogen when determinations from the very weak infrared absorption in the one-phonon region become unreliable.

1.2 Aggregated nitrogen

Many natural diamonds have an absorption spectrum in the ultraviolet region like that shown in *Figure 4*. There is a correlation between the intensities of the sharp lines in this spectrum and the intensity of the absorption in the one-phonon region shown in *Figure 5*. Davies (1976) showed that the absorption in the ultraviolet region is characteristic of a defect consisting of a pair of nearest-neighbour nitrogen atoms. This defect is known as the 'A aggregate'. Diamonds containing aggregated nitrogen are known collectively as 'type Ia' and when most of the nitrogen is present as A aggregates the description 'IaA' is used.

Nitrogen concentrations in type IaA diamond can be determined from the absorption coefficient in the one-phonon region (usually measured at the most intense peak at 1282 cm^{-1}) and are typically 1000 ppm or higher. We see that nature has been very kind to the gem trade; if this concentration of nitrogen were present in the isolated substitutional form the diamonds would have a very unattractive deep yellow/brown colour.

A few natural type Ia diamonds have an infrared absorption spectrum like that shown in *Figure 6*. The most intense peak is at approximately 1175 cm^{-1}. The defect

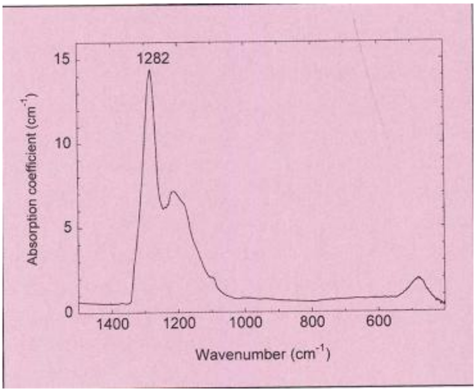

***Figure 5:** Absorption spectrum of a type IaA diamond in the defect-induced one-phonon region, recorded with the specimen at room temperature.*

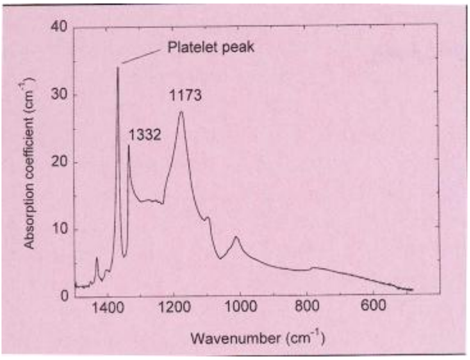

Figure 6: *Absorption spectrum of a type IaB diamond in the defect-induced one-phonon region, recorded with the specimen at room temperature.*

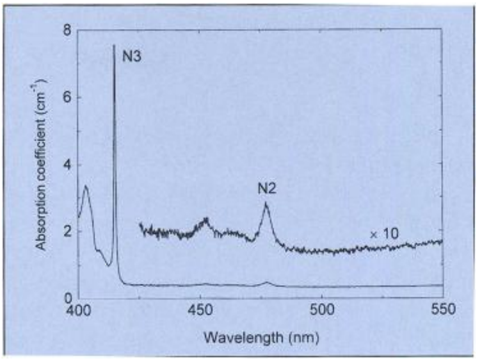

Figure 7: *Absorption spectrum of a cape stone, containing the N3 absorption band, recorded with the specimen at 77 K. The spectrum has been offset from zero for clarity, and the long-wavelength region has been expanded by a factor of 10 to show the N2, and related, peaks more clearly.*

producing this absorption is referred to as the 'B aggregate', and specimens which have most of the nitrogen in this form are called 'type IaB' diamonds. Studies of the B aggregate indicate that it is comprised of four nitrogen atoms surrounding a vacancy (Loubser and van Wyk, 1981). A vacancy is simply a lattice site from which a carbon atom has been removed and placed into an interstitial position (i.e. in between positions normally occupied by carbon atoms in the diamond structure). In the majority of type IaB diamonds these carbon interstitials come together (perhaps with some nitrogen atoms) to form extended defects called platelets. Absorption at these platelets produces a moderately sharp peak at approximately 1365 cm^{-1}, frequently known as the 'B peak' or simply 'the platelet peak'. In what are termed 'regular diamonds' the intensity of the B peak is proportional to the intensity of the absorption produced by the B aggregates. In the remaining ('irregular') type IaB diamonds the intensity of the B peak is less than expected from this proportionality, or may be completely absent. There is some weak absorption in the one-phonon region, called the 'D band', which is associated with the platelet peak, and this must be taken into account when the concentrations of the A aggregates and B aggregates are being calculated from the infrared spectra.

The B aggregate of nitrogen does not cause any absorption in the visible region. However, when it forms another minor structure is produced which is referred to as the 'N3 centre'. This has three nitrogen atoms on a {111} plane, surrounding a common vacancy. Optical transitions at this centre give rise to the N3 absorption band, shown in *Figure 7*, which has a zero-phonon line at 415.2 nm and a structured band to shorter wavelengths. There is, at the N3 centre, another transition which produces the broad N2 peak at 478 nm with weaker peaks at shorter wavelengths. In regular type IaB diamonds the intensity of the N2 and N3 absorption is proportional to the concentration of the B form of nitrogen. Diamonds containing this absorption are known as 'cape stones'. At low concentrations of the N3 centre the colour of the diamond is just perceptibly yellow when compared with a colourless master stone; at progressively higher concentrations the yellow colour becomes increasingly obvious, eventually tending to a fancy colour.

Much of the above understanding of nitrogen in diamond comes from detailed studies of natural diamonds (Woods, 1986) and HPHT aggregation measurements (see, for example, Chrenko *et al.*, 1977; Brozel *et al.*, 1978; Evans and Qi, 1982; Evans, 1992). The aggregation of single nitrogen to A aggregates may be represented by the equation

$$N + N \rightleftharpoons A \qquad (1)$$

At the temperatures experienced by natural diamonds the reverse reaction is negligible and the aggregation process goes virtually to completion over a very long period of time (Evans and Qi, 1982). In the laboratory, at the temperatures necessary to achieve aggregation in a relatively short time, the reverse reaction is appreciable, and it is not possible to obtain complete aggregation. A type Ib diamond therefore cannot be converted to a completely colourless type IaA stone. Furthermore, if a natural diamond containing only A aggregates is heated at around 2000°C, some of the aggregates decompose to form single nitrogen (Brozel *et al.*, 1978). The diamond, previously colourless, then has a pale yellow colour.

The nitrogen defects have been discussed separately, but most natural type Ia diamonds contain a mixture of the A and B forms of nitrogen. These are normally described as 'type IaA/B'. Also many natural diamonds classified as type Ib do have some (perhaps most) of the nitrogen in the A form.

1.3 Boron

Natural diamonds in which substitutional boron is the major impurity are extremely rare. These are the type IIb diamonds, and the presence of boron results in optical absorption which starts at a wavelength of approximately 4 µm in the infrared region and extends into the red region of the visible spectrum. In favourable cases this absorption gives the diamond an attractive blue colour. Boron also produces some absorption in the defect-induced one-phonon region.

1.4 Donors and acceptors

To understand some of the colour phenomena in diamond we need to use a concept familiar in the study of semiconductors. Single substitutional nitrogen in diamond acts as an electrical donor and boron acts as an acceptor. A nitrogen atom may therefore *donate* an electron to a certain defect if the nitrogen and the defect are sufficiently close together. This causes the defect to be in a negative charge state (because an electron has a negative charge), producing a different absorption than if it had no electrical charge and so were neutral. If, instead, boron were the major impurity, it could, in principle, *accept* an electron from a nearby defect, leaving it in a positive charge state. At present there is no clear evidence for optical absorption associated with positively charged defects in diamond, caused by charge-transfer from boron acceptors. However, a number of defects are known to exist in both the neutral and the negative charge states. One of these, the negative N-V-N centre, plays a pivotal role in many of the stones processed by NovaDiamond, as described in section 2.2. Another, the N-V centre in its neutral and negative charge states, provides important clues that a near-colourless diamond could be a GE POL specimen, as described in section 3.3.2.

1.5 Extended defects

We have already encountered platelets in the previous section. Another type of extended defect in diamond is associated with plastic deformation; it appears that in certain stones an external shearing stress has caused some planes of carbon atoms to slip with respect to each other. Many of the brown and pink diamonds produced from the Argyle mine in Australia are in this category. If the crystals are examined under a microscope it is observed that the colour is not uniform, but is striated with the striations oriented in the direction of slip. These striations are referred to as 'coloured graining' in the gem trade (Fritsch, 1998; Harris, 1994). It is not known in detail why the plastic deformation produces coloured diamonds, or why many are brown and some are pink. Indeed, John Chapman (personal communication) reports finding an Argyle diamond which had three distinct regions – brown, pink and almost colourless. One possibility is that a point defect is also involved, and this is trapped at, or 'decorates' the dislocation. An alternative explanation has been proposed by Tom Anthony (personal communication): he has suggested that the pink colour is associated with small displacements of the planes of carbon atoms and that larger displacements result in a brown colour.

Figure 8 shows absorption spectra of a brown type Ia diamond and an Argyle pink diamond (also type Ia). Both diamonds have some N3 absorption present, and both exhibit the broad absorption band with a maximum near 560 nm. The major difference between the two spectra is that the brown diamond has some additional absorption which gets progressively stronger from long wavelengths to short wavelengths.

The absorption in type IIa brown diamonds differs from that shown in *Figure 8*; it is simply a featureless absorption that rises continuously from the red end to the blue end of the visible spectrum (Fisher and Spits, 2000). Pink diamonds predating the Argyle production were often type IIa, but had a similar absorption spectrum to that shown in *Figure 8*.

1.6 Vacancies

Vacancies can be produced in diamond by irradiation with, for example, electrons, neutrons, alpha-particles, gamma-rays, which have sufficient energy to displace some of the carbon atoms. This process leaves vacant sites in the diamond crystal structure and places the carbon atoms into interstitial positions. Absorption associated with the vacancy in its neutral charge state produces the GR absorption features, with a sharp zero-phonon line at 741 nm (the GR1 line) and a band to shorter wavelengths. This absorption gives the diamond a green or blue-green colour. Many uncut natural diamonds have a green 'skin' which has been produced by alpha particles, but this is only a few mm deep. Diamonds with a naturally-produced absorption due to vacancies throughout their bulk are extremely rare; the Dresden Green is one example (Bosshart, 1989) and Hofer (1998) shows photographs of green diamonds from the Aurora Collection.

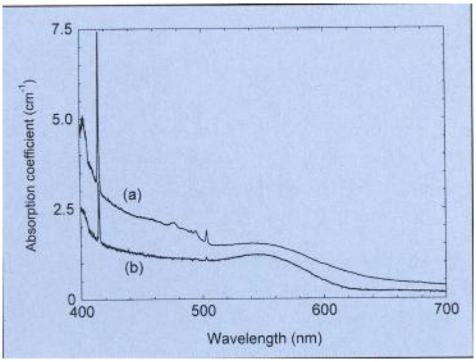

Figure 8: *Absorption spectra in the visible region, recorded with the specimens at 77 K, of (a) a brown type Ia diamond, and (b) an Argyle pink.*

1.7 Complexes involving nitrogen and the vacancy

When diamonds containing vacancies are heated to 800°C the vacancies become mobile, and after an hour or so the GR1 absorption band disappears. In type I diamonds the vacancies are captured by the nitrogen to form new colour centres. The dominant defect in type Ib diamonds is the nitrogen-vacancy centre in the negative charge state $(\text{N-V})^0$ which produces an absorption system with a zero-phonon line at 637 nm and a band to shorter wavelengths. This gives the diamond a pink colour or, with larger amounts of radiation, a pink/red colour. Some nitrogen-vacancy centres may be in the neutral charge state $(\text{N-V})^{\circ}$ and this defect produces a zero-phonon line at 575 nm. The relative absorption intensity of the 575 nm line to the 637 nm line is higher in diamonds with a low nitrogen concentration because the N-V centres are, on average, further away from the nitrogen donors and so remain neutral.

In type IaA diamonds vacancies are trapped by the A aggregates, and a rearrangement of the atoms occurs to produce the structure N-V-N. Research described below (section 2.1) has shown that when all the nitrogen is in the A-aggregate form this centre is in the neutral charge state (N-V-N)^0, and produces absorption in the H3 system with a zero-phonon line at 503 nm and a band to shorter wavelengths. This absorption produces a yellow, orange or brown colour, depending on the amount of radiation to which the diamond has been exposed.

Following radiation and annealing of type IaB diamond, the vacancies are trapped by the B form of nitrogen to produce H4 centres which give rise to an absorption band with a zero-phonon line at 496 nm and a band to shorter wavelengths. Again, this results in a yellow, orange or brown colour.

Most type Ia diamonds have a mixture of A and B nitrogen and, after irradiation and annealing, exhibit absorption in both the H3 and H4 systems. In a large suite of such diamonds (Davies, 1972) it was found that [H3] / [H4] = [A] / [B] where the square brackets represent concentrations of the defects. Some natural diamonds, particularly brown type Ia specimens, exhibit H3 absorption but, even when they contain substantial amounts of nitrogen in the B form, the H4 absorption is negligible in all but a very few samples. The reason for this will be considered in section 2.1.

1.8 Orange or amber diamonds

Collins (1982) describes natural diamonds which have a broad absorption band with a maximum near 480 nm and increasing absorption towards shorter wavelengths. The small stones he examined had an attractive amber colour when examined in white light. The same absorption band appears to be responsible for the colour of the diamonds described by Harris (1994) as orange. The defect responsible for this absorption is not known, and the absorption has not been created in the laboratory by any sort of treatment in either natural or synthetic diamonds to the author's knowledge.

1.9 Luminescence

Absorption of light by many vibronic centres can result in luminescence to the long-wavelength side of the corresponding zero-phonon line. Considering only the visible luminescence, for N3 the luminescence is blue, for H3 and H4 it is green, for the 575 nm centre the luminescence is orange and for the 637 nm centre the luminescence is deep red. Long-wave ultraviolet excitation of amber diamonds which contain the 480 nm absorption band gives yellow emission, while absorption in the band itself (at, say, 488 nm with an argon-ion laser) produces red luminescence. Of the other luminescence bands described above, only those from N3 and H3 affect the colour of a diamond.

The efficiency for the production of luminescence is very different in different diamonds. High concentrations of nitrogen in the A form severely quench the H3 and N3 luminescence (Crossfield *et al.*, 1974); this is probably a general phenomenon for most luminescence centres in diamond. However, a near-colourless diamond with a low nitrogen concentration and a weak N3 absorption will, in sunlight, produce enough blue luminescence to mask the slight yellow colour.

Diamonds are occasionally found which have a yellow colour because of naturally-occurring H3 absorption and which produce intense green luminescence under long wave ultraviolet excitation, or even when traversed by a beam of white light. Diamonds with these characteristics are known in the gem trade as 'green transmitters' (Fritsch 1998). The description 'green transmitter' is rather misleading (Fritsch, 1998). The light transmitted by these diamonds is predominantly yellow, but the diamonds appear green in white light because of their intense luminescence.

There is one other luminescence band that has a relevance to the HPHT processing of diamonds to change their colour. Cathodoluminescence studies of type IaB diamonds which showed evidence of plastic deformation demonstrated that the emission system with a sharp line at 490.7 nm, illustrated in *Figure 9*, actually originated at the slip traces (Collins and Woods, 1982).

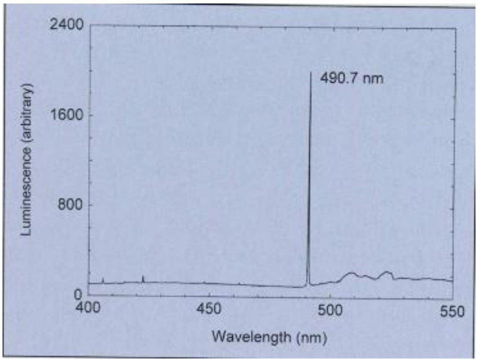

Figure 9: Cathodoluminescence spectrum, recorded with the specimen at 77 K, from a brown type Ia diamond before HPHT processing. The dominant (yellow) emission is the band with a zero-phonon line at 490.7 nm.

This emission is not observed in pure type IIa diamonds which have been plastically deformed, and so it is assumed that in the type IaB diamonds the slip traces are decorated with an impurity. Luminescence in the 490.7 nm line is, in fact, observed in some diamonds classified as type IIa (Smith *et al.*, 2000). However, we noted in section 1 that some diamonds classified as type II may contain small concentrations of nitrogen, and Fisher and Spits (2000) and Smith *et al.* (2000) have shown that part of this nitrogen is in the form of B aggregates.

1.10 Coloured diamond collections

The colour centres described thus far, when taken separately or in combination, in a range of intensities, account for most of the magnificent range of colours observed in fancy diamond collections like those described by Fritsch (1998), Harris (1994) and Hofer (1998). I have not dealt with the chameleon diamonds which change colour from green to yellow, either on heating or being left in the dark for extended periods. Neither have I discussed the violet and grey colours which appear to be connected with high concentrations of hydrogen in diamond. Examples of these colours are illustrated by the above authors, but there is, at present, no scientific understanding of the defects causing the colour, and there are no documented examples of these colours being produced artificially.

2. Changing the colour of diamonds

We have already seen (sections 1.6 and 1.7) how radiation and annealing can be used to intensify the yellow colour of type Ia diamonds or produce pink diamonds from type Ib material. To understand the NovaDiamond process which converts brown type Ia diamonds to yellow/green fancy colours we need to review some earlier work on high-temperature annealing of diamonds that had been subjected to radiation.

2.1 High temperature annealing

Collins (1979) examined the effect of 'high-temperature' annealing on diamonds that had been irradiated and annealed to produce the H3 and H4 absorption. In particular, it was found that when a diamond, which contained predominantly H4 absorption after annealing at 800°C, was further annealed at 1500°C, the H4 absorption was considerably reduced in intensity and the H3 absorption had increased, producing a situation more nearly like that seen in natural diamonds. Collins interpreted this behaviour as the H4 centre breaking up to form H3 centres and small concentrations of other defects like N-V centres. In the context of the present paper those measurements show that the H3 centre is more stable than the H4 centre at the high annealing temperatures employed. Recently the author had the opportunity to visit the NovaDiamond facility; there, an irradiated and annealed (800°C) type IaB diamond was subjected to HPHT processing, using the same conditions as those used to process brown type Ia diamonds. The H4 absorption completely disappeared, and some H3 absorption was produced, confirming the earlier conclusion and its relevance to the NovaDiamond process.

Collins (1980) showed further that when synthetic diamonds that had been irradiated and annealed at 800°C were annealed again at 1500°C, substantial aggregation of the single nitrogen occurred, even though the temperature used was well below that required to produce aggregation in unirradiated specimens. He attributed this behaviour to a vacancy-enhanced aggregation phenomenon. During the annealing, some H3 absorption was produced as a result of vacancies being trapped at the newly-formed A centres.

Mita *et al.* (1990) also investigated the effect of high-temperature annealing of synthetic diamonds that had previously been subjected to radiation and annealing at 800°C. Initially the diamonds had an intense pink colour because of absorption in the $(N\text{-}V)^-$ band. After annealing at 1700°C, a large fraction of the single nitrogen had formed A aggregates, the absorption due to the $(N\text{-}V)^-$ centre had become very weak, and the diamonds had an intense green colour as a result of absorption being produced in the H3 and H2 optical bands. (The H2 system, which will be shown later in *Figure 11*, has a zero-phonon line at 986 nm (in the near-infrared region) and a band to shorter wavelengths which extends into the red part of the visible spectrum.) Their observations led them to propose that the H2 centre was a negative charge state of the H3 centre (i.e. $(N\text{-}V\text{-}N)^-$), and was favoured in their diamonds because of the presence of single substitutional nitrogen (which acts as a donor). Lawson *et al.* (1992) subsequently carried out measurements on the H2 and H3 zero-phonon lines which gave substantial support to the proposal by Mita *et al.*

Note: The temperature quoted for each NovaDiamond run is derived from the thermocouple reading used to monitor the temperature of the heater in the HPHT capsule, and does not necessarily represent the actual temperature of the diamond. In a newer design of capsule, thermocouple readings up to 2300°C are used. In all cases, the value quoted is that recorded near the end of the run, and the diamond experiences the maximum temperature for only a few seconds (Joe Fox, personal communication).

For completeness we recall that Woods and Collins (1986) observed that if a type Ia diamond that has been irradiated and annealed to produce H3 and H4 centres is subsequently given a prolonged annealing at 1400°C, it acquires a 'drab, unappealing green colour'. G.S. Woods (personal communication) subsequently showed that this coloration is a result of H2 absorption being produced, and that in some cases the green colour can be quite attractive. The H2 absorption is occasionally seen in natural diamonds (De Weerdt and Van Royen, 2000), but not at a sufficient strength to affect the colour of the specimen.

2.2 Colour changes produced by HPHT annealing

During the last year, a number of papers in the gemmological literature have described measurements on GE POL and NovaDiamond specimens (see, for example, Chalain *et al.*, 2000; De Weerdt and Van Royen, 2000; Fisher and Spits, 2000; Reinitz *et al.*, 2000; Smith *et al.*, 2000) with some studies being conducted before and after the HPHT processing. The diamonds processed by GE are, for the most part, type IIa and the brown diamonds become near-colourless after HPHT annealing; a very few specimens become pink or blue (Hall and Moses, 2000). The NovaDiamond company processes mainly type Ia brown diamonds, and, after HPHT treatment, these stones become yellow if annealed to 1800°C, and yellow/green if annealed at 2025°C. Many of the NovaDiamonds exhibit bright green luminescence in white light.

Our present understanding of colour centres in diamond allows us to propose the following model for the colour changes:

We have seen that, in many cases, the brown colour of the diamonds under investigation is associated with plastic deformation. In the vicinity of the lattice planes which have encountered slip there is likely to be a high concentration of broken bonds. We have also seen that, in diamonds containing nitrogen in the B form, there is a defect centre localized at the slip planes

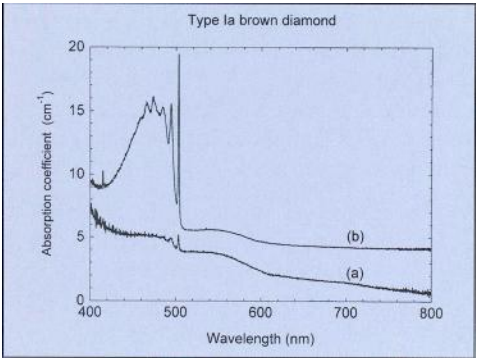

Figure 10: *Absorption spectra, recorded with the specimen at 77 K, of a brown type Ia diamond (a) before, and (b) after HPHT annealing at 1800°C. Spectrum (b) has been moved up by 4 cm^{-1} for clarity.*

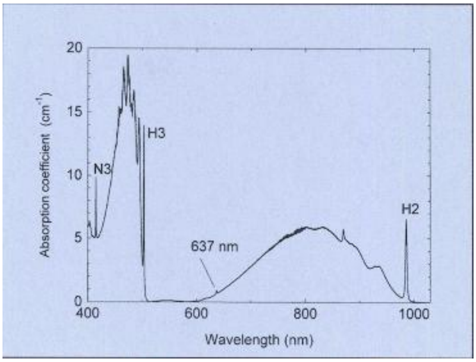

Figure 11: *Absorption spectrum in the visible and near-infrared regions, recorded with the specimen at 77 K, for a brown type Ia diamond after HPHT annealing at 2025°C. The sharp peak at approximately 870 nm is part of the H2 band.*

which gives rise to a luminescence band with a zero-phonon line at 490.7 nm.

When such diamonds are taken to temperatures and pressures where it is known that synthetic diamond can be grown, there will be some healing of any ruptured bonds at the slip planes. This process would result in the release of significant concentrations of vacancies and interstitials. Vacancies may also be released by the interaction between moving dislocations.

We consider first the annealing measurements carried out at 1800°C. Evidence that changes are occurring at the slip planes is the disappearance, reported by Collins *et al.* (2000), of the 490.7 nm luminescence originally present in type Ia brown diamonds.

In diamonds with negligible concentrations of nitrogen we may assume that the vacancies disappear by annihilation with the interstitials. Consequently no new colour centres are formed and the end result is a diamond in which the brown colour is greatly reduced. This is the situation with the GE POL diamonds being processed by Lazare Kaplan and General Electric (Rapaport, 1999; Woodburn, 1999; Johnson *et al.*, 1999; Moses *et al.*, 1999). It is generally believed that GE are treating mainly brown type II diamonds. Occasionally it is possible that they will start with a stone that would have been pink or blue, had the brown colour been absent. Presumably, once such diamonds have been subjected to HPHT processing, the brown colour is greatly reduced and the underlying pink or blue colour is then dominant. (We noted in section 1.3 that type II diamonds that contain boron as the major impurity can be blue and in section 1.5 that some pink diamonds are type IIa.) This seems a reasonable explanation to account for the 11 pink and 4 blue GE POL diamonds examined by Hall and Moses (2000).

Figure 10 shows the absorption spectra of a type Ia diamond before and after annealing at approximately 1800°C. In this case the vacancies are trapped by the nitrogen to form H3 centres (we have shown above (section 2.1) that H4 centres are less stable than H3 centres at high temperature and so presumably do not form at all under these conditions). After the high-temperature annealing we therefore observe an increase in the H3 absorption. There is some nitrogen mobility at the temperature used, and it is perhaps not surprising that the absorption intensity of the N3 band also increases although the processes involved here are less clear at the present time. The annealing also removes some of the brown component of the colour and as a result the diamond,

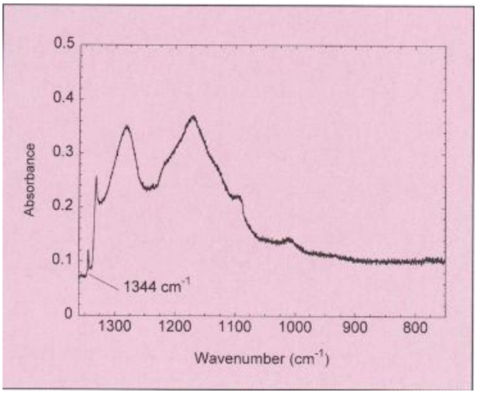

Figure 12: *Absorption spectrum in the defect-induced one-phonon region, recorded with the specimen at room temperature, for a brown type Ia diamond after HPHT annealing at 2025°C. The 1344 cm^{-1} line characteristic of type Ib diamonds is also clearly present.*

originally brown, now has a more attractive yellow/brown colour.

Figure 11 shows the absorption spectrum of a diamond that has been processed at 2025°C by NovaDiamond. At this temperature the reverse reaction in equation (1) becomes significant and appreciable concentrations of single substitutional nitrogen are produced by the break-up of some A aggregates. Consequently, as well as the processes that occur for lower annealing temperatures (1800°C), some N-V-N centres will be in the negative charge state and give rise to an H2 absorption band. In addition, because vacancies trapped at the single substitutional nitrogen form N-V centres, absorption at the 637 nm zero-phonon line may be detected, as in the figure. The relative strength of the H2 to the H3 band will depend on the diamond and on the processing conditions, and the example shown in *Figure 11* has a particularly strong H2 band. As a result of the annealing, the diamond, originally brown, now has an intense green colour because of the transmission 'window' between 500 and 600 nm. Diamonds with a relatively smaller amount of H2 have a yellow/green colour, and most exhibit strong green (H3) luminescence with long-wave UV excitation.

In some cases it is also possible to observe, just outside the one-phonon defect-induced absorption, the 1344 cm^{-1} localized vibrational mode, characteristic of isolated substitutional nitrogen. A typical example is shown in *Figure 12*.

NovaDiamond report that, in order to obtain the strong H3 luminescence which improves the appearance of their product, they need to anneal at 2025°C. More work needs to be carried out to understand why annealing at 1800°C produces H3 absorption without luminescence, whereas a temperature approximately 200°C higher increases the luminescence efficiency in some diamonds.

Finally we examine the effect of HPHT annealing of a typical pale yellow cape stone which has a negligible amount of plastic deformation. The absorption spectra of such a specimen before and after processing are shown in *Figure 13*. The continuous absorption at short wavelengths, present after processing (*Figure 13* (*b*)), is caused by single substitutional nitrogen, at a concentration of approximately 25 ppm. In this particular stone, which weighed 1.86 carats, the colour produced was an intense yellow, but with a smaller diamond, or a lower concentration of single substitutional

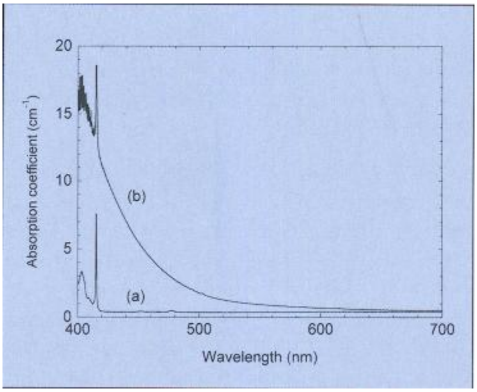

Figure 13: *Absorption spectrum in the visible region, recorded with the specimen at 77 K, for a pale cape stone (a) before, and (b) after HPHT annealing at 2025°C. The absorption in (b) is characteristic of a type Ib diamond.*

nitrogen, a colour similar to 'canary yellow' can be produced. It is just possible in *Figure 13* to detect absorption in the H3 zero-phonon line (and also the H2 which is not shown), but the absorption is negligible in comparison to that produced in the brown diamonds (compare with *Figures 10* and *11*), and makes no significant contribution to the colour.

These observations substantially confirm the interpretations outlined above. Because the cape stone contained a negligible amount of plastic deformation, virtually no vacancies were released during the HPHT treatment and consequently only very small concentrations of H3 and H2 centres were produced. In the absence of H3 absorption, very clear evidence can be seen for the production of single nitrogen atoms (from the break-up of A aggregates – see equation (1)), resulting in the continuous absorption in *Figure 13* (*b*). It was also possible, in this diamond, to detect the 1344 cm^{-1} absorption peak, characteristic of single nitrogen atoms, although this was difficult because of the intensity of the pre-existing absorption in this region.

3. Detection of colour-enhanced diamonds

We will consider in this section ways in which diamonds which have been subjected to radiation to produce fancy colours (with or without subsequent annealing) can be detected, and ways in which diamonds which have been processed using HPHT treatments can be detected. In some cases this is straightforward, and in others it is extremely difficult.

3.1 Green diamonds

Green diamonds can be produced using radiation without annealing, radiation of type Ia diamonds followed by prolonged annealing at 1400°C and by the HPHT processing of brown type Ia diamonds using very high temperatures. In the first case the colour is caused by the GR1 absorption, and in the latter two cases the colour is caused by the combination of H2 and H3 absorption (see *Figure 11*).

3.1.1 Irradiated diamonds

Very few diamonds owe their green colour to naturally-occurring GR1 absorption. The Dresden Green is one (Bosshart, 1989), but the intensity of the band is extremely low; at the peak of the band near 625 nm the absorption coefficient is no more than 0.2 cm^{-1} above the background. The diamond only appears to have a green tint by virtue of its size (40.7 carats). The shape of the absorption spectrum of the Dresden Green differs in no perceptible way from the absorption spectra of some diamonds that have been artificially coloured using radiation. Consequently gem testing laboratories are reluctant to issue origin-of-colour certificates for green diamonds containing the GR1 absorption. However, the author is of the opinion that the Dresden Green, or some other diamond known to have GR1 absorption through natural processes, should be used as a benchmark and that any diamond which exhibited a large GR1 absorption coefficient at 625 nm, compared with the benchmark, should be regarded as a 'treated green'. It would be very helpful in this regard if those diamonds in the Aurora collection (Hofer, 1998), for which the green colour is categorically known to be of natural origin, could be examined spectroscopically.

3.1.2 HPHT-processed type Ia brown diamonds

In the author's experience, H2 absorption does not occur in natural diamonds to a sufficient extent to produce a green coloration. Any diamond that is coloured green or yellow/green because of the presence of H2 absorption should therefore be treated as suspect. The natural brown type Ia diamonds that successfully respond to HPHT processing frequently have low concentrations of nitrogen. Consequently, after processing, a green diamond will exhibit pronounced green (H3) luminescence on excitation with long-wave ultraviolet; this is another indication. Before processing, such diamonds often exhibit brown graining, and this graining is evident in the green and yellow/green colouring of the end product, and in the distribution of the luminescence, providing further confirmation of colour-enhancement (e.g. Reinitz *et al.*, 2000).

In the NovaDiamond process the diamond is heated for a brief time at pressures where graphite is the stable phase of carbon (Joe Fox, personal communication). Consequently the areas of diamond around inclusions, cracks and feathers generally exhibit severe graphitization, again indicating that the diamond has been subjected to HPHT processing. Surfaces of faceted stones are badly etched during processing, and any residual etching on the repolished stone would also suggest that it has been processed. Reinitz *et al.* (2000) have made a detailed study of the green and yellow/green diamonds produced by NovaDiamond, GE and an unnamed Swedish manufacturer, and all exhibited similar features. However it is possible that other facilities can heat diamonds to the required temperature and maintain the pressure in the diamond-stable region; the absence of graphitization does not therefore indicate that the colour is natural.

3.2 Yellow diamonds

Yellow diamonds can be produced by radiation and annealing to approximately 800°C of type IaA diamonds, by HPHT processing of brown type Ia diamonds (to rather lower temperatures than those required to create yellow/green specimens) and by HPHT processing of near-colourless or pale yellow type Ia (cape) stones.

3.2.1 Radiation and annealing

Radiation and annealing of type Ia diamonds produces the H3 and H4 absorption bands which are responsible for the yellow colour. If a heavy irradiation is used the diamond becomes almost opaque to wavelengths less than approximately 500 nm, and may then have an orange colour (Collins, 1982). The treatment also produces a sharp absorption line at approximately 595 nm. This line can be eliminated by annealing the diamond to approximately 1000°C but, as the 595 nm line anneals out, two further absorption lines in the near infrared spectrum are created (Woods and Collins, 1986), known as H1b (2024 nm) and H1c (1934 nm). It is exceedingly rare to find any of these three absorption lines, or the H4 line, occurring naturally in diamond, and it is sensible to regard as treated a stone in which the 595 nm, H1b or H1c lines are found. The H1b and H1c lines can be eliminated if the diamond is annealed further to approximately 1400°C, but then the H2 absorption is produced, giving the diamond a green hue, and again providing evidence of treatment.

3.2.2 HPHT-processing of type Ia brown diamonds

The yellow diamonds produced by HPHT processing of brown type Ia diamonds generally still have some brown component remaining, and, in particular, the broad band at approximately 560 nm may still be present (see *Figure 10*; also Reinitz *et al.*, 2000; De Weerdt and Van Royen, 2000). In addition, the stones exhibit the coloured graining characteristic of the starting material and may have graphitized inclusions. Intense absorption in the H3 band is extremely rare in naturally coloured diamonds, and it is this feature (*Figure 10*) that would first arouse suspicion.

3.2.3 HPHT processing of type Ia pale yellow diamonds

The shape of the absorption spectrum (*Figure 13*) produced by HPHT processing of near-colourless or pale yellow cape stones is virtually identical to that observed in type Ib diamonds and, if the processing conditions are optimised, a colour similar to that of a natural 'canary yellow' diamond can be obtained. (The yellow luminescence in long-wave ultraviolet, characteristic of a true canary yellow diamond, is absent, however.) The infrared one-phonon absorption of the one processed diamond of this sort investigated by Collins *et al.* (2000) was dominated by absorption associated with the A and B aggregates, and the 1344 cm^{-1} peak was detected only with difficulty. The total nitrogen concentration was estimated to be 1500 ppm, with only 25 ppm in the C form. The diamond also exhibited a weak peak at 1480 cm^{-1} which was not present before processing. A peak at around this position has been reported previously (Kiflawi *et al.*, 1998) in diamonds subjected to HPHT annealing in the range 2500 to 2750°C.

The infrared spectrum of the processed diamond is unlike those of the few natural type Ib diamonds that the author has examined. These have had low nitrogen concentrations (typically 20 to 40 ppm) in the A and C forms only, with no detectable B aggregates. However, Steve Kennedy (personal communication) has visible and infrared spectra on record for diamonds believed to have a natural colour, very similar to the spectra of the processed diamond described here, including the feature at 1480 cm^{-1}. Unless a processed diamond contains other clues, such as graphitised cracks or inclusions, it is therefore difficult at present to be sure that the colour has been created artificially.

3.3 Colourless and near-colourless diamonds

Following the GE/LKI revelation, every colourless or near-colourless diamond is potentially a type IIa diamond that has been colour-enhanced by HPHT processing of brown starting material. The first step in investigating such a stone must be to determine whether it is a type II. A simple procedure is to check the ultraviolet transmission at 254 nm (see, for example, Chalain *et al.*, 2000). Diamonds that contain nitrogen in predominantly the B aggregate form are also transparent at this wavelength, and a specimen that is transparent at 254 nm must subsequently be examined spectroscopically in the defect-induced one-phonon region to check whether it is type IIa or type IaB. If the diamond is type IIa, or contains only very small concentrations of nitrogen, further analysis will be required to assess whether it has been colour-enhanced. The experience of Fisher and Spits (2000) suggests that, on average, for every 1000 colourless or near-colourless faceted gemstones examined, approximately eight will be type IIa. (For colour grades D to F only, this figure rises to approximately 50 per 1000 (Simon Lawson, personal communication).)

Fisher and Spits (2000) and Smith *et al.* (2000) have examined a large selection of diamonds before and after processing, and have identified a number of changes that occur in the absorption and luminescence spectra, which will be briefly reviewed in sections 3.3.1 and 3.3.2 below. Many of the phenomena reported are associated with known nitrogen-related defects (we mentioned in section 1 that a diamond nominally classified as type IIa may nevertheless contain a small concentration of nitrogen) and GE, recognizing this, are now processing diamonds with much lower nitrogen concentrations (Smith *et al.*, 2000). This move will make the detection process more difficult and, indeed, on statistical grounds (Tom Anthony, personal communication) may make it impossible (see section 3.3.3).

3.3.1 Absorption spectroscopy

Some nominally type IIa diamonds contain small concentrations of nitrogen, often predominantly in the B-form, which can be detected by very careful infrared spectroscopy. It may also be possible in some stones to detect the N9 absorption at 236.0 nm. If such a diamond is subjected to the HPHT conditions used to produce the GE POL specimens, some of the aggregated nitrogen decomposes to form single nitrogen, and it may be possible to detect this spectroscopically. For GE POL diamonds with colour grades from I to U/V, Fisher and Spits (2000) were able to detect the 1344 cm^{-1} infrared absorption and the 270 nm broad peak, both characteristic of single nitrogen; the 270 nm peak could also just be detected for some of the stones with colour grades of E and F. The vast majority of GE POL diamonds currently being produced has colour grades in the range D to G, with the highest percentage being D and E (Smith *et al.*, 2000). Absorption spectroscopy is not likely to provide definitive results for such stones.

3.3.2 Luminescence spectroscopy

Many type IIa diamonds contain defect centres involving nitrogen and vacancies, but at much too low a concentration to detect using absorption spectroscopy. The presence of these centres, in particular N3, H4, H3, 575 nm [i.e. $(N\text{-}V)^0$] and 637 nm [i.e. $(N\text{-}V)^-$] can, however, be demonstrated using laser-excited luminescence spectroscopy. Significant luminescence is only observed at longer wavelengths than the wavelength of the laser and the relative intensities of features in the luminescence spectrum will depend on the wavelength used for excitation. The laser also produces a 'Raman spectrum' which comprises a first-order line shifted by 1332.5 cm^{-1} from the laser line and a second-order band with shifts from the laser line of between 1900 and 2665 cm^{-1}.

Chalain *et al.* (2000) used a 514 nm argon-ion laser to study luminescence from untreated type IIa diamonds and from GE POL diamonds. They observed 637 nm luminescence from the GE POL diamonds, but not from the untreated stones, and concluded that this might be a way of detecting GE POL specimens. However, Fisher and Spits (2000) found that seven out of 16 of their untreated diamonds exhibited luminescence from the 637 nm centre. (This shows the importance of studying a large number of samples.) The former authors (Hänni *et al.*, 2000) subsequently agreed with the findings of Fisher and Spits. They also noted that, for the 637 nm line, the full width at half maximum height is less than or equal to 0.45 nm, whereas for GE POL diamonds it is greater than or equal to 0.53 nm. They attributed this to the greater amount of random strain in the GE POL diamonds. Smith *et al.* (2000) find that, while, in general, the width of the 637 nm line is greater in GE POL diamonds than untreated diamonds, there is some overlap of the distributions. Consequently, measuring the width of the 637 nm line does not provide an unambiguous differentiation.

Fisher and Spits also made the important observation that, for the seven untreated diamonds that exhibited 637 nm luminescence, in only one was the 637 nm luminescence stronger than the 575 nm luminescence, whereas this was true for 12 out of 14 of the GE POL stones. The explanation for this difference is that the GE POL diamonds contain some single nitrogen (as evidenced by the absorption at 270 nm and 1344 cm^{-1}) and this favours the presence of defect centres in their negative charge states (see section 1.4). However, it is clear that the relative intensities of these two lines cannot be used to decide with certainty whether a stone has been subjected to HPHT processing.

Fisher and Spits also noted that of 23 diamonds selected to have a very low nitrogen concentration and subjected to HPHT processing at the Diamond Research Laboratory, 20 showed no luminescence when excited at 514 nm. None of their 16 untreated colourless diamonds showed a complete absence of luminescence and they suggest that the absence of luminescence may therefore be an indicator of HPHT processing.

Smith *et al.* (2000) made very detailed measurements on seven faceted and three rough type IIa diamonds before and after processing by GE; a type IIa fancy light brown 'control' specimen from the Gübelin Gem Laboratory was also processed by GE and examined by Smith *et al.* They measured absorption spectra in the ultraviolet, visible and near infrared regions (200 to 2500 nm) with the specimens at low temperature, and in the infrared (6000 to 400 cm^{-1}) at room temperature; they also measured photoluminescence spectra, with the diamonds at low temperature and at room temperature, using a range of different lasers to excite the luminescence (excitation wavelengths 244, 325, 514 and 532 nm). Broad-band cathodoluminescence spectra and X-ray topographs were also obtained. The absorption measurements, and photoluminescence measurements using 514 nm excitation, confirmed many of the observations previously reported by Fisher and Spits (2000). The more extensive photoluminescence measurements yielded an interesting, if disappointing, result. Many sharp luminescence lines observed in some untreated type IIa diamonds disappear following HPHT annealing, but no new lines are produced. A few of the lines which disappear on HPHT processing are quite well defined and consequently a diamond in which they are observed could, with reasonable confidence, be certificated as having a natural colour; however, it would be dangerous to assume that a diamond in which they are absent is a GE POL stone.

3.3.3 *The statistical problem*

The investigations briefly summarised above have compared diamonds known to have been subjected to HPHT processing with those known to be untreated, and in some cases the diamonds have been examined before and after processing. A number of important and interesting results have been obtained. However, this is very different to finding which diamond in a bag of 10,000 type IIa diamonds is the GE POL stone. With the small number of GE POL diamonds in circulation, that is the nature of the problem. (Difficulties will only arise, of course, if the GE POL laser inscription has been fraudulently polished off, otherwise identification is trivial.)

We have seen that:

- The nitrogen content in diamonds now being selected for processing may be too small for the resulting single nitrogen to be detected by absorption spectroscopy after the samples have been processed.
- When the 575 nm and 637 nm luminescence lines are present in the spectrum excited by a 514 nm laser the former line is likely to be the weaker in a GE POL stone, but there are examples where this is also the case for untreated diamonds.
- The width of the 637 nm luminescence line is generally greater in GE POL diamonds, but not always.
- Some HPHT-treated diamonds exhibit no luminescence, but there will almost certainly be a few untreated type IIa diamonds for which this is also true; only a handful of specimens has been investigated so far.

Because of this overlap, or possible overlap, of the all the properties investigated so far for untreated type IIa diamonds and for GE POL diamonds, there is a possibility that a few diamonds will be encountered for which it is not possible to say with certainty whether the colour is natural or enhanced.

In the near future we may have to ask 'Does it matter?'. Up to the end of the twentieth century the knowledge of the laws of refraction and the development of technologies for cutting and polishing diamonds, allowed polishers to turn an unattractive colourless pebble into a highly desirable faceted gemstone. At the beginning of the twenty-first century, knowledge about defects and colour centres in diamond, and the availability of technology for subjecting diamonds to HPHT annealing, combined with the pre-existing knowledge and technology, is allowing polishers to turn unattractive brown pebbles into highly desirable faceted gemstones. People should be encouraged to enjoy the end product, rather than fretting about whether it has been subjected to some extra heat and pressure.

As well as classifying the quality of the colour, cut and clarity, and looking for more obvious treatments, gem testing laboratories will, of course, continue to seek new ways to differentiate colourless GE POL diamonds from untreated natural diamonds. But even at the present stage, it is important to realize that, if the tests described above are unable to make such a differentiation, the diamond will still be an exceedingly rare specimen. Should it be an untreated stone, it will be a type IIa diamond that exhibits negligible luminescence. If, on the other hand, it has been colour-enhanced by HPHT annealing, it would originally have been a brown type IIa gem-quality diamond with an undetectably low concentration of nitrogen, and very low inclusion content.

Consequently, if a gem testing laboratory has two nearly identical colourless stones, one of which shows clear evidence that it has not been subjected to HPHT annealing, and the other which has insufficient distinguishing features to decide whether it has, or has not, been processed at HPHT, it would be regrettable, in the author's opinion, to regard the latter as less valuable.

Summary

In this article I have described the scientific understanding of some of the common colour centres in diamond. We have noted that there are other colour centres, for example those giving rise to brown, pink, amber, violet and chameleon diamonds, for which the origin of the colour is still not known. Some of the fancy colours that occur naturally – green, yellow, orange, pink – can be simulated by subjecting suitable diamonds to radiation, with or without subsequent annealing, depending on the colour required. Events over the past two years have also made widespread the knowledge that the colour of diamonds can be changed by HPHT processing. I have shown how fundamental studies of diamonds carried out over many years have enabled an understanding of these colour-enhancement processes to be reached. In most cases detailed tests will reveal whether the colour of a stone has been artificially enhanced. Those few colourless or near-colourless diamonds for which discrimination is uncertain will be so rare as to have an intrinsic value in their own right.

Acknowledgments

I am grateful to:

- Joe Fox and David Hall of NovaDiamond for supplying me with diamonds for study and, more recently, inviting me to visit their facility to be actively involved in the processing of diamonds.
- Colleagues at DTC Maidenhead for useful discussions, and for providing data for the spectra in figures 1, 3, 5 and 6.
- Steve Kennedy of GAGTL for alerting me to spectra in the laboratory records (section 3.2.3).
- Tom Anthony of GE for drawing my attention to the statistical problem outlined in section 3.3.3.

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Letters to the Editor

Diamond synthesis

From W.C.F. Butler

In my letter of 28 July 1997[1], I suggested that Von Bolton[2] might have succeeded in synthesizing diamond by vapour phase deposition in 1911 and, if so, his was almost certainly the first successful synthesis by any route.

I had forgotten an even earlier potential candidate for that achievement, whose experiments appear to have been successfully replicated at the Virginia Polytechnic Institute and State University in 1985.

In a letter to *Nature* in 1905, C.V. Burton[3], a prominent physicist, claimed to have synthesized diamond at ambient pressure by dissolving carbon in a lead-calcium alloy in which carbon is more soluble than in lead alone, then supersaturating the lead by oxidizing the calcium with steam at a dull red heat, thus removing it from the alloy. The carbon precipitated in the form of diamond.

Sebba and Sugarman's[4] attempts to repeat Burton's work yielded a black powder in which were embedded many transparent crystals which scintillated with considerable fire in reflected light. They had a high refractive index and the powder scratched glass. X-ray powder diffraction showed a strong peak at 0.208 nm, which is the strongest peak for diamond but only weak for graphite, although the strongest peak was an unidentified one at 0.251 nm. They concluded that while they could not claim unequivocally that diamond was produced, there was a strong presumption that it had been and, therefore, that Burton had synthesized diamond in 1905.

William Butler

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Some light on the 'topaz-type diffusion process' of natural corundum

From Dr Karl Schmetzer

In a recent article in this journal by S. Kennedy[1], two treated natural sapphires were described. According to microscopic and spectroscopic examination (which revealed the presence of a cobalt spectrum), the author concluded that the colour of the samples had been artificially produced by diffusion treatment. The microscopic properties showed similarities with bluish-green treated topaz that was first described by M.L. Johnson and J.I. Koivula[2]. Their treated samples had been supplied by R. Pollak of California, USA. Because details of this diffusion process for topaz were neither available to Johnson and Koivula nor published in later descriptions of similar topaz samples (A. Hodgkinson[3], T. Underwood and R.W. Hughes[4]), some speculation about the experimental treatment conditions and the correct nomenclature of the process, e.g. diffusion or surface coating, and the nomenclature of treated samples remained (see S.F. McClure and C.P. Smith[5]).

Two recently published patent documents[6,7], however, may help to clarify at least the experimental details of the process used. In both documents, R. Pollak of California, USA, is mentioned as inventor and applicant.

Assuming that the experimental descriptions in these documents are complete, only

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one single treatment step is applied for enhancing the colour of gemstones, comprising: "subjecting a combination of a gemstone and at least one powdered (i.e. finely divided) form of cobalt metal or cobalt oxide to conditions suitable to enhance colour of said gemstone, without causing a significant level of surface damage to said gemstone." A wide range of treatment conditions can be employed using a suitable vessel or crucible in which the faceted sample is surrounded by the metal or metal oxide powder. Typically, temperatures in the range of about 900°C to 1250°C are applied for times of about 3 up to 200 hours. In general, the process is performed at ambient pressure. Two mechanisms of colour enhancement are mentioned, (a) diffusion of the colour-enhancing agent into the outer surface of the gemstone, or (b) chemical bonding of the colour-enhancing agent to the surface of the gemstone.

A wide variety of metals or metal oxides can be employed in combination with the cobalt metal or cobalt oxide, e.g. transition metals or transition metal oxides. Examples are given for the treatment of topaz, chrysoberyl, sapphire, quartz and garnet. "Topaz can be modified to have a light blue to dark blue colour, or a light green to dark green colour, or a light blue-green to dark blue-green colour, depending on the treating agent(s) and treating conditions employed. Similarly, chrysoberyl can be modified to have a light green to a deep blue-green colour; sapphire can be modified to have a light blue to dark blue colour (if clear stones are used for treatment) or green, yellow-green or blue-green stones can be produced if the untreated stones are yellow; quartz can be modified to have a light pink to a dark pink colour; garnet can be modified to have a green to a blue-green colour."

Further research is needed for the different gem materials to clarify the individual causes of colour enhancement. It is possible that different mechanisms, i.e. diffusion and surface coating, may be found for different gem materials and/or for different compositions of the powdered metals or metal oxides used.

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6. International Patent Application, Publication Number WO98/48944, published November 5 1998
7. United States Patent, Patent Number 5,888,918, published March 30 1999

Abstracts

Diamonds
Synthetics and Simulants
Gems and Minerals
Instruments and Techniques

Diamonds

Colour change produced in natural brown diamonds by high-pressure, high-temperature treatment.

A.T. Collins, H. Kanda and H. Kitawaki. *Diamond & Related Materials*, 9(2), 2000, 113-22.

Some suitably chosen natural brown diamonds can be changed to attractive canary-yellow by the 'NovaDiamond' HPHT process. From research involving optical absorption and luminescence spectroscopy, it is shown that the spectra of the treated diamonds are unlike those observed in natural diamonds. It is argued that the brown colour of the natural diamonds is associated with plastic deformation, probably during the ascent of the diamonds to the Earth's surface, resulting in a distortion of the crystal structure. These brown diamonds show clear evidence of internal strain and exhibit 'colour graining' where slip has taken place. On treatment at ~ 2000°C with a stabilizing *P* of ~ 6000 atm, some healing of dislocations and possible re-growth occurs, leading to a reduction of the brown colour. In the case of type IIa diamonds used to produce GE-POL stones, the end result is simply to improve the colour grade of the stones, but in the 'NovaDiamond' process it is mainly the type Ia diamonds typically containing a few hundred ppm of nitrogen.

R.A.H.

Improving the colour of gem-quality diamonds by high-pressure, high-temperature annealing.

A.T. Collins. *Materials Today*, 3(3), 2000, 3-6, illus. in colour.

Reviews with examples and illustrations the present situation with regard to ways in which the colour of gem-quality diamonds can be altered from colours unacceptable to the diamond trade to more attractive and saleable ones using a combination of high pressures and high temperatures. Details on the processes involved are given and there are brief notes on detection. M.O'D.

[Discovery of diamonds in the south-western Uzbekistan.]

A.V. Golovko, N.E. Yakovenko and N.A. Akhmedov. *Proceedings of the Russian Mineralogical Society*, 129(1), 2000, 61-4. (Russian with English abstract.)

Diamonds have been found in SW Uzbekistan in unusual diamond-bearing rocks: lamprophyres and shonkinite-porphyries forming dykes and pipes. These rocks contain xenoliths both of the host rocks and some rock types from greater depths: ultrabasites and eclogitized gabbro. The xenoliths also contain chromspinelids, chromdiopside, Cr-bearing olivine and moissanite. Data are given on the morphology of the diamond crystals, their XRD pattern and their TEM images. The diamondiferous xenoliths are related to the non-kimberlite type of rocks - lamprophyres of camptonite-monchiquite composition and/or shonkinite-porphyries. R.A.H.

Noble gas and halogen geochemistry of mantle fluids: comparison of African and Canadian diamonds.

L.H. Johnson, R. Burgess, G. Turner, H.J. Milledge and J.W. Harris. *Geochimica et Cosmochimica Acta*, 64(4), 2000, 717-32.

The noble gas and halogen geochemistry of fluids trapped in fibrous and opaque cubic diamonds is presented for 15 diamonds from four kimberlite pipes in the North West Territories, Canada, and 15 from Africa. Ar isotopes and halogens are also presented for diopsides and amphiboles from mantle xenoliths from Bultfontein, South Africa. The Canadian diamonds have Br/Cl and I/Cl ratios higher than those of the African diamonds; Br/Cl ratios are above those for crystal fluids indicating that significant halogen variations occur in the mantle. The lowest of these ratios for both diamonds and xenoliths are close to MORB ratios. ^{50}Ar*/Cl ratios are similar for both sets of diamonds, a factor of ~ 100 greater than typical crystal fluids, but agree with a MORB source. Fractional crystallization of a Cl-bearing mineral (e.g. mica, apatite) or partitioning into a low concentration

Abstractors

R.K. Harrison	R.K.H.	M. O'Donoghue	M.O'D.	E. Stern	E.S.
R.A. Howie	R.A.H.	P.G. Read	P.G.R.		

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

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fluid phase in the mantle may account for the high I/Cl and Br/Cl ratios. R.K.H.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure (Eds). *Gems & Gemology*, **36**(3), 2000, 254-9.

Notes are given on blue and pink HPHT annealed diamonds, round brilliants represented as synthetic black diamond but which were identified as very dark bluish-green synthetic moissanite. R.A.H.

Microdiamonds from the Saxonian Erzgebirge, Germany: in situ micro-Raman characterisation.

L. Nasdala and H.J. Massonne. *European Journal of Mineralogy*, **12**(2), 2000, 495-8.

The identity of diamond inclusions in quartz-muscovite gneisses near the Saidenbach reservoir, Saxonian Erzgebirge, was confirmed by laser-Raman micro-spectroscopy, and reinforced by the graphitization of the diamond inclusions by irradiation with a high-energy laser beam. These diamonds are mostly idiomorphic and 1-30 mm in size; they occur mostly in garnet but have also been found in zircon and kyanite. The microdiamond inclusions indicate ultra-high-*P* metamorphism of the host rocks. R.A.H.

GE POL diamonds: before and after.

C.P. Smith, G. Bosshart, J. Ponahlo, V.M.F. Hammer, H. Klapper and K. Schmetzer. *Gems & Gemology*, **36**(3), 2000, 192-215.

A study is reported of 11 (8 faceted stones and 3 crystals) type IIa GE POL diamonds both before and after HPHT annealing by General Electric. The colour-change was dramatic from the N–O range to fancy light brown before, to D–H after. Little change to the inclusions, graining and strain was noted. Photoluminescence (PL) studies (at liquid helium, liquid nitrogen and room *T* in the 245-700 nm range) identified a significant reconfiguration of the lattice involving substitutional impurities, vacancies and interstitials. Key regions of PL activity included the areas of the N3, H3 and N-V centres. X-ray topography identified the extent of lattice distortion. Cathodoluminescence may help to establish that a diamond is not HPHT annealed. A distinction can be made between non-enhanced and colour-enhanced type IIa diamonds by a combination of observations and features. R.A.H.

Fluid regime of diamond crystallization in carbonate-carbon systems.

A.G. Sokol, A.A. Tomilenko, Y.N. Pal'yanov, Y.M. Borzdov, G.A. Pal'yanov and A.F. Khokhryakov. *European Journal of Mineralogy*, **12**(2), 2000, 367-75.

In experiments involving diamond crystallization in the carbonate-carbon systems Li_2CO_3-C, Na_2CO_3-C, K_2CO_3-C, Cs_2CO_3-C, $CaCO_3$-C, $CaMg(CO_3)_2$-C at 7 GPa and 1700-1750°C, the gaseous phase was studied by GC. Unlike in traditional metal-carbon systems, in which diamond forms under highly reducing conditions in the presence of methane-hydrogen fluid, the crystallization of diamond in carbonate-carbon systems occurs in the presence of a H_2O-CO_2-rich fluid. The results provide experimental confirmation of the possibility of diamond crystallization in nature over a wide range of redox conditions. R.A.H.

Gems and Minerals

Waldhambach-klassische Fundstelle für Achata im Pfälzer Wald.

G. Andree and R. Andree. *Lapis*, **25**(8), 2000, 24-5.

Account of the classic ornamental agates found in the region of Waldhambach, Rheinland-Pfalz, Germany. M.O'D.

Granati: nuovo ritrovamenti ad Asbestos e Thetford.

M. Amabili and A. Miglioli. *Rivista Mineralogica Italiana*, 24, 2000, 80-6, illus. in colour.

Fresh discoveries at the Asbestos and Thetford mines, Quebec, Canada, have included fine, gem-quality specimens of pink, orange and green grossular. This latest garnet occurrence was found as previously in a rodingite vein and as the mine is worked in circles the vein and its mineral contents has been and is expected to be encountered periodically. The occurrence lies approximately three hours' drive east from Montreal. M.O'D.

Gemmological news.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(2), 2000, 61-4.

A yellow-brown apatite cat's-eye from Madagascar was found to weigh 5.70 ct with SG 3.20, and RI 1.63. A yellow tourmaline from Nigeria was found to be of the elbaite-tsilaisite series comparable to those found in Zambia. Also from Nigeria an orange tourmaline was found amongst a parcel of spessartine garnets; it became conspicuous because of its distinct pleochroism and relatively low brilliance (6.72 ct, RI 1.620-1.640, SG 3.06).

A large amount of enhanced turquoise has been offered under the name 'Zachery-treated turquoise'. The process was invented by J.E. Zachery, an electrical engineer. It decreases the material's porosity and improves lustre and colour. No oils, waxes or colours are used and the gemmological properties are the same as those of untreated material. Only chemical analysis showed a higher potassium concentration in the treated stones. E.S.

Bernd Munsteiner.

Goldsmiths' review **1999/2000**, 2000, 42-5.

Some examples of gemstone cutting by Bernd Munsteiner are illustrated in colour. The artist bases his designs on the forms of the original crystals and fashions sculptures which may reach considerable sizes. M.O'D.

The Alto Ligonha pegmatites, Mozambique.

M. Bettencourt Dias and W.E. Wilson. *Mineralogical Record*, **31**, 2000, 459-97.

Fine mineral specimens were produced from the Alto

Ligonha pegmatite field in central Mozambique between the 1930s and the 1970s and some mines are still in operation. Gemmologists will remember the exceptional crystals of elbaite above all but other ornamental species have also been found: they include green and blue beryl and morganite, dark red gem-quality manganotantalite, pale tan scapolite, stibiotantalite (colourless to pale brown). The paper ends with a short piece 'Memoirs of Alto Ligonha' taken from a forthcoming book, An African name and an African career, by the senior author of the present paper. The present government of Mozambique is encouraging development in the area and a number of prospectors are working the pegmatites. Recently the Naipa mine has produced large and fine clusters of blue-green tourmaline crystals, among other species. M.O'D.

The geology collections of Museum Victoria, Melbourne.

W.D. BIRCH AND D.A. HENRY. *Australian Journal of Mineralogy*, **6**, 2000, 83-91.

Account of some of the notable specimens and collections in the Museum: they include gemstones, mostly quartz, faceted by local lapidary clubs and several collections of gold. The Museum has an active programme of collaboration with mineral dealers and others so that specimens can constantly be added to the collections. M.O'D.

Die Begleiter des Diamants in den Kimberliten Südafrikas.

B. CAIRNCROSS. *Lapis*, **25**(6), 2000, 39-42, illus. in colour.

Minerals accompanying diamonds in South African kimberlites are described with notes on their occurrence and on the diamonds. M.O'D.

Aquamarine from Erongo Mtn, Namibia.

B. CAIRNCROSS. *Mineralogical Record*, **32**, 2001, 63-4.

Fine deep blue gem-quality aquamarine is described from Erongo Mountain, Namibia, where the occurrence is in a pegmatite. M.O'D.

Spektakuläre Mineralien aus dem Kalahari-Manganerzfeld, Südafrika.

B. CAIRNCROSS AND J. GUTZMER. *Lapis*, **25**(10), 2000, 13-26.

Gem-quality rhodochrosite is described from the manganese ore deposits of the Kalahari area of South Africa. Geology and mineralization are discussed with references to a number of other, non-gem, materials. M.O'D.

Les Pegmatites gemmifères à elements rares du sud de la Californie.

J. FISHER. *Le Règne Minéral*, 31, 2000, 9-36, illus. in colour.

The classic monograph by Jahns and Wright, *Gem and lithium-bearing pegmatites of the Pala District, San Diego County, California*, forming Special report 7A of the California Division of Mines was published in 1951. In 1979 Jahns published something of an update in his paper *Gem-bearing pegmatites in San Diego County*, which formed part of Mesozoic crystalline rocks: *Peninsular Ranges batholith and pegmatites, Point Sal ophiolite*, in Abbot and Todd, *Geological Society of America field trip guide book*, San Diego State University 3-38. A number of other papers have looked at different parts of this area but Fisher has produced a major survey which takes into account the present state of gem mining here, with special reference to tourmaline. Apart from elbaite tourmaline, the mines are North America's chief producers of morganite and kunzite. The Tourmaline King, Tourmaline Queen, Stewart Lithia mine, the Himalaya and Little Three mines are all noted gem crystal producers or have been during past years – fresh discoveries are still being made. At least 400 pegmatite dykes have been identified in the Pala district though relatively few produce gem material. Most California pegmatites are in the lithium and caesium-enriched and tantalum > niobium category and many boron-enriched examples produce tourmaline. The alkali beryls morganite and colourless varieties are commoner than aquamarine and lithium enrichment is indicated by the presence of lepidolite and spodumene, which is abundant in the Pala district but almost always absent in the Mesa Grande and Ramona areas. Topaz from the main Little Three dyke indicates fluorine-enrichment while manganese-enriched dykes such as the Hercules produce spessartine.

The paper includes 67 colour photographs of mines and notable specimens and there is a comprehensive bibliography. *Le Règne minéral* is at Editions du Piat, 1 bis Rue du Piat, 43120 Monistol-sur Loire, France. M.O'D

Eisen in Amethyst: Farbzentren und Zwillingsgefüge.

O.W. FLÖRKE, K. RÖLLER UND F. SIEBERS. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(2), 2000, 65-84, 6 photos, 4 tables, 10 diagrams, bibl. [German with English abstract.]

Prepared sections from natural and synthetic crystals were examined with polarized light microscopy, scanning and transmission electron microscopy, X-ray diffraction, X-ray topography, electron spin resonance, low temperature infrared and atomic absorption spectroscopy. The solubility of iron in the crystal structure of quartz is limited to approximately 100-200 ppm/Si. Higher values point to iron inclusions in the microstructure. The article then deals with the amethyst colour centres and the uneven distribution of the iron, and the interaction of these factors with twinning. E.S.

I minerali dell' isola di Caprera.

A. GAMBONI AND T. GAMBONI. *Rivista Mineralogica Italiana*, **24**, 2000, 72-8.

The minerals found in the Arcipelago di la Maddalena National Park in the island of Cabrera include gem-quality dark citrine and smoky quartz as well as small specimen-quality euhedral almandine-spessartine. Smaller-sized (less than 5 mm) crystals of zircon and sphene also occur. M.O'D.

La provenienza geografica degli smeraldi archeologici.

G. GRAZIANI. *Gemmologia Europa*, **VII**, 2000, 154-98, includes 5 unpaginated tables in Italian and English.

Gemstones discovered at an archaeological site in Rome were tested by various methods and the results described. The occurrence is Tomb no. 2 in the Vallerano Necropolis whose use dates from the second and third centuries ad. The body of a girl of about 16-17 was found with personal jewels including gemstones and silver. Speculations on the origin of the items are presented and there is a short bibliography. M.O'D.

Rubinovoje: die roten Korunde von Rai-Iz im Polar-Ural.

V.V. GRYORIEV, J.V. BURLAKOV, J.A. POLENOV AND V.I. KUZNECOV. *Lapis*, **25**(8), 2000, 37-40.

Ruby crystals of ornamental quality at best are reported and described from Rai-Iz in the polar Urals of Russia. Geology and local mineralization are described. M.O'D.

Blühende Fantasie.

H. HELDNER. *Schweizer Strahler*, **1**, Fév, 2000, 15-17, 2001.

Gives examples of some of the names used for gem materials, including synthetics. M.O'D.

Chiastolite from Kyaukse, Myanmar.

U.T. HLAING. *Australian Gemmologist*, **20**(11), 2000, 479-80, 2 illus. in colour, 1 map.

Chiastolite, a variety of andalusite, occurs in gem qualities in the Kyaukse area of the Mandalay Division of central Myanmar. The samples described by the author came from a biotite schist on Kabaw Hill in the Shautaung-U range. The two illustrated cabochons weighed 4.5 and 5.5 carats. P.G.R.

Calcit aus Idar-Oberstein.

R. HOFFMANN-ROTHE. *Lapis*, **25**(8), 2000, 18-23.

Fine examples of calcite can be found in the area of Idar-Oberstein, Rheinland-Pfalz, Germany. Some remarkable forms are illustrated and described. M.O'D.

Gelbgrüner Opal-CT aus Madagaskar – Ein Beitrag zur Untersuchung mikrokristalliner Opale.

G. HOLZHEY. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(2), 2000, 85-94, 10photos, 2 tables, 1 graph, extensive-bibl. [German with English abstract.]

The yellow-green opals come from Tsivori in South Madagascar, have an RI of 1.460 and SG 2.15. X-ray diffraction showed the water-poor opal as opal CT (lussalite). The opal CT fibres form a line- or grid-like pattern. Under the scanning electron microscope the opal is shown to be characterized by a porous, spongy-spherical structure which is distinct from an aluminium-enriched structured matrix. The diameters of the silica spheres are mainly about 70 nm, but may reach up to 200 nm. E.S.

Determination of relative growth rates of natural quartz crystals.

P.D. IHINGER AND S.I. ZINK. *Nature*, **404**(6780), 2000, 865-69.

The results are summarized graphically of a micro-IR spectroscopic study of a Brazilian gem-quality quartz crystal, producing the size, shape and relative growth rates of each crystal face during its growth. Abundances of hydrogen-bearing impurities (LiOH, AlOH, HOH) are used as monitors of the growth rates of advancing crystal faces. The results, illustrated as sector zones normal to the c-axis, show that most growth occurs on the top of the crystal ($\{01\bar{1}1\}$ and $\{01\bar{1}0\}$ rhombohedral faces) and not on the $\{01\bar{1}0\}$, prism faces, as constant impurity concentrations do not form concentric zones mimicking the perimeter of the crystal. Concentrations of these impurities embedded in the crystal provide a continuous record of the relative growth rates of the individual crystal faces. R.K.H.

Diffraction colours of opal: First spectrometric data.

M. ISTROOUMOV AND H.A. TALAY. *Australian Gemmologist*, **20**(11), 2000, 467-72, 3 illus. in black-and-white, 2 tables.

The broad range of diffraction colours displayed by Mexican 'fire' opals is caused by the diameters of the silica spheres that form regular three-dimensional stacks. This paper details the first spectrometric study of the diffraction colours of precious opal. Around fifty polished opals obtained from Mexican deposits were examined in detail using a Hyperfine Analytical Network instrument to plot their diffraction spectra. In the paper one table contains a list of the subjective visual colour of the opal samples. A second table summarizes the measured VIS absorption spectra of these samples. By calculating colorimetric parameters from these spectra it should, among various possibilities, enable the objective discrimination of natural from synthetic opal, the characterization of rare and unique opals, and the accurate determination of colour varieties of opal. P.G.R.

Das blaue Wunder vom Erongo-auf Aquamarin-Jagd im Innern Namibias.

S. JAHN. *Mineralien Welt*, **11**(6), 2000, 34-41.

Describes a successful journey into central Namibia to search for aquamarine, the Erongo area providing gem-quality material. M.O'D

Die miarolen im Erongo-granit: ein Eldorado für Aquamarin, Schörl & Co.

S. JAHN AND U. BAHMANN. *Mineralien Welt*, **11**(6), 2000, 42-56.

Well-developed crystals of aquamarine are described from miarolitic cavities in granite from the Erongo area of Namibia. Other minerals of interest are green fluorite forming cubes, schorl and purple apatite. M.O'D.

Gem News.

M.L. JOHNSON, J.I. KOIVULA, S.F. MCLURE AND D. DEGHIONNO (EDS). *Gems & Gemology*, **36**(3), 2000, 260-74.

Items mentioned include a triplet composed of tiny angular flakes of iridescent ammonite shell sandwiched between a glass cap and a black opaque backing, gemmy colourless to light pink faceted anhydrite (4–22 ct) from Iran, a 0.69 ct faceted fresnoite, green spots in two pieces of lavender sugilite due to the presence of Cr, and a 2.33 ct tourmaline with an apparent change-of-colour in one pleochroic direction. R.A.H.

Smeraldi dall 'Africa.

J. Kanis. *Gemmologia Europa*, **VII**, 2000, 14-50. (In Italian and English.)

Reviews the occurrence, modes of formation and methods of identification of emeralds from Africa. Deposits in Egypt, Nigeria, Tanzania, Mozambique, Zambia, Madagascar, Zimbabwe and the Republic of South Africa are included with personal notes. There is a short list of references. M.O'D.

Hauyn aus der Eifel – ein attraktiver Edelstein.

L. Kiefert. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(2), 2000, 103-14, 9 photos, 1 table, 5 graphs, bibl. [German with English abstract.]

Haüyne is a rare mineral of exceptional blue colour, belonging to the sodalite group of minerals. It is cubic, and found in USA, Canada, Italy, Tenerife, Morocco and in the Eifel, near the Laach lake in Germany. One hundred faceted haüynes, together with some diamonds and a pink sapphire, were made into a brooch which later was sold by Sotheby's in Geneva for S.Fr.45,000. The unset haüyne stones were examined and this article reports on the gemmological, spectroscopical, microscopical and chemical results. E.S.

Gem-quality haüyne from the Eifel district, Germany.

L. Kiefert and H.A. Hänni. *Gems & Gemology*, **36**(3), 2000, 246-53.

An examination of 100 faceted, blue, round and oval haüyne (0.095–0.173 ct) from Laacher See is reported. They have RI *n* 1.498–1.507 and SG 2.46–2.48; their identity was confirmed by Raman spectrometry, with the key maxima at 543 and 988 cm^{-1}. Mineral inclusions are rare, but apatite and augite were identified. R.A.H.

Unusual inclusions in quartz.

J.I. Koivula. *Australian Gemmologist*, **20**(11), 2000, 481/2, 3 illus. in colour.

A piece of rock crystal, which was reported to have come from Madagascar, yielded two emerald cut gemstones of 23.37 and 31.81 carats, each containing a large yellowish inclusion. Although the Raman spectra produced by the inclusions were excellent, they did not match any of the patterns stored in the Renishaw digital spectral library. As one of the smaller visually identical inclusions reached a polished surface, sufficient inclusion material was available to enable an identification of the rare mineral lithiophilite to be made by means of X-ray micropowder diffraction and Becke line microscopy. P.G.R.

Rodochrosit-Stalaktiten.

W. Lieber. *Lapis*, **25**(11), 2000, 13-20.

Rhodochrosite in stalactitic form is described in locations in Catamarca province, Argentina. Details and theories on how the mineral took this form are given. M.O'D.

Gemstone enhancement and detection in the 1900s.

S.F. McLure and C.P. Smith. *Gems & Gemology*, **36**(4), 2000, 336-59.

In the past decade, growing public awareness of treatments and the greater use of sophisticated technology to enhance the colour and/or apparent clarity of gem materials brought to the forefront the need to maintain/regain consumer confidence. The most controversial treatments were the application of heat and diffusion to ruby and sapphire, the 'oiling' of emeralds and fracture filling of diamonds. The decolorization of diamonds by HPHT currently poses one of the greatest identification challenges. Other enhancement processes discussed range from quench-crackled quartz to the novel 'impregnation' techniques used in the Zachery treatment of turquoise. R.A.H.

Mineral stories.

[Various authors.] *Mineralogical Record*, **31**, 2000, 517-18.

The *Record* occasionally features short and usually amusing accounts of the trials of mineral prospectors and miners. This selection includes Al Ordway, 'A highgrader's story' (concerns tourmaline mining in San Diego County, California) and 'Forgotten emeralds' (Hilton Freed) which features emeralds from King's Mountain, North Carolina. Before incorporating either tale in serious abstracts, read them! M.O'D.

Jewelry of the 1900s.

E.B.Misiorowski. *Gems & Gemology*, **36**(4), 2000, 398-417.

The numerous changes that have occurred in the design, manufacture and marketing of jewellery over the past decade are examined. There was an increasing interest in fancy-coloured diamonds, coloured stones in dramatic combinations, and a shift towards the use of platinum and other white metals. R.A.H.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure (Eds). *Gems & Gemology*, **36**(3), 2000, 254-9.

Notes are given on the glass fracture fillings in Mong Hsu rubies, and a rough 19.49 ct bright violet and blue tourmaline, probably from Paraíba, Brazil. R.A.H.

Kronleuchter aus Bergkristall.

J. Mullis, K. Klappenbach and R. Oberhänsli. *Schweizer Strahler* **1**, Fev, 2000, 4-8, 2001.

Illustrates and briefly describes inclusions in rock crystal from Switzerland. M.O'D.

Pre-Columbian gems and ornamental materials from Antigua, West Indies.

A.R. Murphy, D.J. Hozjan, C.N. de Mille and A.A. Levinson. *Gems & Gemology*, **36**(3), 2000, 234-45.

Two recently discovered archaeological sites in Antigua appear to have had flourishing lapidary industries. Excavation of these sites, which have been dated to ~ AD 250–500 (Saladoid period) has revealed beads, pendants and 'zemis' (Caribbean spiritual ornaments). All of the unworked materials (e.g. shell, carnelian and diorite) are of local origin, but amethyst, nephrite, serpentine and turquoise were found only as finished gems; these are not local and their presence implies that trade or exchange existed between Antigua and other parts of the Caribbean at this time. R.A.H.

Die spektakulären Quarze vom Orange River.

G. Niedermayr and H. Soltau. *Mineralien Welt*, **11**(6), 2000, 57-63.

Rock crystal up to 4 cm long and coloured orange from profuse inclusions of hematite is described from the Orange River area of southern Namibia. Amethyst and sceptre forms also occur. M.O'D.

Aragonit-Pseudomorphosen in Achatmandeln aus Idar-Oberstein.

L.C. Patsch. *Lapis*, **25**(11), 2000, 31-34.

Agate pseudomorphs after aragonite have been found in the vicinity of Idar-Oberstein, Rheinland-Pfalz, Germany. Some specimens are illustrated. M.O'D.

The mineral collection of the South Australian Museum, Adelaide.

R. Pogson, L. Sutherland and G. Webb. *Australian Journal of Mineralogy*, **6**, 2000, 51-8.

History and review of the collections of the Australian Museum in Sydney with notes on gem specimens and on recent acquisitions which include some faceted items. M.O'D.

The mineralogical collections of the South Australian Museum, Adelaide.

A. Pring. *Australian Journal of Mineralogy*, **6**, 2000, 59-70.

History and description of the Museum and its mineral collections, which include a notable collection of South Australian opal. M.O'D.

Rubellitkristalle aus den Pegmatiten von Estepona bei Malága, Spanien.

J.C. Romero Silva. *Mineralien Welt*, **11**(5), 2000, 18-22.

Gem-quality pink tourmaline has been found in pegmatites at Estepona near Malága, Spain. Geological and mineralogical notes are given with a descriptive list of accompanying species. M.O'D.

Die Pegmatite von Alto Ligonha in Nord-Mozambique.

P. Schafer and T. Arit. *Lapis*, **25**(8), 2000, 13-17.

The pegmatites of Alto Ligonha in northern Mozambique are important hosts of tantalum ores and of gem minerals, the latter including tourmaline of high quality in both red and green colours. Emerald from the Morrua mines is already well known: the mines already produce yellow beryl and yellow scheelite. Some crystals of dark red manganotantalite might be faceted into gemstones. The occurrences and local geology of the different species are briefly described. The paper also notes specimens from Alto Ligonha housed in the Bergakademie Freiburg, Saxony. M.O'D.

Farbwechselnde Granate aus Madagascar.

K. Schmetzer and H-J. Bernhardt. *Lapis*, **25**(6), 2000, 46-7, illus. in colour.

Colour-change garnets are reported from Bekily and other locations in Madagascar. Specimens appear blue-green in daylight and yellow to pink or reddish-violet under incandescent light. Rutile needle inclusions have been observed: RI is given between the limits 1.759-1.767 with density between 3.87-3.93 g/cm³ . The composition shows a mixed crystal of pyrope-spessartine with pyrope content between 43 and 51% and spessartine content between 36 and 44%. Chromium and vanadium oxides contribute towards the colour. M.O'D.

Der Brandberg und die Mineralienfunde in seiner Umgebung.

G. Schneider and S. Jahn. *Mineralien Welt*, **11**(6), 2000, 17-33.

The Brandberg area of north western Namibia produces a wide variety of quartz crystals of considerable size. Interesting sceptre and other forms are described: ornamental-quality green prehnite also occurs. M.O'D.

The Gilbert Collection at Somerset House.

T. Schroder. *Goldsmiths' Review* **1999/2000**, 2000, 38-41.

The Gilbert Collection, formally shown in the United States but now housed in purpose-built galleries in Somerset House, London, includes many items of significance to the gemmologist and jewellery historian. While the gold boxes are of outstanding importance, the hardstones used as inlays are also most attractive. A brief history of the collection is given. M.O'D.

Smeraldi dalle Americhe, dall 'Asia e dall 'Australia.

D. Schwarz. *Gemmologia Europa*, **VII**, 2000, 52-82. (In Italian and English.)

Describes emerald locations in the three continents with emphasis on recent discoveries and their potential. Geological and political factors affecting emerald production are discussed. M.O'D.

Sapphires from Antsiranana Province, northern Madagascar.

D. Schwarz, J. Kanis and K. Schmetzer. *Gems & Gemology*, **36**(3), 2000, 216-33.

Since 1996, large quantities of yellow to blue sapphires have been recovered from alluvial deposits derived from basaltic rocks in the extreme N of Madagascar. Their morphology, internal growth patterns, mineral inclusions and trace element contents are typical of 'basaltic magmatic' sapphires. UV-Vis-IR absorption spectra and the results of EDXRF analysis for TiO_2, V_2O_3, Cr_2O_3, Fe_2O_3 and Ga_2O_3 are presented; TiO_2 is generally low (~ 0.2 wt.% for facet-quality samples), but Fe_2O_3 is high (in the range 0.33–1.74 wt. %). Correlation diagrams clearly distinguish these Antsiranana sapphires from those of the skarn-related deposits of Andranondambo in SE Madagascar. Most of the Antsiranana sapphires in virtually all hues are heat treated to remove milkiness and produce a better colour. R.A.H.

Gem localities of the 1900s.

J.E. Shigley, D.M. Dirlam, B.M. Laurs, E.W. Boehm, G. Bosshart and W.F. Larson. *Gems & Gemology*, **36(4)**, 2000, 292-335.

The past decade saw growth in gem exploration, production and marketing worldwide. Important coloured stone producing regions included: SE Asia (Myanamar, Thailand, Vietnam), Africa (Tanzania, Kenya, Zimbabwe, Nigeria and Namibia, as well as Madagascar), South America (Brazil and Colombia), central and southern Asia (Sri Lanka, India, Afghanistan, Pakistan, Russia and China) and Australia. The major sources of diamonds were Australia, central and southern Africa, and Russia (mainly Sakha), with exciting discoveries in N Canada. A comprehensive review is given of those gem deposits that were either new or remained commercially significant in the last decade of the 20th century. R.A.H.

Chinese Pearls: their culturing and trading.

M.G. Tao. *Australian Gemmologist*, **20**(11), 2000, 486-80, 6 illus. in colour.

China's long history of pearl cultivation began in the Song Dynasty (AD 960-1127). From 1990, Chinese pearls, especially freshwater cultured pearls, have played an increasingly prominent role in the pearl jewellery industry worldwide. Production of freshwater pearls is expected to increase to 1500 tons this year. Of total Chinese production (freshwater and saltwater), 40-50% will be sold in China, while 50-60% will be exported. P.G.R.

Lapis lazuli-Lasurit. Zur Kulturgeschichte eines Minerales.

K-L. Weiner and C. Weise. *Lapis*, **25**(11), 2000, 35-42.

A short history of lapis lazuli from its geology and mineralization to its use in ornament, with notes on some of the classic localities. M.O'D.

What's new in minerals.

Mineralogical Record, **31**, 2000, 273-86.

Gem-quality minerals reported from the 2000 Tucson show include fine greenish-blue topaz from the Zapot claim in the pegmatite near Hawthorne, Mineral County, Nevada: fine small crystals of kunzite from the newly reopened Urucum mine in Brazil: bright yellow-green fishtail twins of chrysoberyl from Anzakobe, Madagascar: aquamarine-blue crystals of kunzite from Kunar, Nuristan, Afghanistan (these crystals are reported to be normal pink after some days' exposure to sunlight): fine deep-coloured aquamarine from a pegmatite near Karur, Tamil Nadu, India: red spinel octahedra from Pein Pyit, Burma (some on white marble matrix). The theme of the main show was the minerals of Brazil and many notable, some historic, specimens were on display. M.O'D.

What's new in minerals.

[Various authors.] *Mineralogical Record*, **31**, 2000, 509-12.

Among gem-quality minerals reported from the Delaware, New Jersey, Bologna and other shows in early 2000 are fine green elbaite from the Mutuca mine, Minas Gerais, Brazil: herkimer-like sceptre rock crystal from Sichuan province, China: root-beer brown transparent enstatite from Mpwa-Mpwa, Tanzania: peach-coloured morganite from Alto Ligonha, Mozambique. M.O'D.

Strawberry quartz.

J.S. White. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49(2)**, 2000, 95-102, 6 photos, bibl.

Strawberry quartz is clear quartz containing wispy filaments of red hematite. Sometimes these inclusions are referred to as lepidocrocite, but in the examined samples were shown to be just hematite. The finest examples come from Chihuahua in Mexico, but recently Kazakhstan has produced excellent strawberry quartz. The hematite is concentrated in thin layers near the surface of the crystal and tends to be denser near the edges of the triangular terminal faces. E.S.

New find of gem quality uvarovite in Tibet.

H. Xuemei, C. Keqin and G. Shan. *Australian Gemmologist*, **20**(11), 2000, 473-7, illus. in colour and black-and-white, 1 map, 5 tables.

A cabochon-grade quality of uvarovite has been discovered in a valley in the Bo Mi county of the Tibet Autonomous Region of the People's Republic of China. The emerald-green crystals occur abundantly in a size range of 7 to 21 mm and, following further exploration of the Tibetan deposit, could become a new commercial source of this green garnet. P.G.R.

Instruments and Techniques

Smeraldi in Laboratorio.

E. Gambini. *Gemmologia Europa*, **VII**, 2000, 114-52.

Methods used in gemmological laboratories to determine the nature of emeralds are discussed with notes on the use of energy-dispersive X-ray spectrometry [EDS] and the Raman microprobe as well as on other more traditional methods. The use of inclusion studies for locality determination is also discussed. There is a short list of references. M.O'D.

Technological developments in the 1990s: their impact on gemology.

M.L. Johnson. *Gems & Gemology*, **36(4)**, 2000, 380-96.

Significant technological improvements that have had an impact on gemmology include the widespread availability of computerized communication, the increased prominence of synthetic techniques to gem treatments, and the greater need for expensive instrumentation to solve gemmological problems in general and the broader availability of small dedicated instruments to solve specific problems. R.A.H

Presidium moissanite tester (a GAA Instrument Evaluation Committee report).

T. Linton and K. Hunter. *Australian Gemmologist*, **20**(11), 2000, 243-5, 2 illus. in colour.

The Presidium moissanite tester under evaluation was part of a test kit which also included a Presidium thermal conductivity tester. Both instruments were of the same size and housed in similar cases (black for the thermal tester and grey for the moissanite tester). The moissanite instrument is designed to detect the very small current passed by a semiconductor type material. The user holds the tester with the fingers of one hand in contact with its serrated metal pads and the other hand holding the metal mount of the stone under test. When the instrument's metal probe tip is pressed against the table facet of the mounted gemstone, an electrical circuit is completed through the probe tip, the stone and the hand holding the mount. If the stone is a synthetic moissanite, the instrument detects the minute forward current and illuminates two moissanite red strip indicators. If the stone is a diamond, only the green test indicator is illuminated. A metal test plate is provided for use with unmounted stones. [Abstractor's note: Pure synthetic moissanite is not a semiconductor, and the electrical leakage current detected by this and other synthetic moissanite detectors may be due to impurities in the synthetic material produced so far.] P.G.R.

Synthetics and Simulants

Present Russian synthetic and enhanced gemstones.

V.S. Balitsky. *Australian Gemmologist* **20**(11), 2000, 458-66, 3 illus. in colour, 2 diagrams, 4 tables.

Before the split, the former USSR was a major synthesizer of single crystals for defence, scientific and technological purposes. As a spin off, synthetic gemstones were also produced and used extensively in Soviet jewellery. After the split, the country's developing free market began to import more expensive natural gemstones to supplement the dwindling high quality sources of its own natural gems. This resulted in a reduction of several magnitudes in the production of its synthetic material, with the synthetic product becoming a major export. For the last two decades, enhancement techniques have also been used to improve the quality of the less expensive varieties of gemstones readily found in Russia and other republics of the former Soviet Union. These techniques include surface colouring, impregnation by inorganic and organic reagents, heat treatment and ionizing radiation. The accompanying four tables list the synthetic gemstones produced in the former USSR, the gemstones presently synthesized in Russia and the current production of enhanced natural gemstones. P.G.R.

Gemmological news.

H. Bank, U. Henn and C.C. Milisenda. *Gemmologie. Z. Dt. Gemmol. Ges.*, **49**(2), 2000, 61-4.

Some necklaces bought as ruby were shown to be made of dyed quartz – the red colour was mainly concentrated in cracks in the stones. A translucent synthetic ruby of Russian production showed an interesting inclusion pattern. Viewed in immersion or under crossed polarisers the stones showed glide planes as found in the Verneuil-grown varieties. The transparency was reduced by minute black inclusions, presumably gas bubbles. E.S.

Sintesi e trattamenti degli smeraldi.

H.A. Hänni. *Gemmologia Europa*, **VII**, 2000, 114-52. (In Italian and English.)

The main methods of emerald crystal growth are described and discussed with additional notes on colour enhancement. Methods of detection are outlined. There is a short list of references. M.O'D.

Synthetic gem materials and simulants in the 1990s.

J.I. Koivula, M. Tannous and K. Schmetzer. *Gems & Gemology*, **36**(4), 2000, 360-79.

The past decade saw important developments in the commercial viability of gem-quality synthetic diamonds. Improvements in, and new applications for, existing synthetic processes in the production of coloured gemstones such as ruby, sapphire, emerald, quartz and alexandrite are discussed. The development of new synthetic products such as synthetic moissanite and flux-grown spinel also played an important role. R.A.H

Surface reflectivity of synthetic moissanite – a warning about heating.

T. Linton. *Australian Gemmologist*, **20**(11), 2000, 478, 1 illus.

Correspondence received from M. Kellam, Director of Technology of Charles & Colvard – manufacturer of synthetic moissanite in the USA – advises that some synthetic moissanite set in jewellery gives a diamond response when tested with a reflectance meter. These synthetic moissanites had apparently been heat-treated so that a layer of oxide formed on the surface. On inspection, a sample of heat-treated near-colourless synthetic moissanite revealed a brownish coloration across the surface of all the facets. When cleaned and hand polished using cerium oxide on leather, the sampleís surface reflectivity was restored to 98% that of non-heat-treated material. Jewellers and gemmologists who heat synthetic moissanite to induce colour change as an identifying test, are warned to use relatively low values of heat and apply these for short periods of time to avoid oxidation of the surface. P.G.R.

Gem Trade Lab notes.

T. Moses, I. Reinitz and S.F. McClure (Eds). *Gems & Gemology*, **36**(3), 2000, 254-9.

Notes are given on round brilliants represented as synthetic black diamond but which were identified as very dark bluish-green synthetic moissanite. R.A.H.

BOOK REVIEWS

The retail jeweller's guide (6th edn).

K. Blakemore, revised by E. Stanley, 2000. Butterworth Heinemann, Oxford. pp 306, illus. in black and white and in colour, softcover. ISBN 0 7506 4650 0. £24.99.

It is never easy to assess the value of a textbook which, in remaining in print for more than 30 years, has spanned years in which a great number of developments have taken place over the whole field of retail jewellery and very considerably in gemmology. In matters of style there seems to have been little change, the weight of facts in some places squeezing out rather ponderous sequences of sentences. The impression of learning hardly won, found too in other books of this period, has not entirely vanished. Today's reader will demand some air between the facts which are certainly plentiful.

I would have expected the section on diamond and coloured gemstones to have undergone heavy revision, bearing in mind the recent developments in the diamond and gemstone enhancement contexts, extensively publicized elsewhere. Sadly these have not been incorporated, the reviser having missed the opportunity to incorporate synthetic gem-quality diamond, filling techniques and their identification, and also failing to update the existing sections, clearing them of the stylistic dross that has gathered there and getting some of the facts right. I understand that this chapter is not intended for serious gemmological study and merely forms one part of a much more general text, but students will be puzzled by the appearance of peridot as a sulphate, the resurgence of 'quartz topaz' and 'real topaz' of which they would never have heard had not the author or reviser dragged them out.

The uncertainty pervading this section makes this reader unsure of the validity of the original or the revised material in the remainder of the book. Certainly the glossaries inspire little confidence and the tables are superfluous if they have to be understood with the limited information provided elsewhere. Worst of all there is no bibliography and some of the works cited in the text are of little value or outdated. All this is a pity since the information certainly is interesting and no doubt it is only here that much of it has been collected into so small a compass: the book would even be pleasing to read were it not for the nagging suspicions that all is not well beneath much of the surface.

The real problem with long-established texts of this kind is that the original authors may certainly have collected a great deal of useful information but later on have found themselves increasingly unable to arrange and present it in clear terms by the standards of today. Revisers, on the other hand, may be much less certain of some of the material and lack the detailed knowledge needed to select those parts which need to be retained and omit others on grounds of later-proved incorrectness or obscurity. This seems to be the case at least with the gemstone section of the present book and the only solution would have been to send the text for assessment to competent authorities before printing. As it stands this section is unworthy of publication and performs a serious disservice to students. M.O'D.

The Iron Crown and Imperial Europe: the Crown, the Kingdom and the Empire: a thousand years of history.

G. Buccellati, 1995. Società di Studi Monzesi, Monza, Mondadori, Milan, 1995. [Distributed by Messsagerie Italiane S.p.A., via Caetano 32, 20141, Milan.] Part 1, *The Crown, the King: a thousand years of history*. Part 2, *In search of the original crown*. Two additional parts deal with science and the plates. Volumes in slip cases. To examine a copy of the book contact the publishers.

The Iron Crown of Monza has played an important part in the history of both Italy and its former constituent states Lombardy and Venetia. Not only are many authors drawn in to discuss the possible history of the crown but gemmologists and archaeologists also make as complete a scientific study as possible. One interesting feature is the small scale of today's crown: it is too small to be worn satisfactorily, as Napoleon found when he was crowned in Milan in 1805 – astutely and elegantly he placed it on his own head for a moment only. It is possible, since the crown is made from gold plates fastened together, that there were originally more plates and so it could have been worn more easily. A computer study of this, and of the metals and the gemstones, features in the separate volume on the science of the crown, the additional volume showing plates of computer simulations of how the crown might have been made and used.

This is only a short account of what must be one of the finest Italian books to be produced in recent years.

M.O'D.

The Agates of northern Mexico.

B.L. Cross, 1996. Burgess International Group Inc. Edina, Minnesota [7110 Ohms Lane, Edina, Minnesota 55439-2143]. pp xviii, 201, illus. in colour, hardcover. ISBN 0 8087 7282 1. Price on application.

Already very well received by mineral collectors and connoisseurs, this is an excellent survey of some particularly interesting and ornamental agate deposits. The first part of the main descriptive text deals with the various types (shapes, colours and patterning) of agate from Northern Mexico in alphabetical order of their type names, but this section is preceded by considerable geological and other detail on the area in general in which both maps and coordinates are given for sites at which type specimens have been found. This section also explains some of the names and puts forward interesting theories of agate formation in the area.

Further parts of the book deal with the supply and marketing of Mexican agate, and with some of the colourful personalities associated with the deposits. There is a useful list of references and a glossary of Spanish-English mining and locality terms. While most of the illustrations are in black-and-white there is a well-produced colour section in which 30 outstanding specimens are shown. This is a very desirable book for anyone with an interest in agate or in this attractive area of the Americas. M.O'D.

Diamanten.

CHRISTIAN WEISE VERLAG, MÜNCHEN, 2000. pp 104, illus. in colour, softcover. ISBN 3 921656 53 2. *extraLapis* no. 18. DM 50.

While some of the text is devoted to fashioning and the use of diamonds in jewellery, a quick glance through the pages indicates to the reader that the bulk of the content is concerned with diamond formation and diamond crystals. As invariably with *extraLapis* monographs (and with the journal *Lapis* itself) the photographs are beautiful and the multi-author text reads from end to end without obvious breaks. English translations of the whole series are wanted. M.O'D.

Fire into ice: Charles Fipke and the great diamond hunt.

V. FROLICK, 1999. Raincoast Books [1950 Shaughnessy St., Vancouver BC, Canada V6P 6E5]. pp 354, illus. in black-and-white, softcover. ISBN 1 55192 334 3. Price on application.

Rousing and informative biography (to date) of the discoverer of the Ekati diamond claim in the Northwest Territories of Canada. Fipke is still very much around and continues to work on prospecting: a postscript recounts some of his activities seeking gold in the Yemen. The book includes a great deal of dialogue (real and imagined) and details of the diamond claims, while not too detailed (other rich prospects in the area almost certainly exist!) will show the student in particular some of the problems associated with diamond recovery. A section of photographs show the subject as a boy, passing to shots of the extensive Ekati mine. I enjoyed the book and recommend it to anyone with an interest in diamonds or in gemstone mining in general. M.O'D.

Edelsteinkundliches Fachworterbuch. Gemmological Dictionary.

U. HENN. *Z. Dt. Gemmol. Ges.*, 49, 2000, pp 1-107.

This excellent dictionary/glossary of about 3000 German gemmological items, although written for the German gemmologist, will be most useful to any English-speaking reader of German gemmological material. To be recommended for any specialist library. E.S.

Gemstones. [2nd edn]

C. OLDERSHAW, C. WOODWARD AND R. HARDING, 2001. The Natural History Museum, London. pp 76, illus. in colour, softcover. ISBN 0 565 09155 7. £7.95.

It is surprising how relatively little publicity has been given to one of the world's most important collections of gemstones in recent years when photographic and production techniques have taken great strides. The balance has been in part addressed by this excellent and beautiful book, very reasonably priced, in which the temptation towards didacticism has been successfully avoided in favour of the presentation of some of the well-known (and, very commendably, the less well-known) specimens on display. A photograph of the vanadium kornerupine when so many other green stones are in the collection shows a praiseworthy catholicism on the part of the authors, and there are other examples. Some identification techniques are painlessly introduced: there is a short bibliography and though there are one or two insignificant typos they can be ignored. This is a book worthy of the collections. M.O'D.

Planetary materials.

J.J. PAPIKE (Ed.), 1998. Mineralogical Society of America, Washington DC. pp xv, later 7 chapters individually paginated, softcover. ISBN 0 939950 46 4 (*Reviews in mineralogy*, vol.36) US $30.00.

Before anyone queries the relevance of this book to gemmology it should be said that it is one of the best recent texts from which mineral formation can be followed and understood, notwithstanding the described occurrences being extra-terrestrial. Serious students should consider buying this inexpensive though large book for an introduction to their subject. M.O'D.

Artists' jewellery in contemporary Europe: a female perspective.

D. PLANTZOS (Ed.), 2000. Ilias Lalaounis Jewelry Museum, Athens. pp 127, illus. in colour, softcover. ISBN 960 7417 11 9. Price on application.

A catalogue of an exhibition devoted to jewellery designed by women artists, this attractively-produced book includes not only high-quality illustrations of some of the exhibited pieces but also commentaries by women critics. The British designers Wendy Ramshaw, Dorothy Hogg and Jaqueline Mina are among those featured. Each artist is given a useful biography which includes details of pieces exhibited, prizes won and the whereabouts of major collections. M.O'D.

Professione Gemme: Anuario 2000.

Collegio Italiano Gemmologici, 2000. The College, Milano. pp xxvi, 185, illus. in colour, hardcover. Price on application.

This yearbook celebrates the five-year period 1995-2000 and takes the form of invited papers and details of the organization and members of the College. Papers include an illustrated study of inclusions and brief coverage of other topics: most have their own lists of references. Readers can safely disregard perceived language difficulties and will find much useful information. M.O'D.

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

AN APPRECIATION OF ERIC MOORE BRUTON

by David Callaghan

I am not sure when I first met Eric, unsure because looking back I seem to have known him virtually throughout my career in the jewellery trade. Certainly it would have been in the 1960s and I suspect shortly after he founded *The Retail Jeweller* in 1962. It is one of the privileges of my life that I met him, a privilege made all the more by our long and close friendship.

Eric's career as a writer has been so well documented that I shall not catalogue it here. However, anyone who writes 11 detective novels, books on clocks, the standard work on diamonds – the title of his finest and enduring book – is obviously a truly remarkable person. And so he was.

Without doubt Eric possessed the most intense curiosity about the world we live in, the nature of our planet, the philosophy of life, man's ingenuity – every aspect of life that came his way. He was so excited by life, so enthusiastic about every project he tackled and he was so adept in all the crafts to which he applied himself. Crafts such as: water colour painting, stained glass, silversmithing, marquetry, sculpture, Chinese brush painting, paper making, decoupage – name it he had done it. And to those of us who may have tried even one of these things – and failed – he was infuriatingly good at all of them. Such hobbies came later in life to a man who in his earlier years had become accomplished in horse riding, tap and ballroom dancing, figure skating, ski-ing and golfing – and in some of these he gave instruction. Yet you would not have known it, for he was the most unassuming of men. This did rebound on him on one occasion and, typically, he did not hesitate to tell me.

He was in a small queue in a branch of W.H. Smith the booksellers not long before Christmas one year, and in front of him was another man and a woman who was about to buy a book. She wished to give the book as a Christmas present but the dust-jacket of the particular volume she had in her hand was torn. She asked the shop assistant if she could have another copy with the jacket in good condition.

"I think this is the last copy we have, madam", said the assistant. "but I will ask to make sure." A departmental manager was then called and confirmed that it was the last copy they had. The customer then asked when the shop would be replacing the book – Eric's book on *The English Longcase Clock*.

"I am sorry, madam, but we shall not be re-ordering any further copies of this particular book", replied the manager – and before any other question could be asked a voice from further down the queue was heard to ask:

"Why not?" – and to his horror Eric recognized the voice as his own! Before anyone could ask what business it was of his he continued, somewhat lamely, "I wrote it."

At this point the man in front of Eric grabbed the book opened it, turned to a particular page and began a long and involved story about a clock in his family that was exactly the same as the one illustrated. He pointed to a particular clock – except that his had a different dial, a different chapter ring, did not have a lacquered case – and so on, and on, and on!

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Eric in his garden at Great Bentley – aged 82.

It took Eric some 15 minutes or so of prolonged agony to extricate himself from the shop, having learned very definitely to keep his mouth firmly closed against any and all apparent insults to his professionalism as a writer!

Following Anne's death in 1976, he applied himself to cooking and became an excellent cook. He had such boundless energy and all of us who were invited to his house were quite used to seeing him moving from room to room, or to the garden and back to the kitchen at the run ... it wasn't that he was in a hurry, it was simply the way he worked. My family remember well the first time he invited us to his house at Widmer End for Sunday lunch. The five of us arrived to find the cooking in full swing – the fact that three young children were coming didn't faze him in the least. They were under strict instructions to be on their best behaviour as this 'Uncle Eric' was not used to having young children around him. After lunch one of the children sat in a swivel chair in Eric's sitting room, struggling hard to avoid the temptation of swinging round and round. Eric then proceeded to show her exactly how best to do it and soon they were all taking it in turns to swing round and round, he being the ringleader!

His own garden was a pleasure to visit. Planned with the eye of an artist his meticulous attention to detail was shown in the total view from all angles.

In order to achieve this, a plan of the garden was stored on his computer showing the careful positioning of each plant, suitability of the soil, the pruning and feeding of them. He had trained his mind to focus on each and every task in hand, and many of his books are 'littered' with numerous little notes inserted so that he could study various passages of text at a later date.

Nobody could have lived a fuller life. His infectious enthusiasm for life shone through in everything he did and he took as much pleasure in hearing the exploits of others. He had a great sense of humour, particularly a sense of the ridiculous, and with it an infectious laugh. Furthermore, I have yet to see any photograph in which Eric appears where he is not cheerful, listening to others, generally showing interest and being thoroughly involved. His company was always stimulating and very relaxing. Cynicism was not in his nature and, seemingly a shy person, his inner warmth shone through. I never heard anyone speak ill of Eric and he always saw the best in other people.

Many of his fellow retail jewellers travelled on study tours sponsored by *The Retail Jeweller*, tours he organized. They studied diamonds in South Africa, emeralds in South America, cultured pearls in Japan, the fabulous buildings and collections in St Petersburg and Moscow – to name but a few – all live in the memory of those who toured with him.

Eric was not an acquisitive person yet his house is filled with interesting objects collected from all over the world. And he loved 'useless' information. He and I were always swapping the sort of information that starts with – 'did you know?' and usually finishes with 'Not many people know that.' In his desk was a box labelled 'Useless Information' and many of the contents were cuttings I had sent him. I found an alphabetical list of the countries in the world he had visited. Only two letters of the alphabet are not shown – the letters X and O! And books, literally thousands of books on every subject you can imagine.

For the last 15 years of his life he suffered from leukaemia, and even this he found 'interesting' and studied the subject deeply. Latterly he suffered from short-term memory loss and even in this he saw an advantage. He told me he was now able to re-read books with enjoyment even though he had read them only a short time before!

Although not a churchgoer Eric was a very spiritual person and had read widely of the many main faiths. Indeed he was about to write a book encapsulating his thoughts – and this at the age of 85. His life depicted always the positive – positive thinking, positive action and above all a positive example. He didn't just enrich the lives of those lucky enough to have known him, he extended their horizons.

In the obituary he wrote of himself [published in the January issue of *The Journal*] he spoke of having no direct descendants. That may be so genealogically, but he does leave descendants in us, those who knew him, respected him, studied from his books and who will be ever grateful for the way in which he touched our lives. His, and Anne's, favourite song was 'What a wonderful world'. I believe that if we can follow Eric's enthusiastic example in the way in which we lead our lives we, too, will find that it is a wonderful world in which we live.

BEQUEST

Hugh Boyd Crawford FGA, who died in January 2000, has bequeathed his gem testing equipment to the GAGTL, to be used 'to help and assist Scottish students'. The equipment includes a Rayner model S refractometer, a Rayner prism spectroscope, a Rayner dichroscope, a Rayner polariscope and a Biolam microscope with high intensity light and dark field illuminator.

The Association is most grateful for the bequest which will be used in Scotland for teaching purposes.

OBITUARY

Margaret J. Biggs FGA (D.1929, with Distinction), Farnham, Surrey, died in March 2001. A full obituary will be published in the July issue of *The Journal*.

Judith A. Brown FGA DGA (D.1967), St Columb Major, Cornwall, died recently.

Michael B. Clough FGA DGA (D.1965), London, died on 31 January 2001.

Thomas L. Ellis FGA MBHI (D.1935), died peacefully on 1 January 2001 at the age of 87.

Dr John W. Franks FGA (D.1979), Bowdon, Cheshire, Treasurer of the North West Branch of the GAGTL, died in March 2001. A full obituary will be published in the July issue of *The Journal*.

Jeanne S. Miller FGA (D.1966), Front Royal, Virginia, U.S.A., died on 15 February 2001.

Jacqueline K. Murray FGA (D.1984), Whalton, Morpeth, Northumberland, died on 17 August 2000.

Catherine Osmond FGA DGA (D.1989), London, died on 26 February 2001.

MEMBERS' MEETINGS

London

On 1 February at the Gem Tutorial Centre, 27 Greville Street, London EC1N 8TN, Stephen Whittaker of Fellows & Sons, Auctioneers of Birmingham, gave a talk on jewellery at auction entitled *Psst! Wanna buy a diamond ring, guv?*

On 1 March at the Gem Tutorial Centre, Guy Clutterbuck gave an illustrated talk on the *Gemstones from the Hindu Kush.*

On 22 and 23 March visits to De Beers were held.

GIFTS TO THE ASSOCIATION

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

Dr Alexander Bulatou, Stillwater, MN, U.S.A., for a synthetic moissanite.

Freda Cartwright, Ivinghoe, Buckinghamshire, for a collection of books, journals and instruments.

Pat Daly, Windsor, Berkshire, for rough specimens including emerald, sapphire and turquoise.

Michael Hendrix, Minarex, San Antonio, NM, U.S.A., for a yellow opal from Nevada.

Robert James, San Antonio, TX, U.S.A., for a colbalt-coated topaz.

Martin Kuncovsky, Intergem, Cardiff, for four stones including two tourmalines.

Roger Kutchinsky, Bushey Heath, Hertfordshire, for a collection of books and instruments that had belonged to the late Joseph Kutchinsky.

Kyaw Khaing Win, Yangon, Myanmar, for a pale green crystal of herderite.

Michael Parsons, Bath, Somerset, for a collection of gemstones.

Andrew H. Phillips, Stevenage, Hertfordshire, for a bag of jig concentrates from an alluvial diamond mining property, containing pyrope, chrysoberyl and corundum.

Mariana Photiou, Mt Olympus Mining Co., San Francisco, CA, U.S.A., for a rough piece of Oregon sunstone from the Dust Devil mine.

Peter G. Read, Bournemouth, Dorset, for *Professione Gemme: Annuario 2000* published by the Collegio Italiano Gemmologi.

Bear Williams, Jefferson City, MO, U.S.A., for rough garnets from the Tocantins region of Brazil.

Midlands Branch

On 26 January at the Earth Sciences Building, University of Birmingham, Edgbaston, a Gemmology Quiz and Bring and Buy event was held.

On 23 February at the Earth Sciences Building a talk entitled *The garnet group – understanding solid solution* was presented by Professor Henry Hänni.

On 30 March at the Earth Sciences Building Shena Mason gave a talk entitled *The toyshop of Europe*.

North West Branch

On 21 March at Church House, Hanover Street, Liverpool 1, David Callaghan spoke on the *Jewellery of the Art Nouveau era coupled with the art of Renée Lalique*.

Scottish Branch

On 16 January at the British Geological Survey, Murchison House, West Mains Road, Edinburgh, a Quiz Night was held.

On 16 February at the British Geological Surrey Gamini Zoysa gave a talk entitled *Gems and gem mining in Sri Lanka*.

On 21 February John Faithfull gave a talk entitled *The quest for Scottish diamonds*.

South West Branch

Inaugural Meeting

The inaugural meeting of the newly formed South West Branch was held on Sunday 21 January at the Royal Literary and Scientific Institute, Bath. The meeting began with the formation of the branch and election of officers. Dr Roger Harding and Alan Hodgkinson were guest speakers.

There was an excellent turnout on the day and thanks are extended to those who attended for their support. The enthusiasm shown has certainly set the scene for a South West Branch.

Details of the next meeting and contact information are given in Forthcoming Events on p. 379.

GEM DIAMOND EXAMINATION

In the Gem Diamond Examination held in January 2001, 78 candidates sat of whom 56 qualified, including 11 with Distinction and eight with Merit. The names of the successful candidates are listed below:

Qualified with Distinction

Chai Shixiu, Beijing, P.R. China
Checkley, Emma L., Birmingham, West Midlands
Cooke, Caroline, London
Cruse, Toby, Eastbourne, East Sussex
Deljanin, Branko, New York, NY, U.S.A.
Greslin-Michel, Valerie, London
Jiao Ning, Beijing, P.R. China
Ngan Hin Wah, Michael, Hong Kong
Sherman, Gregory E., Sea Bright, NJ, U.S.A.
Thomas, Allyson, Birmingham, West Midlands
Zhou Xiaoyang, Beijing, P.R. China

Qualified with Merit

Mayne, Glen R., Reston, VA, U.S.A.
Pala, Sunil Vinod, Coventry, West Midlands
Pelser, Stephan, Freiburg, Germany
Qin Fei, Beijing, P.R. China
Tan Hewen, Beijing, P.R. China
Wong Shuk Ching, Hong Kong
Xu Jun, Beijing, P.R. China
Ye Hong, Beijing, P.R. China

Qualified

Armati, Alexander V., Henley-on-Thames, Oxfordshire
Ayukawa, Yasuyo, London
Backsh, Illahi, Karaikal, India
Basch, Elizaveta Z., London
Bruce-Lockhart, Simon, London
Campbell, Paul, Birmingham, West Midlands
Chen Wei, Tiffany, Kowloon, Hong Kong
Chitondo, Martin Chitalu, Edmonton, London
Efejuku-Inegbenebho, Rosemarie, London
Feldman, Luke, London
Han Yenan, Beijing, P.R. China
Ito, Eiko, London
Kessler, Paul, London
Ko, Yuksan, London
Kwan, Susana, Kowloon, Hong Kong
Lam Koon-Wah, Francis, Kowloon, Hong Kong
Lei Xiong, Wuhan, Hubei, P.R. China
Lin Fan, Wuhan, Hubei, P.R. China
Liu Ying, Wuhan, Hubei, P.R. China
Moltke, Nicholas, London
Parmar, Sejal, London
Pattison, Noel, Eaglescliff, Cleveland
Ricard-Elbek, Rebecca, London
Rimmer, Ray, Bootle, Merseyside
Sang Yan, Wuhan, Hubei, P.R. China
Song Zheng, Wuhan, Hubei, P.R. China
Susser, Jennifer L., London
Tao Feng, Beijing, P.R. China
Tsang, Jasmine, Kowloon, Hong Kong
Tsoi Pui Pui, Karen, Kowloon, Hong Kong
Wei Yakun, Wuhan, Hubei, P.R. China
Wong Kwok Man, New Territories, Hong Kong
Wong Man Kuen, Purdey, New Territories, Hong Kong
Wong Lai Mun, Phyllis, New Territories, Hong Kong
Xianlong Sun, Wuhan, Hubei, P.R. China
Yu Choi Lin, Denise, New Territories, Hong Kong
Zou Hon Wah, Hong Kong

New Merit award

From January 2001, candidates sitting the Gemmology Diploma and the Gem Diamond Diploma Examinations will be eligible for a Merit award.

To gain a Merit in the Gemmology Diploma examination, candidates need to achieve between 70% and 79.5% for the two theory papers, and 80% for the practical paper. To gain a Merit in the Gem Diamond Diploma examination, candidates must achieve between 75% and 79% for each paper.

For both Diplomas, the Distinction award remains at 80% for theory and practical. All awards are at the discretion of the Examiners.

EXAMINATIONS IN GEMMOLOGY

In the Examination in Gemmology held worldwide in January 2001, 122 candidates sat the Diploma Examination of whom 62 qualified, including two with Distinction and eight with Merit. In the Preliminary Examination, 100 candidates sat of whom 89 qualified. The names of the successful candidates are listed below:

Diploma

Qualified with Distinction

Dong Lan, Wuhan, Hubei, P.R. China
Molesworth, Helen, Rotherhithe, London

Qualified with Merit

Keating, Shelley, London
Kim Ah Rong, Jeollanam-Do, Korea
Kim Yu-Mi, Kwangju, Korea
Long Zhen Xing, Guilin, Guangxi, P.R. China

Lwin Pwint Phue, Yangon, Myanmar
Pace, Michael, El Grove, California, U.S.A.
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Chen Ji Juan, Guangxi, Guilin, P.R. China. 2000
Chen Liang H., Toronto, Ontario, Canada. 2000
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Fang Liang, Guangxi, Guilin, P.R. China. 2000
He Jia Mu, Guangxi, Guilin, P.R. China. 2000
Heaviside, Desmond, Skelton-in-Cleveland. 1974
Hicks, Suzanne C., Yardley, Birmingham. 2000
Holdsworth, Christopher J., Armadale, Victoria, Australia. 2000
Khan, Abdul Jabbar, Mumbai, India. 1991
Kong Bei, Guangxi, Guilin, P.R. China. 2000
Loe Su-Mon, Taipei, Taiwan, R.O. China, P.R. China. 2000
Ma Rui, Guangxi, Guilin, P.R.China. 2000
Ndirangu, Joseph Kirangu, Nairobi, Kenya. 2000
Nootenboom, Winnie Lee-Bing, Yan Yeerd, Sai Kung, N.T., Hong Kong. 1977
Park, Stephen W., Lymington, Hampshire. 1983
Park, Suzanne S., Lymington, Hampshire. 1983
Qu Han, Guangxi, Guilin, P.R.China. 2000
Shi Kai, Guangxi, Guilin, P.R. China. 2000
Song Xiau Hua, Guangxi, Guilin, P.R. China. 2000
Su Nan, Guangxim Guilin, P.R. China. 2000
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Tzou Jyh-Jeng, Taipei, Taiwan, R.O. China, P. R. China. 1995
Vlahos, Nick, Pireas, Greece. 1995
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Winter, Nicola Kim, London. 2000
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FORTHCOMING EVENTS

25 April	**North West Branch**. *My 40 years with gems. Dr KURT NASSAU.*
27 April.	**London**. *My 40 years with gems. Dr KURT NASSAU.*
27 April	**Midlands Branch**. *A new combination gemstone finger-printer and high RI refractometer. DR JAMIE NELSON. This meeting will include the Branch AGM.*
29 April	**Midlands Branch**. *Light and colour – beautiful complexity. DR KURT NASSAU.*
3 May	**London**. *Light and colour – beautiful complexity. DR KURT NASSAU.*

Scottish Branch Conference
4-7 May 2001
Queen's Hotel, Perth

The programme will include:

RICHARD DRUCKER: Coloured stone guide. Gemstone values: sources of reference

ERIC EMMS and *ANA CASTRO*: D is for Gemmology

ROGER HARDING: Gem collections of the Natural History Museum

ULRIKA AL KHAMIS: Averting the Evil Eye: Semi-precious stones in Islamic culture

JEAN-PAUL VAN DOREN: GAGTL – Gemmology and the future

The Conference will also include a
workshop session, a field trip and a Ceilidh (dinner dance).

For further information from Catriona McInnes (contact details given below).

7 June	**London**. *The gem becomes the jewel. DAVID CALLAGHAN.*
10 June	**South West Branch**. *Sapphires of Montana. MICHAEL O'DONOGHUE.*
12 June	**Scottish Branch**: *Scottish pebble jewellery. MURDO McLEOD.*
20 June	**North West Branch**. *Bring and Buy.*
23 June	**Midlands Branch**. *Summer Supper Party.*
25 June	**London**. *AGM, Reunion of Members, and Bring and Buy Sale.*

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

London: Mary Burland on 020 7404 3334 e-mail: gagtl@btinternet.com

Midlands Branch: Gwyn Green on 0121 445 5359 e-mail: gwyn.green@usa.net

North West Branch: Deanna Brady on 0151 648 4266

Scottish Branch: Catriona McInnes on 0131 667 2199 e-mail: cm@scotgem.demon.co.uk

South West Branch: Bronwen Harman on 01225 482188 e-mail: bharman@harmanb.freeserve.uk

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Daramy, Soulaiman B., Colindale, London
Davis, Fitzroy Paul, Godmanchester, Cambridgeshire
De Caux, Stephen J., Keymer, West Sussex
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Hiroaka, Kenji, Suginami-ku, Tokyo, Japan
Ishida, Kohei, Kitanoshinchi, Wakayama City, Japan
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Volume 27 No. 6 April 2001

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A flower carved in hte long sein jade. (See 'Hte long sein – a new variety of chrome jadeite jade' pp.321-7)

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