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The Gemmological Association and Gem Testing Laboratory of Great Britain
27 Greville Street, London EC1N 8SU
Telephone: 071-404 3334
Fax: 071-404 8843

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Cover Picture

Interference colours from cleavage in gem sphalerite.
Photograph by Wilma van Opstal, FGA **(see Photographic Competition, p.523)**

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In this issue...

The GAGTL Photographic Competition this year again drew from members some beautiful images. The competition theme was 'The spectrum of gemstones' and this allowed a wide choice of interpretation of the spectra displayed by gems, of interference phenomena, of multi-coloured jewellery or of the colour range shown by a particular gem species. It also allowed the demonstration of some newer techniques which enable initially more obscure features of a gem to be seen in greater detail, and one submission involving phase contrast photography gained second prize.

In a wide range of entries, many highlighted interference phenomena and one of these, reproduced on the front cover, won first prize. Another, depicting paua shell, won third prize and the three prizewinners together with a selection of other entries will appear in the 1996 calendar.

The papers in this issue cover ruby and sapphire deposits in China, composition and treatment of jadeite, the features of Russian synthetic emerald and a major contribution to the methods for distinguishing natural from synthetic diamond. This latter topic is of growing importance in the gem world and it formed the subject of Professor Sunagawa's keynote lecture at the last GAGTL Annual Conference. The distinctive features of natural and synthetic diamond are described and related to their origins and to how they may be recognized.

Treated jadeite is another important gem material which can stretch the capabilities of those with only basic gem testing equipment. However methods are now available in laboratory and university which enable the economic testing of important pieces, and the paper by Dr Tan and his colleagues outlines one which can yield quite definitive information on surface treatments. The location of the equipment used to provide this information may seem at first to be foreign to the habits of traditional professionals in the trade but with the rapid expansion of materials science - especially in such disciplines as semi-conductors and polymers - more and more universities throughout the world are installing the relevant equipment and we should be ready and able to make use of it on an economic basis.

R.R.H.

Chinese ruby and sapphire – a brief history

Olivier Galibert, FGA, AG, and Richard W. Hughes***

*GPO Box 11626, Hong Kong

**4894 Briar Ridge Court, Boulder, Co 80301–3980, USA

Abstract

China is one of the largest countries in the world, with a rich cultural and scientific tradition. Yet for non-Chinese, until recently little was known of her mineral resources. A brief survey of China's ruby and sapphire deposits is given and an eyewitness account of one of the most important of China's sapphire deposits – Penglai, Hainan Island, – is described.

Keywords: China, ruby, sapphire, corundum, gems, Penglai, Hainan Island

History of Chinese corundum

Like Vietnam, China has never been considered a historical source of ruby or sapphire. Vague mentions of corundum in Tibet exist (Gregor, 1803), but none have been confirmed. The authors have been unable to find any evidence of historic deposits of gem corundum in China proper, but there are reports that impure corundum was used as a grinding material due to its hardness (Needham, 1959).

Still, the Chinese were aware of ruby and sapphire from outside the country. While the Chinese have never been noted as great travellers, historically they have ventured outside their borders on military or diplomatic missions, or for religious pilgrimage (Bretschneider, 1887). Fa Hien (Fa Hsien) was selected by the Chinese emperor to travel to India to obtain accurate information on Buddhism. In the account of his journey, which occurred during AD 399–414, he did mention the occurrence of many precious stones in Ceylon (Legge, 1965). One Chinese author, Thao Tsung-I, wrote a brief treatise on the precious stones known about AD1366. A short section of this was translated by Bretschneider (1887). In this, *la* (balas ruby, or spinel) is described, as well as *yakut (yaqut)*, which is Persian for corundum.[1] Thus it is apparent that some in China were aware of the corundum gems from abroad, but domestic occurrences were not reported until the late-1970s, when economic and political reforms made it possible to openly discuss 'bourgeois' subjects, such as gems.

Tu Wan's *Stone Catalogue of Cloudy Forest* dates from about AD1126 (Schafer, 1961). This book contains descriptions of various stones known to the Chinese in the twelfth century, but apart from the banded blue–green 'Stone of the Office of the White Horse' (*Ho-nan-fu*), none accurately describe corundum.

According to Liu Guobin (1981), the finest historical work on precious stones in China is the *Lapidarium Sinicum* of H-C Chang (1921). The authors have not seen this book. In the 1990s, gemmological periodicals have appeared in China but, as the authors cannot read Chinese, the following is drawn from sources using the Roman alphabet.

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[1] According to Bretschneider (1887), the Chinese word for ruby is *hung pao shi* (red precious stone), while that for blue sapphire is *lan pao shi* (blue precious stone).

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Fig. 1. Corundum localities of China. Gem deposits are found in Fujian, Hainan, Heilongjiang, Jiangsu, Qinghai, Shandong, Sichuan, Xinjiang and Yunnan Provinces. Note that the position of some localities is approximate only.

Corundum in China

Information on Chinese localities is difficult to come by, as access often involves obtaining permission from the Chinese military, which controls most mines. A second factor is location; many mines are in remote areas where travel is difficult. The following information is as accurate as present circumstances will allow.

Ruby and sapphire have been reported from a number of different areas in China. Of these, the most important are the sapphire occurrences of Shandong, Fujian and Hainan in eastern China. In each of these places, sapphires occur in alkali basalts as dark, inky-blue material similar to that mined in Australia.

Penglai (Hainan Island)

Getting there

Hainan Island is located in the South

China Sea, due east of Vietnam. Reached by air from Guangzhou (Canton) and by air or (irregular) boat from Hong Kong, Haikou, the island's provincial capital, is the jumping off point for trips to Penglai.

Access from the provincial capital of Haikou is typical for third-world backwaters; several hours on a livestock-infested bus along what the charitable term 'roads'. The December–February rainy-season flooding, which turns the Penglai area into a swamp, will give travellers further fuel for spinning porch-side yarns in the twilight of their lives ('I remember when I was on the road to Penglai ...').

Penglai's sapphire mines lie 2km south-east of the town of the same name, covering some 25km^2, in the north-east corner of Hainan Island. Due to the difficulty of getting there, few foreign gem dealers visit. Fortunately, the journey is not the only reward: the Penglai area produces some of China's finest sapphires.

Mining and cutting

Sapphire was first discovered on Hainan Island in the early 1960s by a local farmer, Zhang Changde, who found a beautiful stone on the ground near to where his animals were grazing. Fascinated, he began collecting more but apparently must seek his reward in heaven for, upon turning the gems over to the local geological team, he received just 1.6 yuan (~$1.00) (Wang Furui, 1988).

In 1982 an exploration team was sent to study the deposit (Wang Furui, 1988), but since Olivier Galibert's first trip to the area in 1987 only Hainan Island natives have been involved in mining. Digging generally takes place in the evenings by farmers (and even government officials), particularly after heavy rain. Excavation methods are primitive, along the lines of traditional corundum mining in south-east Asia. What sapphire is recovered is often kept in small bags sewn into the miners' trousers.

Among the reasons this deposit has not been worked on a larger scale are the policies of local officials, who hesitate to decide just who will be blessed with the appropriate permission. This is common among mining projects in some nations, where local officials do everything possible to both retain authority and sell it to the highest bidder.[2] At the time of Galibert's last visit in 1991, most production was being sold to Thai and Hong Kong dealers; no sapphire-cutting factories existed on the island.

Gemmology of Penglai sapphires

Alkali basalt is thought to be the source rock of the sapphires, which are recovered at a depth of 2–3m, with pyrope garnet, black spinel, pyroxene, olivine and zircon. Penglai sapphires tend to occur as small- to medium-sized hexagonal prisms and fragments. The average size is 2–5mm, with the largest reported at 35.5 ct. Colours are mostly blue, with stones varying through bluish-green, green and yellowish-green. Most are dark. Stones containing traces of Cr have also been found, but are rare.

Gemmological properties are typical for sapphire. Straight, angular colour zoning is common, with associated clouds of unidentified silk. Solid inclusions may be opaque and black; white crystals have also been found. Both types may be surrounded by tension haloes. Like most sapphire, Penglai stones are commonly heat-treated (Wang Furui, 1988).

Heat treatment

Attempts to heat treat Penglai material have met with varying degrees of success. Professor Qin Bingsheng of the Guangdong geological office has run experiments which resulted in increased transparency, but darkening of colour, thus reducing value. Similar results have been obtained by Thai burners.

While much of the Penglai material dis-

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[2] Or bidders. During one author's (RWH) residence in Vietnam, he heard of several cases where the 'exclusive' rights to mine a deposit did not 'exclude' native digging on the same land.

Fig. 2. Sapphire diggings at Penglai, Hainan Island, China. *Photo: Olivier Galibert*

plays the oily diesel effect common to Sri Lankan geuda sapphires, Sri Lankan sapphires contain silk which is relatively pure rutile (TiO_2). In contrast, the silk of basalt-sourced Fe-rich sapphires is generally mixed crystals of rutile and ilmenite ($FeTiO_3$). Due to its quadrivalent state, Ti^{4+} diffuses into corundum some 10 000 times faster than either iron or chromium (John Emmett, pers. comm., 11 July 1994). Thus when such crystals are heat treated, the Ti diffuses into the corundum, leaving the iron behind. The result is that, unless heating is performed for extended periods of time, some silk always remains.

Other Chinese localities

Fujian Province

The following is based on the report of Keller and Keller (1986). Sapphires were first discovered near the town of Mingxi in 1980, during diamond exploration. Mining takes place approximately 10km north-west of the town in secondary deposits derived from alkali basalts.

Colours of the material range from yellowish-green, green, through greenish-blue to blue, with rough averaging 2ct in weight. The largest faceted gem reported was 2.1ct. Virtually no information is available on the inclusions of this material. Crystal habits tend to be barrel and dog-tooth shapes, similar to sapphires from Australia (which the material strongly resembles).

Shandong Province

The following is based on the report of Jingfeng Guo *et al.* (1992). Sapphire was discovered near Wutu, Changle County, Shandong Province in the late 1980s, first in alluvial gravels, later *in situ* in alkali basalts. Mining is taking place in the secondary deposits, while primary deposits are worked for mineral specimens. Similar to other basaltic sapphires, crystals tend to be barrel-shaped. Many show rounded, etched surfaces due to partial solution by magma during their eruptive trip to the surface.

Most stones are dark blue; some material ranges from greenish-blue to yellow in colour; material is often strongly zoned. While material ranges in size from 5–20mm, larger material tends to be too dark. Solid inclusions identified in Shandong sapphire include U- and Th-rich zircon crystals of orange-red colour, Ti-rich columbite (black, metallic), Na-feldspar, apatite, ilmenite and Mg-Fe spinel. Specimens with silk are found, but the identity of the silk has yet to be reported. Virtually all are heat treated.

Yunnan

Ruby in marble was discovered in the Ailao Mountains of Yunnan Province in the late 1980s, with placer deposits being mined (Qian Tianhong *et al.*, 1992). Vague reports regarding ruby deposits in Yunnan claim that this material is similar in colour to that from Myanmar and Vietnam (Anonymous, 1991a–b). These deposits are said to have potential, with clean rough as large as 8ct being found.

Shortly after the find was made, people descended on the area in droves, possessed with 'ruby fever'. This was not exactly the type of 'resettlement policy' the central government had in mind, and a quick halt was put to the proceedings.

In Yunnan, the Shunning Fu prefecture was described as a source of sapphire, ruby and green sapphire; these gems were said to occur in other parts of that province, as well (US Consular Reports, 1990).

Heilongjiang

Ruby and volcanic sapphire have been reported from Heilongjiang (Anonymous, 1989). Weather conditions are said to be difficult, allowing mining only 3–4 months of the year. The army is said to control the area and little is being recovered; most stones are of small sizes.

Fig. 3. Rough sapphires from Penglai, Hainan Island, China. *Photo: Olivier Galibert*

Jiangsu

Low-quality (dark) blue sapphire is said to occur in Jiangsu, but the reports of ruby are said to have been confused with garnet, which is of good quality.

Qinghai

Both ruby and sapphire have been reported from Qinghai (Dong Bingyu, 1993). Mining is said to be difficult due to the 3000m elevation of the Qinghai plateau. Translucent ruby of pale pink to medium red is said to occur in an oligoclase-biotite gneiss. Star rubies are said to be possible. (Anonymous, 1991b.)

Sichuan

Ruby has been reported from Nanjiang, Sichuan Province (Chikayama, 1986).

Xinjiang

Ruby has been reported from Kalpin, far western Xinjiang (Keller and Fuquan,

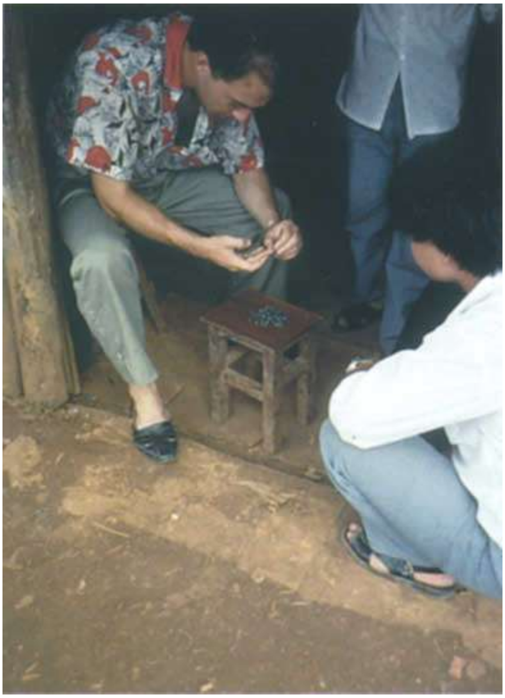

Fig. 4. French dealer, Olivier Galibert, examines sapphire rough from Penglai, Hainan Island, China. *Photo: Olivier Galibert*

1986). Sapphire has also been reported from Taxkorgan in Xinjiang (Chikayama, 1986).

Conclusion

Blessed with varied and plentiful natural resources, it is only a matter of time before China joins the ranks of major gem-producing nations. Already, corundums have been found in Fujian, Hainan, Heilongjiang, Jiangsu, Qinghai, Shandong, Sichuan and Xinjiang provinces. While China has yet to produce corundums of top quality, Hainan Island's sapphire deposits display promise, and rumours of quality ruby in Yunnan suggests that China could become an important force in the world market for ruby and sapphire.

Acknowledgements

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Richard Hughes would like to thank Bob Frey, expert in various things Chinese, who has gone above and beyond the call of duty in both editing and locating obscure references. The help of both John Emmett and Ted Themelis on the subject of heat treatment is also greatly appreciated.

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Identification of bleached wax- and polymer-impregnated jadeite by X-ray photoelectron spectroscopy

T.L.Tan, T.S. Tay**, F.C. Loh*, K.L. Tan* and S.M. Tang**

*National University of Singapore, Department of Physics, Faculty of Science, Lower Kent Ridge Road, Singapore 0511

**Far East Gemmological Laboratory, #B2-02, Tanglin Shopping Centre, Singapore 1024

Abstract

X-ray photoelectron spectroscopy (XPS) is found to be a useful non-destructive technique distinguishing unambiguously bleached impregnated jadeites (B-jade) from the natural and untreated ones. The impregnation substance can be identified by chemical analysis of the surface of the jadeite. Results of an XPS study on 16 jadeite samples show that some have been impregnated with wax, polymer or both. XPS results were further supported by basic gemmological tests and complemented with infrared absorption spectroscopy.

1. Introduction

The use of infrared absorption spectroscopy for the identification of bleached and polymer-impregnated jadeite or grade B jade (B-jade) was reported first by Fritsch *et al.* (1992). It was found that the presence of strong multiple absorption peaks in the 2800–3100cm^{-1} range indicate the presence of polymer, thus implying that the samples had been treated with polymer. As polymer can be quite easily detected using infrared spectroscopy in this frequency range, manufacturers may use alternative materials as fillers in the bleaching process, such as paraffin wax (Fritsch, 1993) or other substances which are not detectable by infrared absorption techniques. Indeed, recent findings of high concentrations of wax in some jadeites have created some controversy between laboratories (Tay, 1992). Some claim that wax has been part of the polishing agent used by manufacturers for centuries to improve the quality of polish on jadeite and that this process is considered to be an acceptable trade practice (Ehrmann, 1958; Crowningshield, 1972). In a quantitative way, infrared absorption peaks at 2852 and 2920cm^{-1} attributable to normal wax polish tend to be relatively low in comparison with the extremely high peaks found in some jadeites with modern treatments. However, the identification of treated jadeite using infrared spectroscopy is severely limited by its response in only certain parts of the mid- and near-infrared frequency ranges and by the restriction of this measurement to specimens of thin jadeite which is not opaque to infrared transmission.

The structure and texture of jadeites may reveal that they have been treated (Ou Yang, 1993). In the study carried out by Tay *et al.* (1993) using a scanning electron microscope, photomicrographs of some bleached jadeites showed both the interlocking crystal grain structure damaged by

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Fig. 1. Natural rough jadeites. For identification, the jadeites are numbered 1 to 4 (from top to bottom)

bleaching and the concentration of impurities between grain boundaries; but the proper interpretation of the photomicrographs requires a good understanding of the texture and structure of jadeite crystals. Although an energy dispersive X-ray fluorescence (EDXRF) spectrometer can be used to detect differences in iron content in jadeites, it is not capable of detecting light elements such as carbon, hydrogen, oxygen and nitrogen which constitute most polymers (Fritsch *et al.*, 1992). Thus the photomicrographs do not provide any information on the type of impregnation materials other than to indicate that they would be of low atomic number.

In this work, the X-ray photoelectron spectroscopic (XPS) technique was used to study the chemical compositions of the surfaces of treated jadeites for the first time. Our results show that such chemical analyses provide unambiguous information for discriminating between natural and B-jades, and between wax- and polymer-impregnated jadeites.

2. Materials, preliminary tests and results

Four unbleached weathered jadeites with newly-sawn rough surfaces (Figure 1), five natural-coloured polished jadeites and seven bleached wax- or polymer- impregnated coloured polished cabochons (Figure 2), were studied using basic gemmological instruments and an infrared absorption spectrometer. All the samples originated from Myanmar (Burma). The results of these preliminary investigations are summarized in Table I.

The 'spot' refractive index was found to be about 1.66 for all polished jadeites, which is within the jadeite range. It was not possible to measure the refractive index of the weathered jadeites because of their rough surfaces, but all were placed in di-iodomethane (specific gravity 3.32). As can be seen in Table I, it is not possible to discriminate between natural and treated jadeite on the basis of immersion in di-iodomethane. Both natural and treated jadeites showed very similar visible absorption lines using a prism spectroscope (Table I). Some but not all the treated jadeites fluoresced under long-wave or short-wave ultraviolet irradiation whereas all natural jadeites were completely inert to such irradiation.

For all the samples studied, infrared absorption spectra were recorded using a Bomem DA3.002 Fourier Transform Infrared (FT-IR) spectrophotometer (Tan *et al.*, 1992) to determine whether they were

Fig. 2. Five pieces of natural wax polished jadeite, numbered 5 to 9 (upper row, from left to right). Seven pieces of bleached wax- or polymer-impregnated jadeite, numbered 10 to 16 (lower row, from left to right)

wax-polished, wax- or polymer- impregnated, or untreated. The resolution of the spectra was 1cm^{-1}. The absorption peak values are listed in Table I. Typical weak peaks at 2852 and 2920cm^{-1} as illustrated in Figure 3(a) confirmed that jadeite samples 4 to 9 were polished with wax whereas strong peaks (Figure 3(b)) showed a high content of wax impregnated in samples 12 (off white) and 13 (red brown). No absorption peaks were observed for samples 1 to 3, showing that the presence of wax and polymer were negligible. On the other hand, if a spectrum contains several strong and distinct peaks in the 2800–3100cm^{-1} range, these are due to the absorption of polymer material and indicate that the sample was polymer-impregnated. A spectrum with peaks at 2875, 2931, 2966 and 3060cm^{-1} typical of samples 10, 11 and 14 to 16 is shown in Figure 3(c).

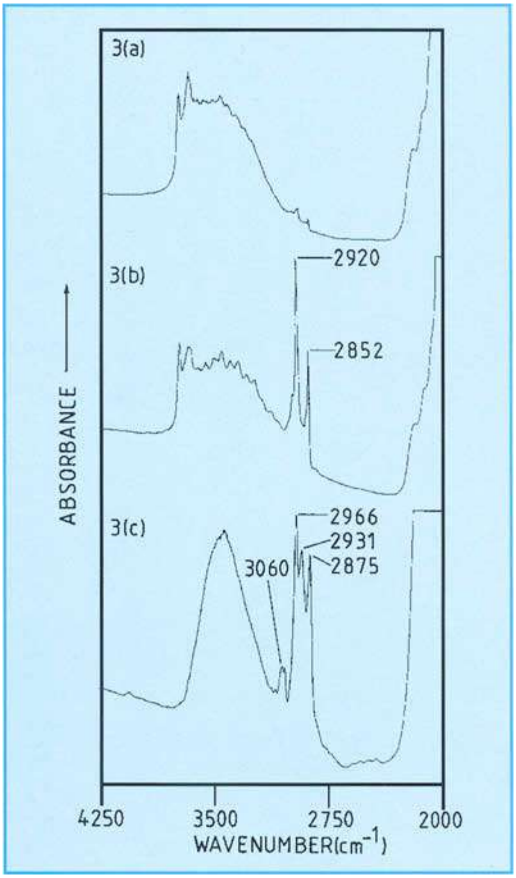

Fig. 3. Infrared absorption spectra of:
(a) natural jadeite with wax-polish (samples 4–9)
(b) bleached wax-impregnated jadeite (samples 12,13)
(c) bleached polymer-impregnated jadeite (samples 10,11, 14–16)

Table I. Gemmological and spectroscopic data on natural and impregnated jadeite

Sample	SG (3.32)	Ultraviolet fluorescence	Microscopic observations	Infrared peaks (cm^{-1})
1, 2	Sink	None	Rough and newly-sawn. Lavender colour with thick brown fissure.	None
3	Sink	None	Rough and newly-sawn. Very very light green.	None
4	Sink	None	Weathered with polished surface. Dark green.	2852, 2920 (very weak)
5	Sink	None	Light green oval shape cabochon. Several brown spots. Green veins.	2852, 2920 (weak)
6	Sink	None	Very light even green oval cabochon. No fissures. Some slight breaks.	2852, 2920 (weak)
7	Sink	None	Medium dark brown carved pendant showing cracked-like effect on surface. Suspected heat-treated.	2852, 2920 (weak)
8	Sink	None	Green oval cabochon with fine fissures. Green veins.	2852, 2920 (weak)
9	Sink	None	Light yellow carved pendant showing patches of white mineralization.	2852, 2920 (weak)
10	Float	Chalky blue (long-wave)	Very light green with large pit marks. Green veins.	2875, 2931 2966, 3060 (strong)
11	Sink	None	Light green patches with brown stains on face. Some pit marks and fine fissures.	2875, 2931 2966, 3060 (strong)
12	Sink	None	Very light green oval flat cabochon. Fine fissures.	2852, 2920 (very strong)
13	Sink	None	Medium brown oval flat cabochon with brown veins. Fine fissures throughout surface. Cracked-like appearance. Suspected heat-treated.	2852, 2920 (very strong)

14	Float	Weak chalky blue (long-wave)	Very light green cabochon. Green veins and pit marks on surface.	2875, 2931 2966, 3060 (very strong)
15	Float	Chalky blue and yellow patches (long-wave)	Light green cabochon. White patches and minute pits on surface.	2875, 2931 2966, 3060 (very strong)
16	Sink	Chalky yellow (long- and short-waves)	Green oval high dome cabochon. Green veins and patches. Fine polishing marks. Tinted slight yellow.	2875, 2931 2966, 3060 (strong)

3. X-ray photoelectron spectroscopy (XPS)

Surface analysis by XPS is accomplished by irradiating a sample with mono-energetic soft X-rays (photons) and detecting and analysing the energy of the emitted electrons. MgK_α (1253.6 eV) X-rays are commonly used. These photons have limited penetrating power in a solid, extending between 1 and 10 μm depending on their energy and the nature of the substance. They interact with atoms in the surface region, causing electrons to be emitted by the photoelectric effect. The emitted electron has a measured kinetic energy given by

$$K.E. = h\upsilon - B.E. - \phi_s$$

where $h\upsilon$ is the photon energy, *B.E.* is the binding energy of the atomic orbital from which the electrons originate, and ϕ_s is the spectrometer work function.

Each element has a unique set of binding energies, and as such XPS can be used to measure these energies and identify and determine the concentration of the elements on the surface. Variations in the elemental binding energies (chemical shifts) arise from the differences in the chemical potential and polarizability of compounds. These chemical shifts can be used to identify the chemical state of the compounds. Probabilities of electron interaction with matter far exceed those of the photons, so while the path length of the photons is of the order of micrometres, that of the electron is of the order of nanometres or tens of angströms. XPS is thus a surface-sensitive technique capable of the chemical characterization of the surface of a solid, in this case jadeite.

Technical details

XPS has been shown to be a useful tool for studies of chemical compositions of polymers (Loh *et al.*, 1993, 1994). The surfaces of all 16 samples as listed in Table I were thoroughly cleaned with a light dose of highly volatile propanol in order to remove any contaminant present due to handling immediately before they were placed in the evacuated analysis chamber. The XPS measurements were made on a VG ESCALAB MkII spectrometer with an MgK_α X-ray source (1253.6 eV photons). The X-ray source was run at a reduced power of 120W (12 kV and 10 mA). The core-level spectra were measured at a take-off angle of 75°. To compensate for surface charging effects, all binding energies were referenced to the C(1s) neutral carbon peak at 285 eV. Surface chemical compositions were determined from peak area ratios, corrected with appropriate experimentally-determined sensitivity factors, and were liable to a ±5% error. The normal

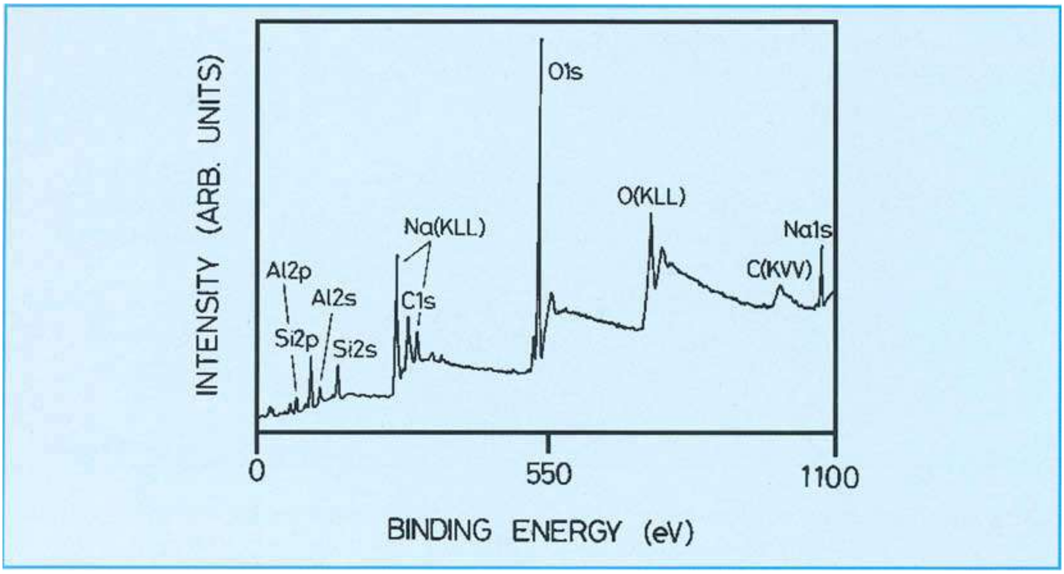

Fig. 4. XPS survey scan spectrum of natural jadeite (samples 1–3). KLL and KVV refer to the electronic levels at which the vacancy is created by the excitation source (electrons); the de-excited electron originate, and the Auger electron originate respectively.

operating pressure in the analysis chamber was less than $5x10^{-9}$ mbar.

Gemmologists will recall that the basic structure of the atom can be thought of in terms of shells of electron orbitals labelled in sequence from the nucleus outwards K, L, M and N. Photoelectron spectroscopy detects and measures the energy levels of electrons in the different orbits, s, p, d or f in the shells and the concentrations of each element can then be calculated.

4. Results and discussion

A typical XPS survey scan spectrum of the surface of a natural rough jadeite such as that obtained from samples 1 to 4, is shown in Figure 4. The spectrum recorded in the binding energy range of 0 to 1100 eV was able to provide identification of all the elements present on the surface of the jadeite. As shown in Figure 4, the main peaks are silicon (Si(2p) peaks at about 99 eV, as given by Moulder *et al.*, 1992), sodium (Na(ls) at about 1072 eV), aluminium (Al(2p) at about 73 eV), and oxygen (O(1s) at about 531 eV), consistent with the ideal composition of jadeite, $NaAlSi_2O_6$ (Deer *et al.*, 1978). Traces of carbon (C(1s) at about 285 eV), and calcium (Ca(2p) at about 347 eV) were also found. The relatively weak carbon (C(1s)) peak (Figure 4) can be attributed to a small amount of carbon (hydrocarbon) impurity (such as little traces of wax or grease) present on the surface of the jadeite which was detected by the highly sensitive XPS spectrometer. Due to the small sampling depth (approximately 50Å) of the XPS techique, bulk elements which may include Fe and Cr were not detected.

For the natural jadeite (samples 4 to 9) which were wax-polished, a higher C(1s)/Na(1s) ratio of about 12 was observed as compared to a ratio of about 2.5 for the unwaxed natural jadeite. The presence of a higher C(1s)/Na(1s) ratio is indicative of the presence of wax which consists mainly of carbon, hydrogen and a trace of oxygen, as shown in Figure 5(a). The XPS spectrum of wax is shown in Figure 5(b) and shows two significant peaks: a major C(1s) peak and an associated trace O(1s) peak. The C(1s)/Na(1s) ratio of about 11.0 (as shown in Figure 5(c)) for the wax-impregnated jadeite (samples 12 and 13) is comparable to that of the wax-polished jadeite. Since wax-impregnation would result in a higher carbon concentration in the bulk of the jadeite, it would not be possible to differentiate a wax-polished jadeite from that which is wax-impregnated from surface analysis using XPS. For the purpose of determining bulk analysis, it would be essential to measure a mid-infrared absorption spectrum in the range which shows wax peaks (Figure 3(a), (b)).

All of the bleached polymer-impregnated jadeites (samples 10, 11, 14–16) showed a very intense carbon peak with a C(1s)/Na(1s) ratio of about 35, as typically shown in Figure 6(a). The C(1s)/Na(1s) ratio for such jadeite was found to be much stronger than that of either wax-polished or wax-impregnated jadeite (Figures 5(a), 5(c)). The XPS spectrum of a polymer commonly used as a filler for jadeite showed intense peaks of C(1s) and O(1s) (Figure 6(b)) which were expected from the chemical composition of the polymer.

From the overall analysis of the XPS survey scans recorded, the intensity of the C(1s) peak appeared to be the most important determinant for the identification of B-jades. A closer examination of the C(1s) core-level spectra of both the wax- and polymer-impregnated jadeites revealed additional differences between the two treated jadeites. Figures 7(a) and 7(b) show the high resolution C(1s) core-level spectra of the wax- and polymer-impregnated jadeites respectively. By a process of peak-analysis, the C(1s) core-level peak envelope can be resolved into its peak components. As shown in Figure 7(a), the C(1s) peak is generated from three arrangements of bonds, namely, the aliphatic (-C-C-), the ether (C-O) and the ester (O=C-O). In contrast, as shown in Figure 7(b), the broader C(1s) core-level peak of the polymer-impregnated jadeite can be resolved into four components. They are the aliphatic, the aromatic/phenyl (O), the carbonyl (C=O) and the ester bond structures.

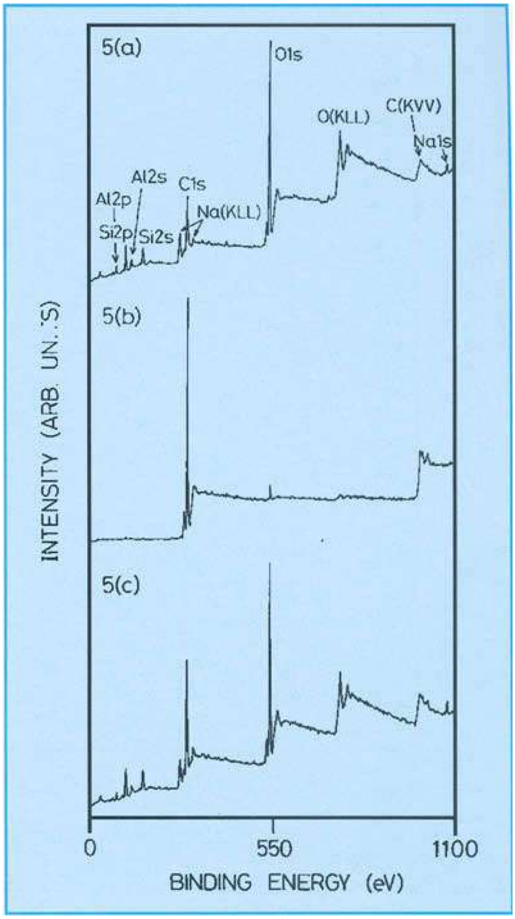

Fig. 5. XPS survey scan spectrum of:
(a) natural wax polished jadeite (samples 4–9)
(b) pure paraffin wax
(c) bleached wax-impregnated jadeite (samples 12, 13)
KLL and KVV refer to the electronic levels at which the vacancy is created by the excitation source (electrons); the de-excited electron originate, and the Auger electron originate respectively.

5. Conclusion

Basic gemmological tests such as the measurement of specific gravity and the observation of luminescence to ultraviolet radiation can only provide limited indications of any treatment to jadeites. Observations of damaged grain boundaries using scanning electron microscopy can give an indication of the extent of bleaching of the jadeite, but a more satis-

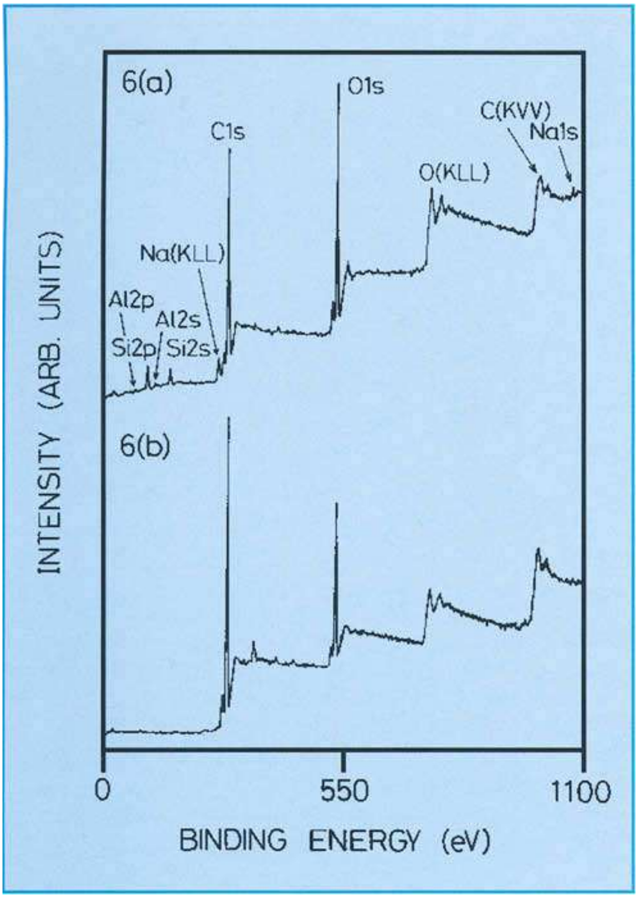

Fig. 6. XPS survey scan spectrum of:
(a) bleached polymer-impregnated jadeite (samples 10, 11, 14–16)
(b) a polymer.
KLL and KVV refer to the electronic levels at which the vacancy is created by the excitation source (electrons); the de-excited electron originate, and the Auger electron originate respectively.

factory test uses infrared absorption spectroscopy which identifies wax and polymers in certain infrared regions. However, even this advanced technique may not be able to detect impregnation materials other than wax and polymers. Furthermore the infrared absorption technique is limited to thin jadeite which allows the transmission of infrared radiation. These limitations can mostly be circumvented with the use of XPS. This non-destructive technique has been found to be capable of determining the chemical composition of the surface of the jadeite and thus can identify any foreign elements present. The surface analysis used in the XPS technique is complementary to determination of the bulk composition by infrared absorption spectroscopy.

From the results of our XPS study, the impregnation materials used in the bleached jadeite samples are paraffin wax and polymer. High C(1s)/Na(1s) ratios of about 11 indicate the presence of wax in jadeite. A C(1s)/Na(1s) ratio of about 35 is indicative of the presence of polymer. In addition, impregnation by wax or polymer can be further distinguished by analysing the differences in the carbon peaks. The ether carbon is characteristic of the wax whereas the phenyl and the carbonyl species are characteristic of the polymer used for impregnation. Hence, our work has shown that X-ray photoelectron spectroscopy is an independent and accurate technique for the identification of bleached wax- and polymer-impregnated jadeite.

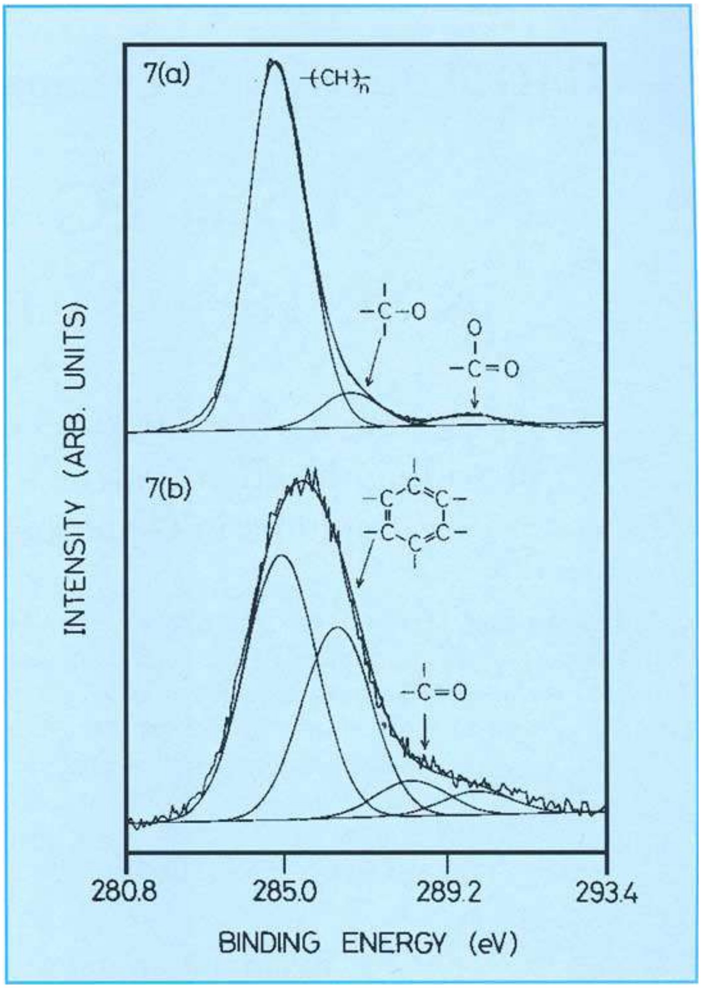

Fig. 7. XPS C(1s) core-level spectrum of:
(a) bleached wax-impregnated jadeite (samples 12, 13)
(b) bleached polymer-impregnated jadeite (samples 10, 11, 14–16).

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The distinction of natural from synthetic diamonds

Ichiro Sunagawa

Yamanashi Institute of Gemmology and Jewelry Arts, Tokoji-machi 1955–1, Kofu, 400 Japan

Abstract

Important concepts necessary to understand the mechanisms of crystal growth and the reasons why crystals of the same species can adopt a wide variety of morphologies are explained. This is followed by an explanation, based on thermodynamic analysis, of growth conditions of natural and synthetic diamond crystals in the diamond stable region, and of CVD diamonds in the diamond labile region. Due to differences in growth conditions and ambient phases, diamond crystals develop different morphological characteristics during their growth processes and may be considered as three types. The main difference between natural diamond and two types of synthetic diamond is found in the roughness at the growth surface of {100} faces. The {100} interface behaves as a rough interface, on which an adhesive type of growth mechanism operates, when diamond grows in a silicate solution (natural), whereas it behaves as a smooth interface when diamond grows in a solution of metal and carbon or by chemical vapour deposition; a two-dimensional nucleation growth mechanism or spiral growth mechanism is operative on {100} during synthetic growth.

Since these variations may be recorded in different single crystals as differences in growth sectors, growth banding, spatial distribution of dislocations and other lattice defects, they can be detected and visualized with the appropriate method even if a crystal is cut and polished. For this purpose the best method for use in gemmological laboratories is cathodoluminescence topography, combined with optical microscopy. Examples are given to demonstrate how CL images can differ between natural and synthetic diamonds of gem quality.

Introduction

In 1959, a research group of the General Electric Company in the USA published a paper in *Nature*, reporting, for the first time, how to synthesize diamond (Bovenkerk *et al.*, 1955). In this paper, they reported that there was no detectable difference between natural and synthetic diamonds. In issues of the same journal a few weeks later, Tolansky and Sunagawa (1959, 1960) published two papers, reporting that surface microtopographic observations revealed distinct differences between natural and synthetic diamonds. The authors inferred that these features resulted from differences in ambient phases and growth conditions experienced by the two kinds of diamond. It was possible to make such a comparison with confidence, because in Tolansky's laboratory a database on surface microtopograhic observations on natural diamond crystals had been accumulated.

They noticed the following differences between natural and synthetic diamonds.

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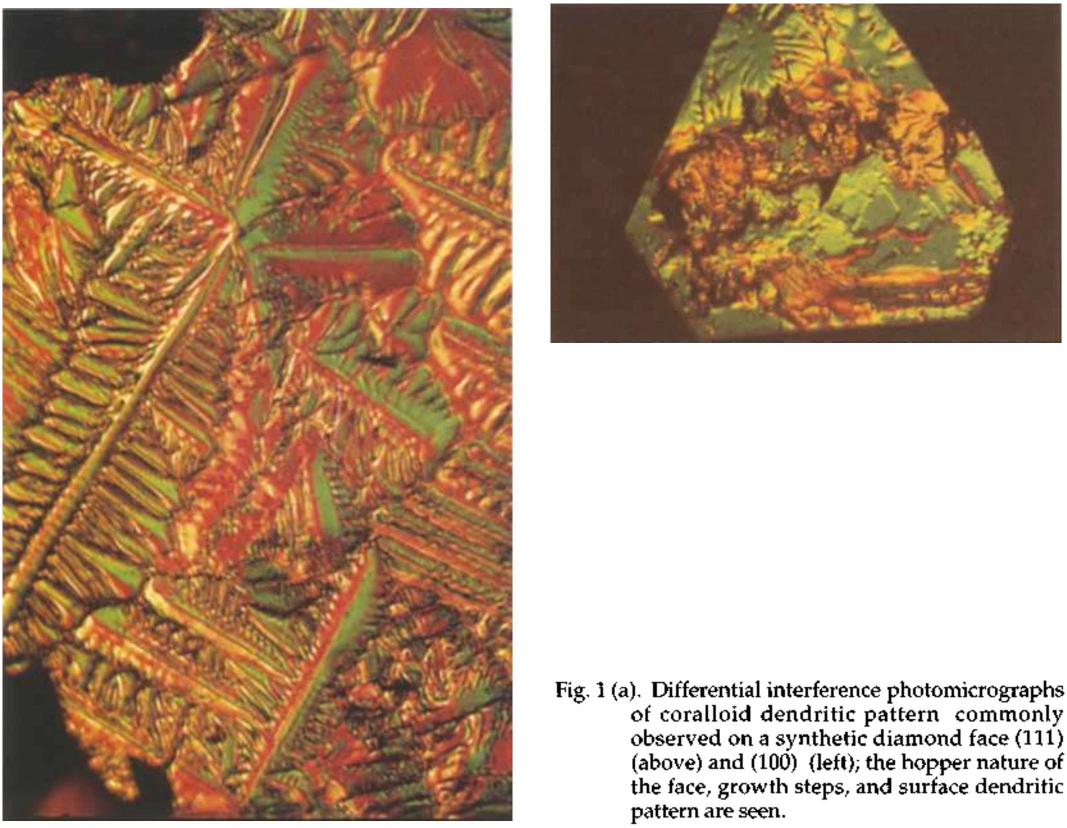

Fig. 1 (a). Differential interference photomicrographs of coralloid dendritic pattern commonly observed on a synthetic diamond face (111) (above) and (100) (left); the hopper nature of the face, growth steps, and surface dendritic pattern are seen.

1. Synthetic diamonds showed a cubo-octahedral habit bounded by {111} and {100} faces, which is not common among natural diamonds.
2. Dendritic or hopper crystals were commonly encountered among synthetic diamonds, which reflected growth under a higher driving force (supercooling or supersaturation). It is interesting to note that such crystals are no longer common among synthetic diamonds because modern crystal growth is better controlled.
3. Surface patterns resembling coralloid dendrites were universally seen on the surface of synthetic crystals, but were not observed on natural diamonds. These surface patterns are now understood to be due to quenched products from metal-carbon solutions. Figure 1a represents such a pattern.
4. The {100} faces of synthetic crystals showed either extremely flat and smooth surfaces, or growth spirals. The growth spiral shown in Figure 1b was the first to have been observed on diamond crystals. Growth spirals have also been observed on {111} faces of synthetic diamonds (Figure 1c). The relatively rare {100} faces of natural diamond show only a rugged surface, and neither growth spirals nor smooth surfaces are present.

Gemmological laboratories have to realize, whether they like it or not, that cut synthetic diamonds of gem quality have already been submitted for identification and certification. Some jewellers may pretend that synthetic diamonds of gem

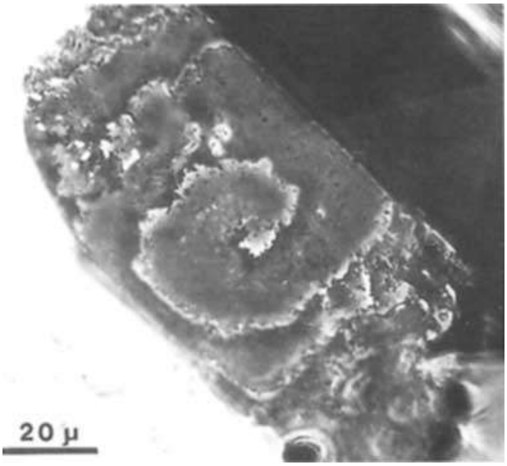

Fig. 1 (b) (above). Phase contrast photomicrograph of growth spirals observed on a (100) face; from Tolansky and Sunagawa, 1959.

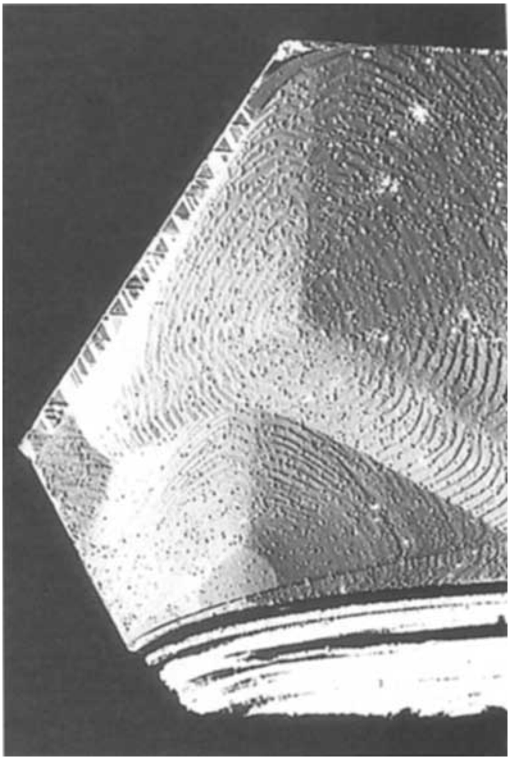

Fig. 1 (c) (right). Growth spiral hillocks on (111) face of a synthetic diamond crystal. *Courtesy of Dr H. Kanda.*

quality will not come onto the market for many years because of higher production costs than natural diamond. But technological improvements have cut the cost of synthesizing gem quality diamonds, and control of colour is becoming easier, since we know which metal solvents act as getters of nitrogen, the main cause of colour in diamond. We should also note that natural diamond of near gem quality with various colours has already gained in popularity in the gem market. Under these circumstances, gemmological laboratories should prepare themselves to be able to distinguish between natural and synthetic diamonds with a high degree of confidence.

The two papers by Tolansky and Sunagawa provided an initial framework to distinguish natural from synthetic diamonds and it is the aim of this article to discuss the methods we should now adopt. If we can understand the mechanisms of crystal growth, which give rise to morphological characteristics, and the perfection and homogeneity of crystals during their growth, then that knowledge will provide a firm foundation when we try to distinguish between natural and synthetic gemstones, since each grows in different chemical and physical environments.

Physical properties such as specific gravity, specific heat, hardness, magnetic properties and optical properties, which are principally determined by the chemical composition and the structure of the crystal, do not vary much between samples of one crystal species. Such physical properties are called intrinsic properties and form a basis for identification of the different gem species. However, there are also physical properties which are greatly influenced by physical perfection, chemical purity or homogeneity of crystals, and thus vary greatly from sample to sample of the same crystal species. These so-called structure-sensitive properties include colour, and the electronic, spectroscopic and plastic properties of crystals. Such properties help to discriminate between natural and synthetic gemstones of the same mineral species, or between untreated and treated stones, since (1), the properties are influenced by the growth conditions, ambient phases and how conditions fluctuate during the growth process (through which imperfection and inhomogeneity are formed in the growing crystals) and (2) they are also modified by post-growth treatment. Distinction between natural and flux or hydrothermally grown emeralds by means of careful measurement of specific gravity, refractive indices and IR spectroscopy is based on the factors in (1), whereas distinction between natural and irradiated coloured diamonds is due to (2). The widely used gem identification method based on microscopic observations of syngenetic inclusion content also belongs to category (1), but this currently has only an empirical basis, lacking somewhat in theoretical understanding. However, inclusions represent only one aspect of the growth process of crystals and we shall concentrate in this article on explaining other more subtle growth features of crystals using diamond as an example.

Concepts and mechanisms of crystal growth

Much crystal growth takes place at the solid-liquid interface. Depending on how rough the interface is on an atomic scale, growth mechanisms are different. If atomistically rough and consisting only of kinks (which give rise to the rough interface), an adhesive type of growth mechanism operates. The interface advances continuously in a direction normal to the interface, since the atom or the growth unit arriving at the interface can immediately find a site to be incorporated into the crystal. If an interface is atomistically smooth (smooth interface, corresponding to a low index crystal face) and consists largely of a flat terrace with a few steps and kinks, an adhesive type of growth mechanism is not operative, since the growth unit arriving at or on the interface has difficulty immediately in finding an adhesive position on the crystal. The growth unit may be incorporated into the crystal only after surface migration to a kink or step. As a result, growth proceeds in a two-dimensional manner by spreading growth layers parallel to the interface, a mechanism called layer-by-layer growth. There can be two growth mechanisms in such a case; growth layers originating from a two-dimensional island-like nucleus (two- dimensional nucleation growth, the so-called 2DNG mechanism) and those originating from a step created on the surface through the outcrop of a screw dislocation giving rise to spiral growth (spiral growth mechanism). Depending on the growth mechanism, the relationships between the normal growth rate of the interface and the driving force (i.e. the degree of supersaturation or supercooling) are different. Since the morphology of crystals is determined by the relative growth rates in different crystallographic directions, the resultant morphology of crystals can differ depending on the interface roughness, the growth mechanism and the driving force, which are related to growth conditions, their fluctuation and ambient phases.

The morphology of a crystal can be related to crystal growth by various means. These can include surface microtopographs of crystal faces (morphology of growth steps on crystal faces), morphology of a bulk crystal (dendritic, hopper, polyhedral, or more normal crystal habits), internal morphology observed in a single crystal (growth sectors, sector boundaries, growth banding, spatial distribution of dislocations and other lattice defects) and textures of polycrystalline aggregates. All these can vary during the growth process. The science of crystal growth is concerned with how crystals nucleate and grow and how

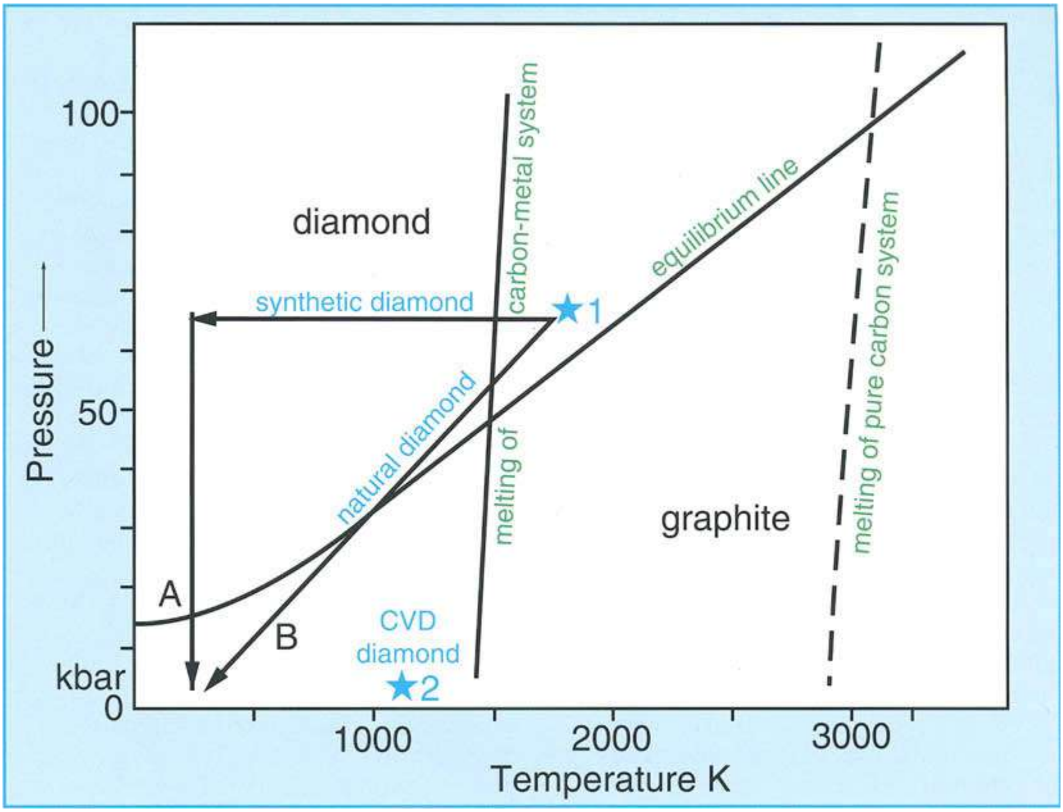

Fig. 2. Schematic phase diagram of diamond and graphite (see text for details). Star 1 corresponds to a point where diamond is expected to nucleate and grow in the stable region, whereas star 2 indicates diamond nucleation in the diamond labile region. Arrows A and B respectively indicate the routes whereby synthetic (A) and natural (B) diamond pass through the labile region.

morphologies, physical perfection and chemical homogeneity are determined by growth conditions, ambient phases and processes of crystal growth. Clearly, the knowledge achieved in these studies forms the basis of gemmology, since the main task of the gemmologist is to identify natural, synthetic and treated gemstones. Fortunately, since most of the important natural gemstones are obtained from well crystallized single crystals of high perfection, it is appropriate for the time being to consider polyhedral single crystals bounded by low index faces which grew by two-dimensional nucleation growth or spiral growth mechanisms on smooth solid-liquid interfaces.

Growth of diamond

Figure 2 shows a schematic phase diagram of diamond and graphite. In the region above the equilibrium line in the pressure-temperature diagram of Figure 2, diamond exists stably, whereas in the region below this line graphite is stable. On the equilibrium line diamond and graphite co-exist, but neither nucleation nor growth of diamond or graphite will ever take place if the thermodynamic condition on this line is unchanged. To nucleate and grow diamond, it is necessary to realize a condition away from the equilibrium line and into the diamond stable region. The difference between this condition and the equilibrium line provides a driving force to nucleate and grow diamond.

Thermodynamically, therefore, we expect that diamond can nucleate and grow in the *P-T* region above the equilibrium line.

When only pure carbon is used as a starting material in diamond synthesis, very high *P-T* conditions are required. This situation corresponds to crystal growth from a melt phase, similar to the synthesis of silicon single crystals by the Czochralski method or of ruby by the Verneuil method. Alternatively, if carbon is dissolved by a solvent to form a carbon- solvent solution, the *P-T* conditions of diamond growth are reduced to lower values. This is crystal growth from a solution phase and crystals grown in fluxes, hydrothermally or from aqueous solutions, as well as in magmas belong to this type. In Figure 2, the vertical solid straight line represents the line of melting of a hypothetical solution containing carbon and the dotted line is the melting line of pure carbon. The position of the first solid line depends on the nature of the solvent because interaction energies between solute and solvent components are different.

From the above circumstances, it is clear that the orthodox way to grow diamonds is to subject starting mixtures of carbon and solvent to higher temperature and pressure conditions than the region bounded by the solid straight line and equilibrium curve marked *1 in Figure 2. This position in the phase diagram is enough to allow the diamond to grow, but to ensure that the product is diamond and not graphite we initially drop the temperature rapidly to room temperature while keeping the pressure unchanged and follow this by releasing the pressure; route A in Figure 2. For natural diamond, the process is partly paralleled when crystals are brought up to the Earth's surface in a magma at speeds of as much as 100 km/h, and undergo an adiabatic quenching through volcanic eruption. Their path to the surface will follow route B in Figure 2. During this ascent, natural diamond crystals experience dissolution processes, which produce rounded crystals and surface etch features such as trigons.

Although the orthodox way of growing diamond crystals is to subject starting materials to high *P-T* conditions, it is also possible to nucleate and grow diamond crystals in conditions where diamond is thermodynamically not stable, such as from position (*2) in Figure 2 (see also Sunagawa, 1990). Such processes involve metastable nucleation and growth. Diamond synthesis by chemical vapour deposition (CVD), to create diamond- like films is one example occurring at atmospheric pressures and appropriate temperature conditions. An example of metastable growth in the natural world would be the formation of aragonite, normally a high pressure phase of $CaCO_3$ (Deer, Howie and Zussman, 1962, p. 308), by the biological activity of shellfish.

Table I summarizes our present understanding of the thermodynamic conditions of diamond growth and the ambient phases from which these crystals grew, both for natural and synthetic crystals. Clearly, diamond crystals grown under stable and metastable conditions can be distinguished. Among stable diamond growth we see a marked difference between natural and synthetic diamonds in the chemistries of their solvent components. Natural diamonds grew in silicate liquids of either eclogitic or ultramafic composition, whereas synthetic diamond grew from metal or alloy solutions. The difference in the growth solvent is important, because this may result in different morphological characteristics between the two systems about which a detailed explanation will be given later. Although tiny diamond crystals have recently been successfully synthesized using non-metallic solvents such as carbonates, sulphates (Akaishi *et al.*, 1990 a,b) and even silicates in the form of kimberlite powder (Arima *et al.*, 1993), the crystals are too small to be cut as gemstones (see Table I). Similarly, synthetic diamond crystals grown by CVD are

Table I. Conditions of diamond growth and ambient phases

	Temperature	Pressure	Ambient Phases
Thermodynamically Stable Conditions			
Natural	1000–1600°C	40–55 kbar 4–5.5 GPa	Silicate solution (ultramafic and eclogitic)
Synthetic	1400–1700°C	50–70 kbar 5–7 GPa	Metal and alloy solution carbonates (Akaishi *et al.*, 1990a) sulphates (Akaishi *et al.*, 1990b) silicates (kimberlites) (Arima *et al.*, 1993)
Thermodynamically Metastable Conditions			
Synthetic	800–1000°C	1 bar 0.1 MPa	Pyrolysis or chemical vapour deposition of hydrocarbons including CH_4 and C_2H_2

too small to cut. Thus the problem for gemmologists in the coming ten to twenty years will be to recognize those diamonds synthesized by the temperature gradient method, using seed crystals and metallic solvents. It must not be forgotten, however, that CVD diamond has a potential to be used as coating material to improve the colour grade of cut diamond or to enhance the hardness of other gemstones.

Review of morphology of crystals

The morphologies of crystals are controlled both by internal structural factors and by external factors. Theoretically, if one entirely neglects the effect of external factors, a crystal species should show a unique polyhedral morphology which is determined by the internal chemical bonding and crystal structure. Such a hypothetical morphology can be deduced from such concepts as Bravais' law, Donnay-Harker's extension of Bravais' law and a Hartman-Perdok's PBC (Periodic Bond Chain) analysis (for a reference, see below). This structural morphology does not necessarily relate to the thermodynamic parameters of pressure and temperature. In contrast, if a crystal attains equilibrium with the ambient phases, the morphology is uniquely determined for the given thermodynamic condition. Such a morphology is called the equilibrium form. The equilibrium form can be deduced theoretically for simple crystals from a basis of surface energy calculations. On the other hand, the morphology of crystals arising from a growth process which is not in equilibrium, are called growth forms, and these can be plural. What we need to understand is how growth forms of crystals change depending on growth conditions, and what the external controlling factors are to create morphological variations of crystals. This subject is discussed in a great detail in *Morphology of crystals, part A and B* edited by Sunagawa (1987a). Variations in crystal morphologies appear as the product of dif-

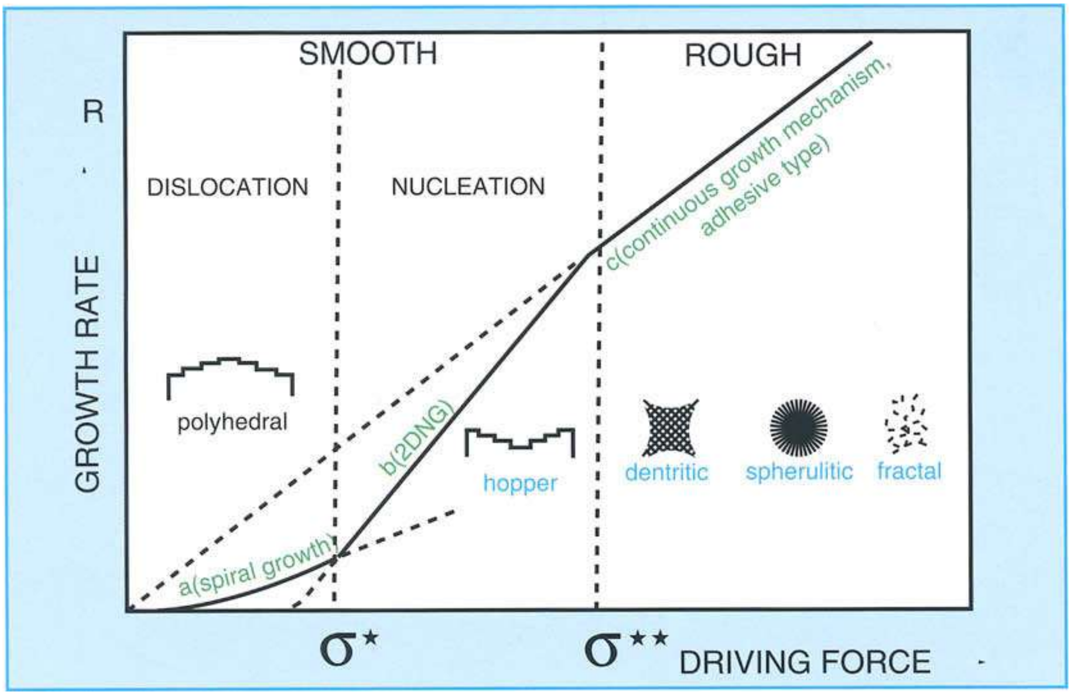

Fig. 3. Schematic diagram explaining the relationship of interface roughness (rough and smooth), growth mechanisms (a, spiral growth-line a; b, 2DNG-line b; c adhesive type continuous growth) and morphologies. The morphological variations of crystals are related by growth rate R versus driving force; from Sunagawa (1987b).

ferent growth rates of different crystal faces and because the growth rate relates to the roughness of the solid-liquid interface, the growth mechanism and the driving force, we shall now examine these problems on this basis.

Figure 3 illustrates the relation between growth rate (R) and the driving force for a theoretical crystal. Curve *a* corresponds to the R vs driving force relation expected for the spiral growth mechanism, *b* that of the 2DNG mechanism, and *c* to the adhesive type continuous growth mechanism. For further information on these mechanisms, the reader may refer to text books of crystal growth (e.g. Chernov, 1984; Sunagawa, 1984a, 1987a,b).

We see in Figure 3 two intersections of curves a,b and c respectively denoted by σ* and σ**. In the region to the right of σ**, solid-liquid interfaces are expected to be atomistically rough, where a continuous growth mechanism will be operative, and dendritic, spherulitic and further fractal morphologies are expected. Dendrites appear because a growing rough interface becomes morphologically unstable, creating protrusions, which develop as dendritic branches. Spherulites appear when crystals grow in radial directions from centres much more quickly than and before morphological instability of the interface occurs. Fractal is a pattern due to self-analogous repetition of a smaller pattern, such as may be observed in dendrites of manganese oxide. In the region between σ* and σ**, where solid-liquid interfaces should be smooth and the 2DNG mechanism is principally operative, crystals will form hopper morphologies. In the region to the left of σ*, the solid-liquid interface is also expected to be atomisti-

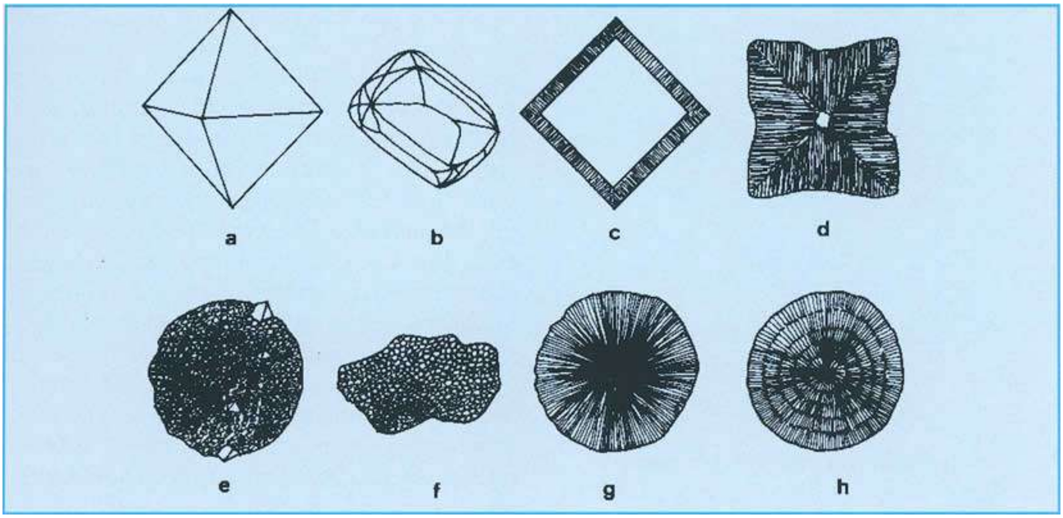

Fig. 4. Morphology of natural diamond crystals. Category 1, single crystals, a and b; category 2, polycrystalline, d to h; category 3, combined single crystalline and polycrystalline, c.

cally smooth, and a spiral growth mechanism will principally operate. In this region, the expected morphology of crystals is polyhedral bounded by flat low index crystal faces. We also note that in this region crystals of the same species may take a wide variety of crystal habits. From Figure 3 we also see that polyhedral crystals form when crystal growth occurs under a smaller driving force than σ^*, hopper crystals occur between σ^* and σ^{**}, whereas only dendritic crystals and polycrystalline spherulitic morphologies occur above σ^{**}.

Morphology of natural diamond

Natural diamonds have experienced a dissolution process whilst being transported from depths within the Earth. Evidence for such a process includes the rounded dodecahedroidal faces of diamond and the ubiquitous trigon observed on {111} faces. If we restore the original as-grown morphology (i.e. pre-dissolution), diamond crystals may be classified into three categories, schematically illustrated in Figure 4.

Figures 4a and b are single crystalline diamonds (category 1), which are the principal kinds used for gems, whereas Figures 4d to h depict polycrystalline diamonds (category 2), used only for industrial purposes. Figure 4c illustrates the texture of a coated stone, consisting of a single crystalline core and polycrystalline rim forming a combined type (category 3); the core portion is commonly of gem quality.

From Figure 3 and the discussion above, we can surmise that diamond crystals of category 1 grew under a driving force smaller than σ^*, (spiral growth mechanism), and those of category 2 were formed under a driving force larger than σ^{**}. Crystals of category 3, experienced two growth stages; they initially grew as single crystals under a driving force smaller than σ^*, followed by a driving force condition higher than σ^{**} giving rise to a polycrystalline overgrowth. Such a situation may occur if a magma containing single crystalline diamond of category 1 is uplifted to a shallower position in the mantle with consequent changes in pressure and temperature.

The major forms of single crystals of diamond are {111}, {110} and {100}. The hardness of diamond along these planes decreases in this order and corresponds to

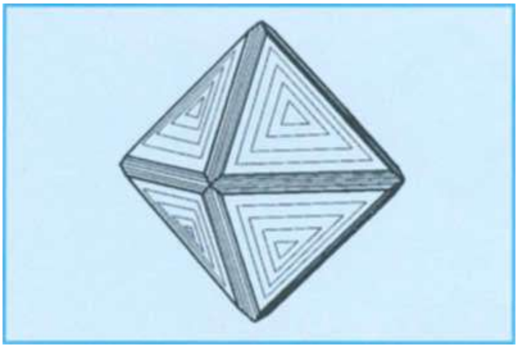

Fig. 5. Structural form of diamond as deduced from periodic bond chain (PBC) analysis.

the decreasing order of reticular density (number of atoms per unit area in a lattice plane) and the number of C-C covalent bonds per unit area.

Structural forms of diamond can also be deduced by means of Periodic Bond Chain (PBC) analysis and, according to Hartman and Perdok (1955), crystal faces are classified into an F (flat) face, which contains more than two PBCs, an S (stepped) face containing only one PBC and a K (kinked) face containing no PBC. If a crystal structure is examined in order to find directions with strong chemical bonding between the neighbouring atoms or ions, one can find more and stronger periodic bond chains on some faces than on others. Depending on the number of PBCs contained in crystallographic faces, Hartman and Perdok classified crystallographic faces into three types. Following the explanation given in the previous sections, an F face corresponds to a smooth interface, which grows by 2DNG or by the spiral growth mechanism and develops large faces, whereas a K face corresponds to a rough interface which grows by the adhesive type of growth mechanism and thus does usually not appear on growth forms. An S-face has an intermediate character between an F and a K face, and should show only striations.

According to PBC analysis of a diamond crystal, {111} is an F face, {110} an S face and {100} is a K face. The structural form of diamond is therefore an octahedron with small striated {110} faces. On the {111} faces, growth layers with triangular form in accordance with the triangle of the face should be expected, whereas no {100} faces will appear. Since {100} is a K face, no growth layers are expected to develop on this face. The structural form of diamond can therefore be drawn as shown in Figure 5. This morphology can be used as a criterion in analyzing growth forms exhibited by polyhedral crystals of diamond formed under different conditions. We shall in the following focus our attention on the morphological characteristics of the three faces, and compare them as they are developed in natural diamonds, synthetic diamonds grown in the thermodynamically stable region and those grown metastably.

Critically reviewing previous observations reported in many papers and also those made by the present author on bulk morphology, surface microtopography of crystal faces and internal morphology (growth sectors, growth banding, etc.) of natural diamond crystals, we can summarize the situation as follows.

1. Natural diamond crystals have experienced dissolution processes to varying degrees. However, there are crystals which have been little affected, preserving almost as-grown surfaces, like those from Siberia. Growth forms and their changes during growth history can also be revealed by visualizing the internal morphology, such as growth sectors and growth banding, by applying appropriate methods to be described later.
2. The {111} faces are the only ones on which layer-by-layer growth or spiral growth takes place. Evidence of spiral growth was obtained on crystals from Siberia which were only slightly dissolved, through a combined investigation of surface

microtopography and X-ray topography (Sunagawa *et al.*, 1984b). Observations of growth banding revealed by etching gem quality natural diamond crystals, reported by Seal (1965), showed clearly that {111} faces grew by a layer-by-layer growth mechanism throughout their growth history. Straight crystallographic growth banding in {111} growth sectors is a universally observed feature on X-ray topographs of natural diamonds, as witnessed by extensive X-ray topographic work carried out by Lang (e.g. 1965, 1979).

3. {110} faces usually appear on larger crystals due to dissolution of original octahedral crystals as reported by Seal (1965). On these crystals, the {110} faces are rounded and split into four curved {hhl} faces. They are not truly crystallographic dodecahedral faces, but dodecahedroidal faces. In contrast, on much smaller diamond crystals only a few micrometres across {110} faces often appear as flat and as true dodecahedral faces, their only obvious feature being striations parallel to an edge with the neighbouring {111} face. No growth layers have been observed on these faces, although they are considered to have appeared by a growth process through piling up of steps of growth layers developing on {111} faces (Sunagawa, 1984b) and not by a dissolution process.
4. {100} faces are always rugged, and never appear as flat crystallographic faces. They are not cubic faces, but cuboid faces. As seen in Figure 3d, cuboid crystals with depressed cuboid faces appear due to polycrystalline growth. Analysis of the so-called centre cross pattern sometimes detected by X-ray topography, cathodoluminescence or by etching methods at the centres of gem quality diamond crystals has indicated hummocky, non-straight growth banding in {100} growth sectors, in contrast to the straight banding seen in the {111} growth sectors of the same crystal. Rugged {100} surfaces were also reported on tiny diamond crystals occurring in eclogitic garnet by Sobolev *et al.* (1991).

Thus {111} faces are the only ones which provide a smooth interface during the growth of natural diamond and on which layer-by-layer or spiral growth operates. In contrast, {100} faces always behave as a rough interface on which layer-by-layer or spiral growth does not take place. {110} faces may appear either by growth or dissolution. During growth it behaves as an intermediate face between smooth and rough interfaces, on which layer-by-layer or spiral growth does not take place. During dissolution dodecahedroidal faces appear when the dissolution preferentially proceeds from the edges and corners of an as-grown octahedral crystal. It should be noted that morphological characteristics of natural diamond crystals are in accordance with those of structurally deduced morphologies shown in Figure 5.

Morphology of synthetic diamond

The morphological characteristics of diamonds synthesized in metal-carbon systems are markedly different from those of natural diamonds; see Figure 6 for the preferred conditions of formation of different faces. If the surface dendritic pattern due to quenched metal-carbon solution is removed from the surfaces of synthetic diamond, both {111} and {100} faces show growth spirals, indicating that both faces have grown as smooth solid-liquid interfaces. Growth spirals on the synthetic {111} faces take on a triangular form in accordance with the triangular outline of a {111} face (as is the case of natural diamond crystals), whilst synthetic {100} faces show a rectangular form, bounded by [011] steps.

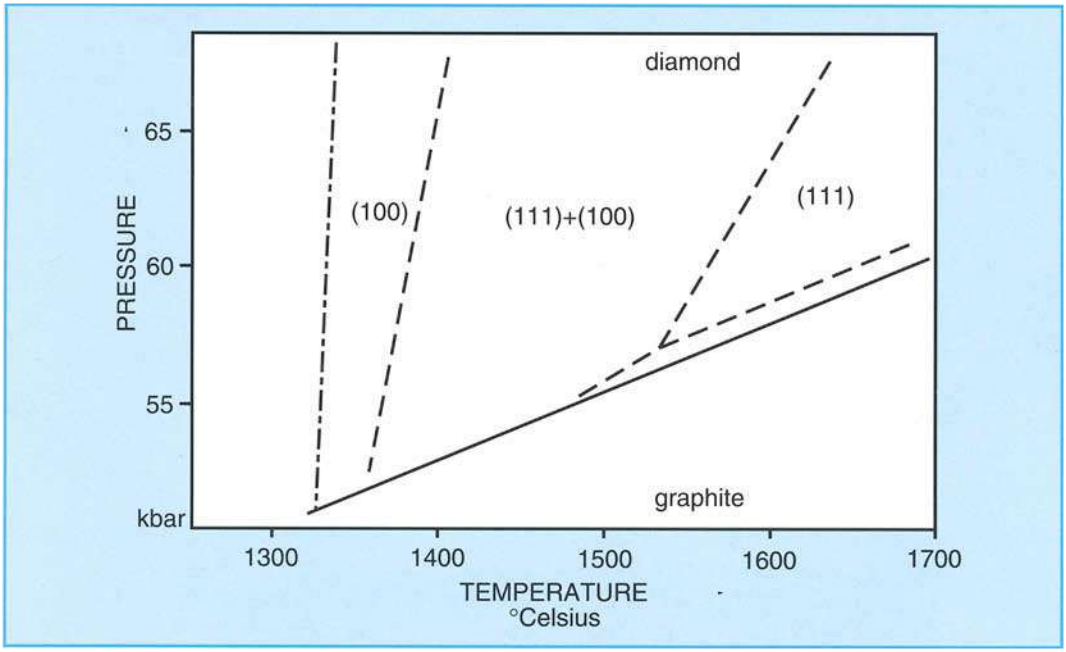

Fig. 6. Morphological phase diagram (morphodrom) of synthetic diamond growth in the diamond stable region; after Sunagawa (1984b).

The principal difference therefore between the surface characteristics of natural and synthetic diamond is that in natural diamond {100} behaves as a rough interface.

The origin of the contrasting behaviours of growth on {100} faces when both natural and synthetic diamond are grown in stable conditions can only lie in the different solvent components; natural crystals grow in silicate solutions, whereas synthetic crystals are derived from metallic solutions. In the silicate system it is possible that the presence of oxygen ions prevents the development of smooth {100} faces. Indeed, when diamond crystals were synthesized in a silicate solution using kimberlite powder as nutrient, crystals took a simple octahedral habit, no {100} faces being developed (Arima et al., 1993).

CVD diamond crystals show cubo-octahedral habit bounded by {111} and {100} faces, and both faces may exhibit growth spirals. This situation, therefore, is essentially the same as for other synthetic diamonds grown from metallic solutions in conditions stable for diamond. However, some distinctions have been observed and these are summarized below (see also Sunagawa, 1990).

1. Multiply twinned particles, which are considered to represent the morphology of crystalline particles in a metastable state, are commonly encountered among CVD diamonds. A twinned crystal is in a higher energy state than a single crystal, since interface energy is additionally required to join the two individuals to form a twin. Multiply twinned particles are ubiquitous among ultra-fine metal particles produced by evaporation and condensation; they collapse and rearrange themselves to form single crystals when they exceed a critical size.
2. On {111} faces triangular growth

spirals are oppositely oriented to the triangular outline of the face. This is in contrast to the morphology of growth spirals observed on {111} faces of both synthetic and natural diamond grown in the diamond stable region.

3. {111} faces become larger with increase in the driving force, an observation which contrasts with that observed on synthetic diamonds grown in the diamond stable region.
4. {100} interfaces are smoother than {111}, a situation which is opposite to that for synthetic diamonds grown in the diamond stable region.

Internal morphology

In gem identification, the characteristics of surface microtopographs and the bulk morphology of diamond crystals may appear to have no direct importance, since gemstones for investigation are cut and polished. Gemmologists may appreciate that the knowledge is fundamentally interesting but think that it is outside their field. However, this is not so.

During the growth history of a crystal, growth conditions may vary, resulting in the fluctuation of growth rate, which leads to morphological variations and the formation of physical imperfections and chemical inhomogeneities. Often these features are orientation-dependent and produce distinct differences in crystals from either similar or different starting materials. Growth sectors, sector boundaries, growth banding, dislocations and other lattice defects are such internal features. Even if a stone appears to be completely perfect, transparent and homogeneous to the naked eye or under ordinary magnification, the stone will show some inhomogeneity or imperfection, if appropriate methods are applied. Thus, if a crystal or cut stone appears to be perfectly homogeneous then the gemmologist should consider whether or not the analytical method applied was sensitive enough to detect imperfections and inhomogeneities.

Techniques, such as X-ray topography, cathodoluminescence topography and laser-beam tomography, plus the use of sensitive optical microscopy like phase contrast, differential interference contrast and polarization microscopy, may be mentioned and have been developed in recent years to characterize perfection and homogeneity of crystalline materials. Some of these methods ought to be in standard use in gemmological laboratories. For example

(a) X-ray topography is a powerful method to reveal dislocations and other lattice defects, as well as growth banding, although its use requires sophisticated knowledge and technique (Sunagawa, 1984);

(b) laser-beam tomography visualizes spatial distribution of light scattering centres on a submicron scale and identifies luminescent centres and dislocations in single crystals. Such a powerful technique could be used to distinguish natural, synthetic and treated stones in a gemmological laboratory;

(c) sensitive optical microscopy enables one to observe weak strain fields associated with various lattice defects and growth sector boundaries;

(d) cathodoluminescence; the most useful instrument, perhaps, for gemmological laboratories is a conventional CL system which is commercially available as a combination of optical microscopy with a vacuum system and electron gun. Ponahlo (1992) has pioneered this technique in the gemmological field. For research in universities, this method may be used in combination with a scanning electron microscope.

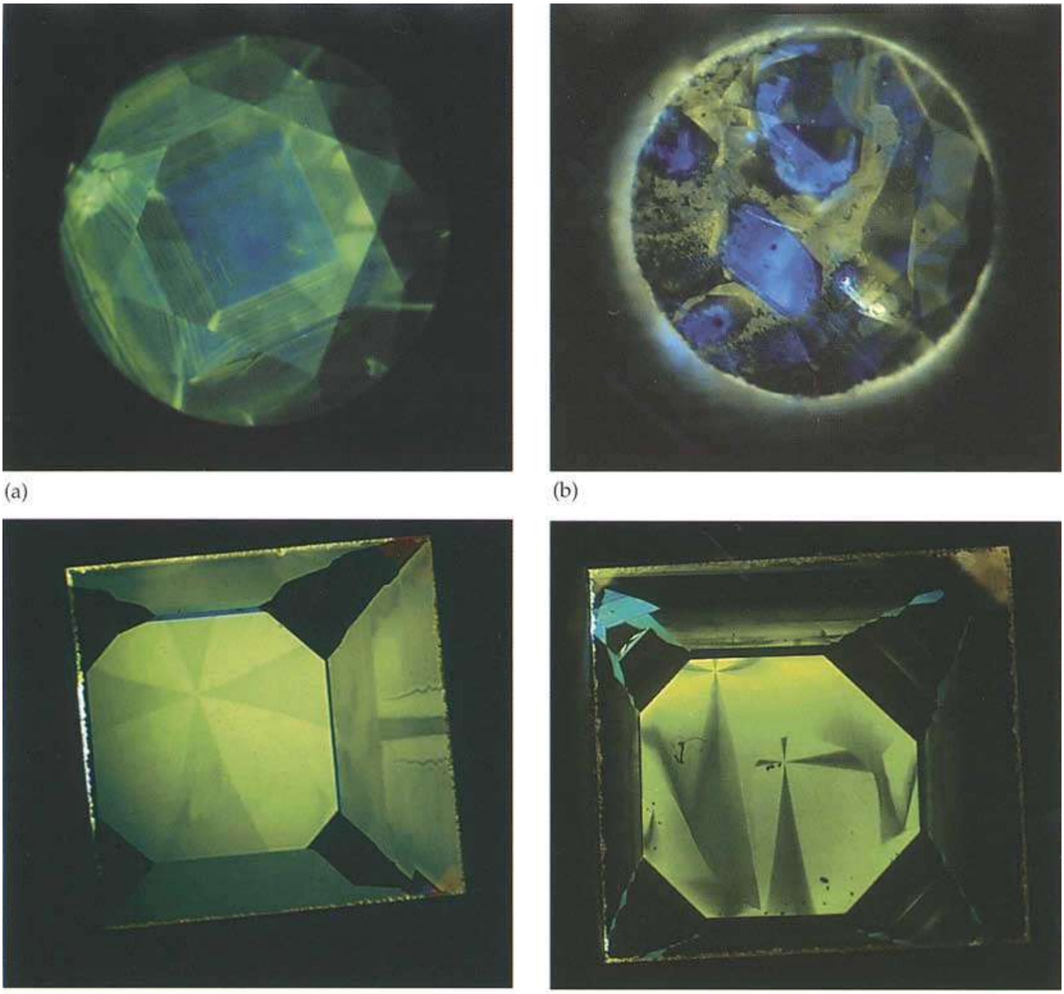

Fig. 7. Examples of CL images shown by round brilliant cut natural diamonds (a) and (b) and an as-grown synthetic Sumitomo diamond (c) and (d). *By courtesy of the Gemmological Association of All Japan.*

To demonstrate what sort of images can be obtained by a conventional cathodoluminescence microscope, four CL photographs are shown in Figure 7, taken by the Gemmological Association of All Japan. Figures 7a and 7b show CL photographs of natural round brilliant cut diamonds, which show {111} growth sectors with growth banding and a centre cross pattern consisting of {111} and {100} growth sectors. Figures 7c and 7d show CL photographs of a Sumitomo synthetic stone with platy habit parallel to the (100) face, which reveals {111} and {100} growth sectors originating from plural centres. Clearly there is a distinct difference between natural and synthetic stones, which is the result of differences in crystal growth.

Concluding remarks

This article has demonstrated how and why crystal growth and the resultant morphological characteristics can differ between natural and synthetic crystals, taking diamond as a representative example. Using such knowledge, it is possible to distinguish between natural, synthetic and treated gemstones, even after they have been cut and polished. These arguments apply not only to diamond but also to other gemstones, such as emerald, ruby and sapphire. A knowledge of crystal growth, therefore, ought to be considered an important aspect of gemmological education.

Acknowledgements

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Russian hydrothermal synthetic emeralds: characterization of the inclusions

Federico Sosso and Benito Piacenza***

* Istituto Gemmologico Italiano, Viale Gramsci 228, 20099 Sesto S. Giovanni, Milan, Italy

** Via Enrico Fermi 14/A San Donato milanese, Milan, Italy

Abstract

This work contributes to the description of the internal features of Russian hydrothermal synthetic emeralds which have been produced recently. SEM-EDS analyses carried out on some metallic crystalline inclusions reveal that they consist mainly of Fe, Cr and Ti oxide or oxides of undetermined structure. Lanthanum and cerium were also found in one of these metallic inclusions.

Introduction

At present the Russian hydrothermally-grown synthetic emeralds are produced in many plants at several localities in Russia. Together they represent a significant share of the European commercial production of synthetic emeralds.

The physical and gemmological properties of Russian hydrothermal synthetic emeralds have been described by Fryer *et al.* (1983), Koivula (1984; 1985), Lind *et al.* (1987), Scarratt (1987), Schmetzer (1988), and Brown *et al.* (1989). In the emeralds investigated by these authors many typical inclusions were found and described: liquid veils and feathers, two- and three-phase inclusions, colour zoning, angular growth structures, irregular boundaries between sectors or subgrains as well as minute opaque grains or platelets. In particular Schmetzer (1988), provided much information on the presence of the seed-plate, its orientation with respect to the optic axis and its influence on colour zoning and growth inhomogeneities.

In the present paper the inclusions occurring inside numerous faceted samples of Russian hydrothermally-grown synthetic emeralds are described; they are believed to have been produced in the first half of 1994 but the manufacturing plant is not known. The object of the present study is also to investigate the chemical nature of the crystalline and opaque inclusions.

Materials and methods

A rough synthetic emerald weighing 39g, 8.2 x 2.7 x 1.2cm in size (Figure 1), with synthetically-grown portions symmetrically developed about a central seed plate approximately 1mm thick was cut and pol-

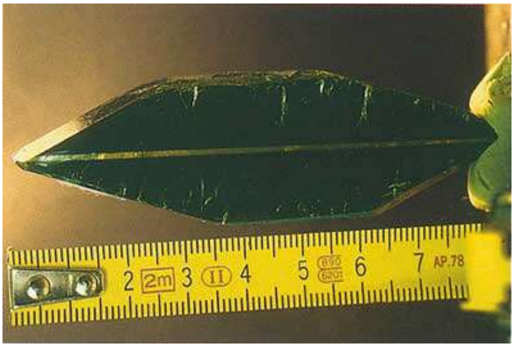

Fig. 1. The 39g rough of Russian hydrothermally-grown synthetic emerald, displaying the colourless beryl seed in the middle.

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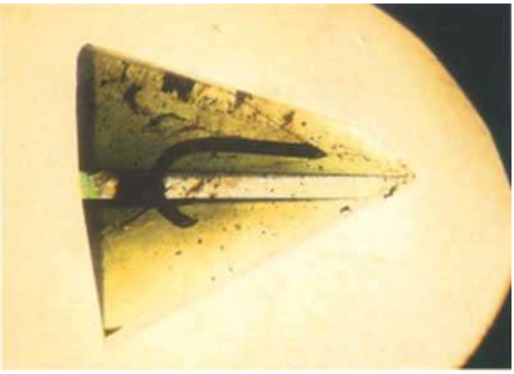

Fig. 2. Residual metallic wire on which the seed plate was suspended. 4x.

ished into seven stones ranging from 2.72 to 5.71ct. At the two ends of the rough, two stumps of the wire used to support the seed plate inside the growth vessel were visible (Figure 2).

The rough sample and the faceted emeralds obtained from it were observed under the optical microscope and the scanning electron microscope (SEM). The qualitative chemical analyses of the inclusions were carried out on a Leica-Cambridge Stereoscan-360 SEM equipped with a Link energy-dispersive system (SEM-EDS) belonging to the SGEL department of AGIP SpA.

Results

Description of the rough synthetic emerald

The original rough sample showed an intense green colour with a remarkable blue overtone; on the two longest parallel surfaces many 'shield-shaped' growth figures were present (Figure 3). On the same surfaces a complex system of superficial cracks was also noted (Figure 4). The fissures were completely eliminated after cutting and polishing.

In observing the seed plate sited in the middle of the rough, it was possible to see, at the two ends, where a hole of about 1cm in diameter containing a 'U'-shaped metallic wire (with a cross-section of 0.8mm) had been placed. In addition to growth on each side of the seed plate, synthetic emerald also filled the holes and came into direct contact with the metallic wire.

Metallic inclusions and their chemical composition

The qualitative chemical analysis (Figure 5) indicates that the wire is made of an iron, chromium and nickel alloy; the same elements that were also found everywhere in the 'bulk' of the investigated synthetic emeralds (Figure 6). These elements are responsible for the colour of the samples. It is therefore possible to suppose that the incorporation of a certain amount of Cr, Ni and Fe in the growth solution was due to the initial corrosion of the metallic wire next to the walls of the steel autoclave used during the industrial process.

Schmetzer (1988) and Cozar *et al.* (1992),

Fig. 3. Shield-shaped growth-figures on a surface of the 39g Russian synthetic emerald rough. 20x.

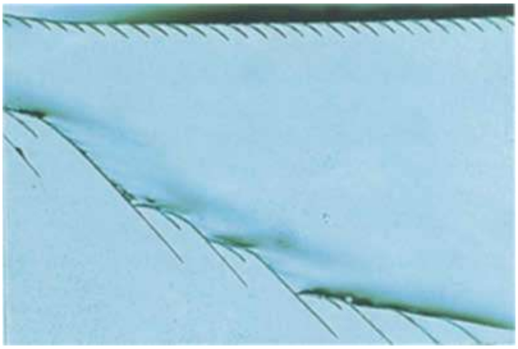

Fig. 4. On the surface of the rough-emerald different series of hook-shaped fissures are visible. 250x.

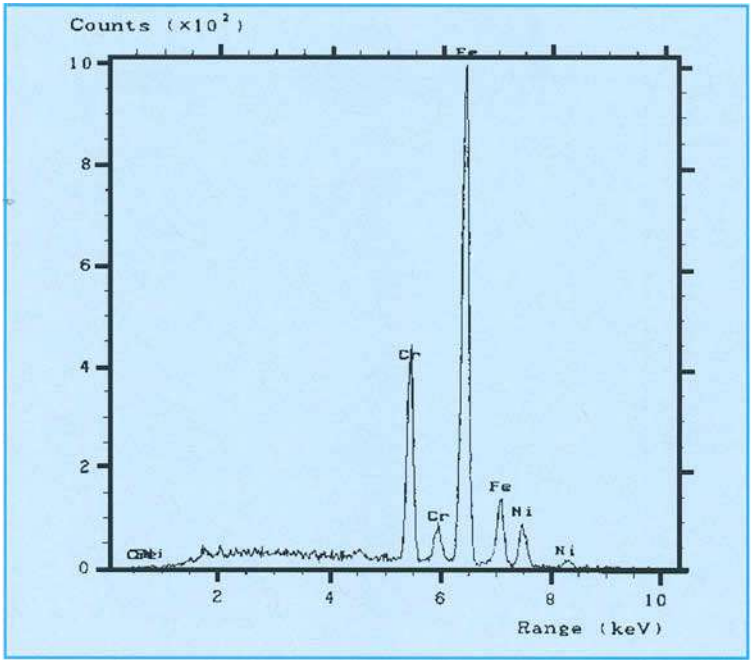

Fig. 5. SEM-EDS chart showing the characteristic peaks of the elements present in the metallic wire on which the beryl-seed was hooked (see Figure 2).

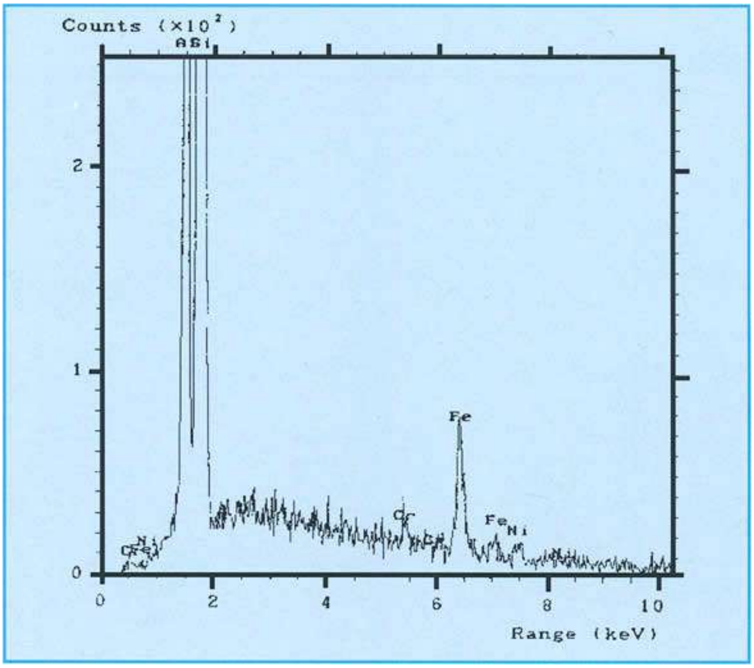

Fig. 6. SEM-EDS chart showing the chemical composition of the Russian hydrothermal synthetic emeralds examined.

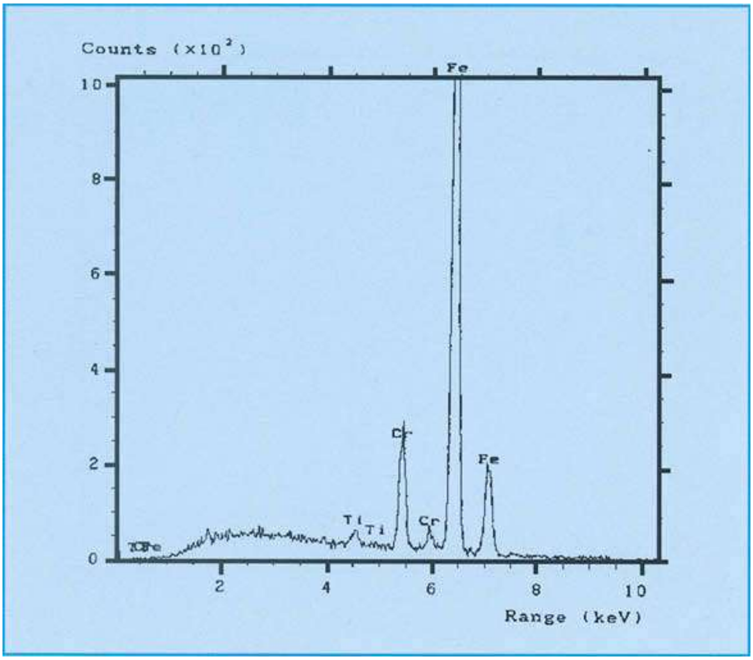

Fig. 9. SEM-EDS chart of the constituents of the pseudo-hexagonal, opaque metallic crystals (see Figure 8).

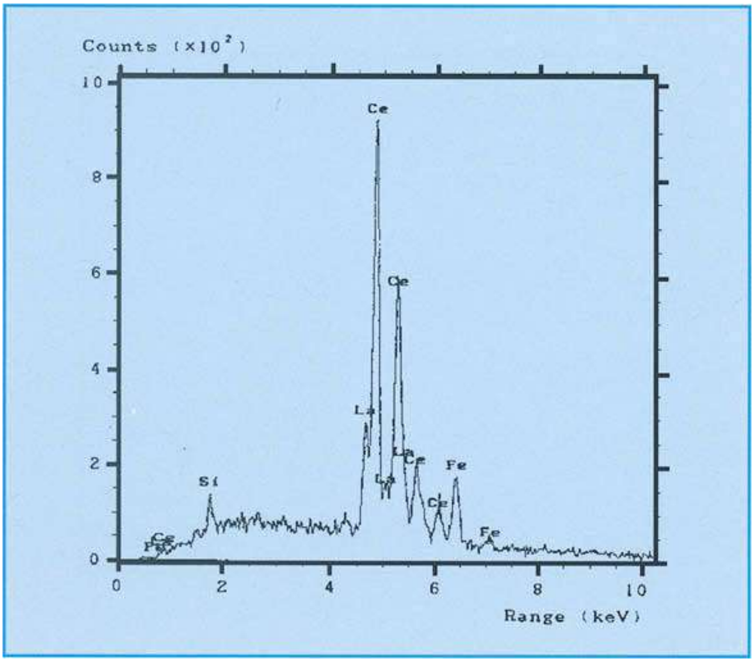

Fig. 11. SEM-EDS chart showing the presence of lanthanum and cerium inside an opaque metallic crystal (see Figure 10).

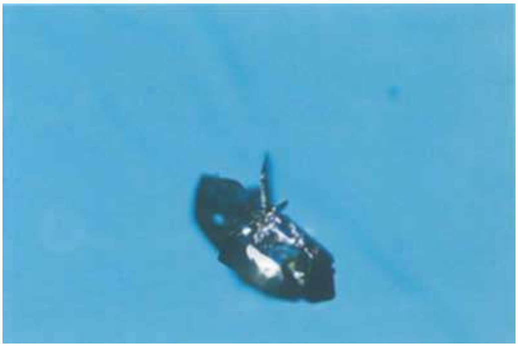

Fig. 7. Inclusion of an aggregate of black, opaque, lamellar metallic crystals. 400x.

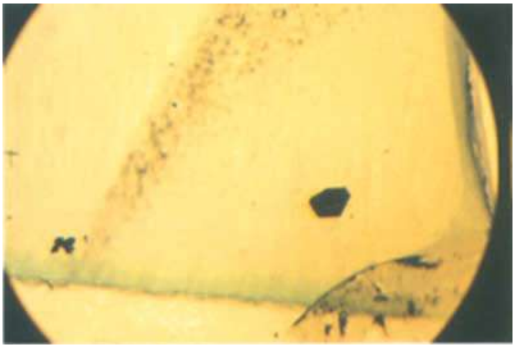

Fig. 8. Six-sided opaque lamellar crystal sited near the boundary of the colourless seed and synthetic emerald. Behind the focal plain many pin-point opaque inclusions are visible. 100x.

described hydrothermally-grown Russian synthetic emeralds containing copper in similar percentages to those of the other minor elements. Copper was not detected either in the metallic wire or inside the emerald described here.

Scattered inside the cut synthetic emeralds and particularly concentrated near the metallic wire of the original crystal, numerous crystalline, opaque pin-point and/or lamellar inclusions were found (Figures 7, 8). The lamellar inclusions show pseudo-hexagonal outline, are dark grey or black and have a metallic lustre. These small inclusions are composed of iron, chromium and titanium oxides (Figure 9). Titanium was not detected in the metallic wire and has not previously been reported in the literature as a component of the inclusions in hydrothermal synthetic emerald. In his 1988 paper, Schmetzer suggested that the metallic particles he described were hematite.

At this stage it seems reasonable to suggest that these inclusions are chromiferous hematite, the chromium and titanium forming a solid solution with iron in the hematite structure.

During examination of the various opaque inclusions one particular metallic crystal showed more reflecting portions, both under the optical microscope and on the secondary electron-image in the SEM (Figure 10). The reflecting portions are formed by crystalline micro-aggregates of rare earth elements lanthanum and cerium (Figure 11). The most likely explanation is that lanthanum and cerium were present as monazite or other rare-earth minerals in the colourless beryl used as a seed plate for growing the hydrothermal emeralds, transferred to the growth-solution and precipitated in their present form. The presence of a small silicon peak (Figure 11) may also be due to incorporation of that element from the seed plate.

Other microscopic features

Dissolution of the beryl seed during the initial stage of the growing process could have been the cause of the development of

Fig. 10. Secondary electron-image of a polished section of a synthetic emerald: an opaque metallic crystal with strongly reflecting zones is visible.

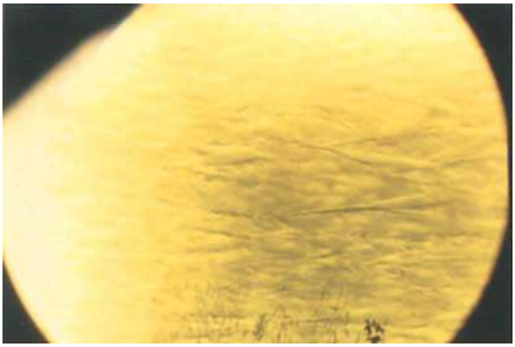

Fig. 12. Angular and spindle-shaped growth planes form an intersecting pattern. 5x.

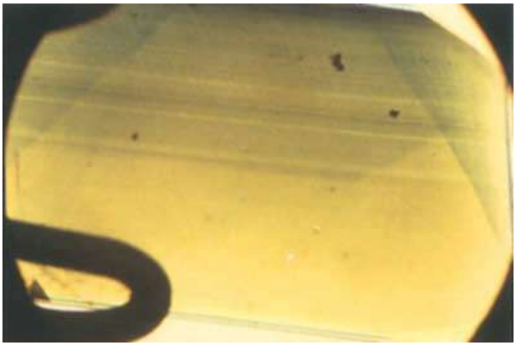

Fig. 13. Faint colour zoning parallel to the contact surface between the colourless seed plate and the synthetic emerald. 200x.

Fig. 14. Isolated phenakite crystal: around it many reflecting metallic inclusions are visible. 400x.

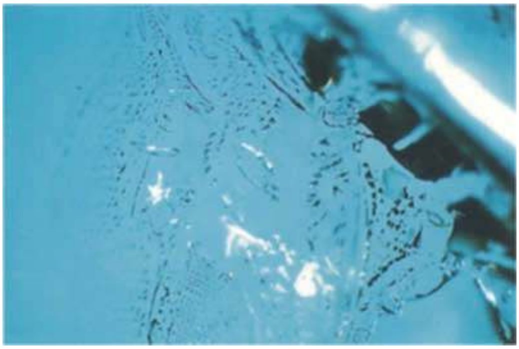

Fig. 15. Liquid feathers and films observed inside Russian synthetic emerald. 200x.

Fig. 16. Flat negative crystals having a shape very similar to that of the growth- figures seen on the surface of the emerald rough. 60x.

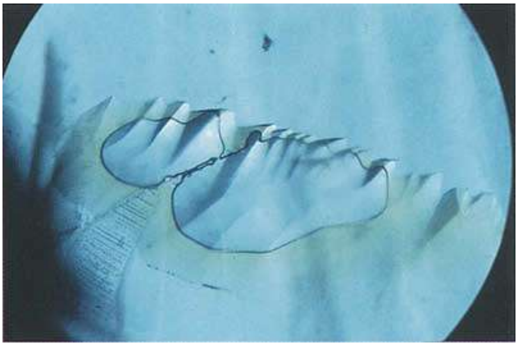

Fig. 17. This negative crystal hosts a two-phase inclusion. 100x.

the minute unevenness observed on the seed surfaces. These irregularities appear as a mosaic of microscopic reliefs which acted as nuclei for the growth of crystals of synthetic emerald similar to those described by Schmetzer in his paper of 1988.

The results are visible under the gem microscope, using an immersion liquid, as spindle-shaped growth lines arranged in an intersecting pattern (Figure 12). These angular growth patterns are the most striking and diagnostic features of Russian hydrothermal synthetic emeralds.

Other features seen in the examined emeralds include unusual colour-zoning with an orientation parallel to the seed plate (Figure 13), isolated phenakite crystals (Figure 14) and liquid feathers with two-phase inclusions inside minute negative crystals (Figure 15). Peculiar to the examined emeralds are quite large and flat cavities (negative crystals) whose walls are arranged in geometrical patterns similar to the growth figures observed on the surfaces of rough synthetic emerald (Figure 16). These cavities are also filled by two phase inclusions: liquid and gas or two immiscible liquids (Figure 17). The seed plate and the overgrowth have the same optic orientation, the length being inclined at 43° to the *c*-axis.

Conclusions

The latest Russian synthetic emeralds contain inclusions typical of Russian synthetic emeralds previously described by other authors: irregular step-like or angular growth lines, phenakite crystals, liquid feathers of mono and two-phase inclusions and minute, opaque granular or lamellar metallic particles. In addition, the stones described in this paper contain large and flattened negative crystals filled by two immiscible liquids.

Transition elements detected in the synthetic emeralds, in dispersed form or as metallic particles, are similar but not identical to those previously described and this is probably due to the different wire metal support and autoclave lining used in this production.

Acknowledgements

The authors are grateful to Mr E. Giomo of AGIP SpA for professional work on the SEM-EDS. Many thanks also go to Mr A. Piana who carried out the photographic work.

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Trace elements as colouring agents in jadeites

H. Harder

Göttingen

Abstract

Jadeite may be white, pink, lilac, brown, red, orange, blue, black or many shades of green, and contains different trace elements as colouring agents. Of these trace elements, iron shows the highest concentration and its oxidation states of ferrous or ferric iron produce different colours. In white jadeite nearly all iron is present as ferric (trivalent) iron, while in black jadeite half is ferrous (divalent) and half ferric. In the leaf green jadeites the Fe^{2+}/Fe^{3+} ratio ranges from 0.1 to 0.2.

The finest green Burmese jadeite, whose colour is caused by up to 0.3 per cent chromium, has been called 'Imperial jade' or 'emerald jade'. Contents of iron (up to 0.6% Fe) and nickel (0.04% Ni) can modify the rich chromium green of the jadeite. Lilac, mauve or lavender jade may contain manganese (up to 0.01% Mn), cobalt (up to 0.001% Co), chromium (up to 0.001% Cr) and iron (from 0.006 to 0.3% Fe).

Introduction

The term 'jade' (or 'green stone' as it was previously known) actually refers to different mineral assemblages. Today the definition covers only jadeite and nephrite. Nephrite was a valued material and was used as an 'axe-stone' by many prehistoric human communities for more than 7000 years. Even the famous old Chinese jade artefacts were made from nephrite; jadeite was introduced only in the eighteenth century. Jadeite was also known by the Indians in Central America and in pre-Spanish times they produced very impressive carvings (Foshag, 1955). In those times the Chinese used only nephrite. They called this material 'Chèn Yü', which can be translated as 'real jade'. These two cultural centres stimulated the work in jade and similar elements of craftsmanship were developed.

In the eighteenth century Burmese jadeite was brought to China as 'Yünnan jade'. After some time jadeite also was called 'Chèn Yü', i.e.'true' or 'real' jade. The beauty of some qualities of Burmese material significantly affected the market situation even in the older days. Today the colour is the most important feature of jade and not its toughness, which was its most valuable property in prehistoric times. When we look at the current jade market we must realize that even in China many of the real jade qualities have not the marvellous appeal they had in former times. Nephrite occurs throughout the world in relatively large quantities and is nowadays not an expensive gem material. Only some qualities of jadeite have preserved some of its glory. The rarity of jadeite itself and of its top colours are the major factors in its evaluation. The quality of the material is determined not only by its colour but also by the evenness of the colour distribution, translucency and fineness of grain.

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Fig. 1. Multi-coloured jadeites from Burma. The colour of the emerald-green jadeite, caused by chromium, can also be influenced by iron or nickel. The colour of the blue jadeite is probably due to its high content of titanium and iron. In the mauve jadeite cobalt and manganese may be acting as colouring agents.

The colour range of jadeite

Jadeite occurs without colour as white jade ('Pai-Yü' moon jade, the Chinese symbol also meaning white silk) or in a very wide range of colours, mostly in light shades, but also in stronger pinks, reds, oranges, browns, greens, blues and black. Many shades and hues between the different colours are possible. A single block of jadeite will display different colours in different parts of the block, so it is very difficult to set prices of raw jadeite boulders which have a grey weathering crust. For trading a small window is cut and polished on the surface of each boulder in order to see the quality underneath the weathering skin. The most highly valued colours are the finest emerald green and mauve or lavender. Translucent stones of the superb green colours are called in the trade 'Imperial jade', and this quality is most appreciated and the most expensive in the Far East.

Trace elements in jadeite

The colour range of jadeite indicates that it is an allochromatic mineral. Chemically pure jadeite is white and its colours are acquired from trace elements. The depth of colour in jadeite depends on the content of these trace elements. As jadeite is formed in the vicinity of metamorphic ultrabasic rocks, it is possible that iron, nickel and cobalt may be incorporated in the structure of the newly formed jadeite. Many natural minerals have more than one colouring agent while, in contrast, only one of these colouring elements is usually present in man-made materials.

In white, black and in some green

Table I: Trace elements in Burma jadeite

Colour	*Cr%*	*Ni%*	*Mn%*	*Ti%*	*Fe%*	*Fe^{2+}/Fe^{3+}*
White jadeite *Pai-Yii* (Moon jade)	0.00	0.00	0.001	0.00–0.02	0.03–0.3	0.01
Black jadeite *Hsi-Yii*	0.01	0.001	0.03	0.04–0.1	0.3–2.0	1.0
Leaf-green jadeite ('Chinese cabbage')	0.00	0.003	0.02	0.01	0.7–1.0	0.1–0.2
Brown jadeite ('Mouth jade')[1]	0.00	0.003	0.02	n.d.	0.7–1.0	0.2
Emerald green ('Imperal jade')						
chrome-rich	0.3–0.4	0.01–0.03	0.01–0.02	n.d.	0.3–0.05	n.d.
nickel-rich	0.01	0.04	0.02	n.d.	0.5	n.d.
iron-rich	0.01	0.01	0.001	n.d.	0.6–0.02	n.d.
Blue jadeite (very rare)[2]	0.03	0.00	0.00	0.16	0.18	n.d.
Mauve jadeite ('lavender jade')[3]	0.001	0.004	0.002–0.01	n.d.	0.006–0.3	0.5[4]

Notes:

1. Cremating gift jade will change colour from green to brown with heat.
2. Only one piece could be analysed by X-ray fluorescence.
3. Mauve jadeite contains 0.001% Co.
4. Only poor qualities could be analysed by wet chemical analyses.

n.d. not determined

Analyses by X-ray fluorescence with Si standard; valency state of iron determined by wet chemical methods.

jadeites iron is the only trace element. All iron ions in white jadeite are found in the trivalent state. In black jadeite – with a higher total iron content – half of the iron ions are in the divalent state. In leafgreen jadeite the ratio of Fe^{2+}/Fe^{3+} is 0.1–0.2. Iron alone does not provide the emerald-green shade of 'Imperial jade'. This is due mainly to chromium but also small quantities of iron and nickel can be found in the high value 'Imperial jade' qualities (Table I). Some high quality green jade samples look similar to the nickel-containing chalcedony, or chrysoprase. Others show a tint of leaf-green, which indicates the presence of iron. In all jadeite samples – even the different emerald-green ones – iron content is higher than that of chromium and nickel. But the colouring effectiveness of iron in jadeites depends very much on its oxidation state. Trivalent iron has little or no influence on the colour in low concentration. Only divalent iron can influence the green colour. So the natural colours are different from one piece to another and the 'beauty' cannot be measured only by the content of chromium or other elements. In jadeite the lines in the absorption spectra are noticeably diffuse (Gübelin, 1974), probably because it is an assemblage of minerals rather than one single crystal. Chromium should produce a doublet, but the band at 691.5nm is not resolved. A spectral band at 437nm is related to the iron content. The Ni content in the analysed samples was not high enough to be detected as absorption bands in the violet part of the spectrum which was already showing low transmission due to the presence of iron. The subtleties of colours produced by chromium or iron can entail enormous differences in value and in beauty.

Not only emerald-green 'Imperial jade' is highly prized. Lavender jade is also sold at extremely high prices in the Far East. Webster (1970) and Gübelin (1974) speculated that manganese is the reason for the mauve colour and Rossman (1974) related the mauve colour of jadeite to charge transfer from Fe^{2+} to Fe^{3+}. My own analyses have revealed only small amounts of manganese and cobalt in mauve jadeite and it may be that this attractive colour is related to these elements. But with only a few analyses, the interpretation of the mauve colour remains uncertain and the cause of this colour is still a mystery.

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Letters

From Howard L. Blackmore, FGA, antiquary

Dear Sir

I was very interested to read James Gosling's intriguing account of the Cheapside Hoard (*Journal of Gemmology*, 1995, **24**, 6) as I knew George Fabian Lawrence (Stony Jack), the man who obtained the hoard for the London museums. He was, as Gosling says, a quiet gentle man and he did his best in the 1930s to encourage me as a schoolboy to take an interest in archaeological artefacts. Gosling kindly mentions the tributes to Stony Jack's work for the museum but why does he call him 'a vague and shadowy figure'? He was anything but that. He was a dedicated amateur archaeologist but in 1900–1903 he was entrusted with the task of arranging and cataloguing the collections at the Guildhall. He then became Director of Excavations for London until his retirement in 1928. He acted as assistant to the Directors of the London Museum, first to Sir Guy Laking and then to Sir Mortimer Wheeler. If ever a man deserved the description of antiquary it was Stony Jack. In his retirement from his shop in Wandsworth (open all day only on Saturday), he continued his work of rescuing historical remains from the excavations in London. When he died in 1939, Mortimer Wheeler (another antiquary) wrote:

'This Museum, like others, owed more to him than to any other individual and his name will always be associated with the formative period of the collections. Alas, no one has succeeded him. Indeed no one can.'

Yours etc.
Howard L. Blackmore
Caterham, Surrey
5 May 1995

Response from James G. Gosling

Dear Sir

Thank you very much for passing on the intriguing letter from Howard Blackmore. How fortunate to have known the man who could have answered all the questions about the Cheapside Hoard confusion.

In the world of the professional antiquarian George F. Lawrence (Stony Jack) was undoubtedly held in high esteem and clearly he was an important member of the London Museum but when it comes to the Cheapside Hoard discovery things are very different. There appears to be no eyewitness account of the actual discovery and there are at least four distinct versions of the actual find. In three of these the role of Lawrence is very different and unclear.

No – I stick to my phrase 'a vague and shadowy figure' certainly in connection with the Cheapside Hoard for every time I seemed to have the answer a new item of confusion would appear. If only Lawrence had left a diary or some notes – perhaps members of his family still have information about this great event.

I am very grateful to Howard Blackmore because he has focused attention on the remarkable character of Stony Jack. Perhaps this will encourage someone to write a biography of George Fabian Lawrence as, according to Morton, 'no other man has saved so many relics of ancient London for the education and pleasure of future ages'.

Yours etc.
James G. Gosling
Pattingham, Staffordshire
12 May 1995

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Abstracts

Diamonds

Gems and Minerals

Instruments and Techniques

Synthetics and Simulants

Diamonds

Radiolucency of diamond and its simulants.

R. Coates. *Australian Gemmologist*, **18**(11), 1994, 348–51, 8 illus. in black-and-white.

Although the difference in transparency to X-rays for diamond and its simulants has been well documented, unusual circumstances required comparisons to be made in conditions simulating the human stomach, bowel and bony pelvis.

R.J.P.

Gem Trade Lab notes.

R.C. Kammerling and C.W. Fryer. *Gems & Gemology*, **30**(3), 1994, 184–90, 16 illus. in colour.

A yellow-green Old European-cut diamond was found to owe its colour to americium-241 and the stone should not legally be sold until the 50th century. A marquise-shaped brilliant cut diamond showed an unusual triangular inclusion filled with graphite. It was postulated that the inclusion was originally lonsdaleite which being less stable than (isometric) diamond later reverted to graphite. R.J.P.

Gem News.

J.I. Koivula, R.C. Kammerling and E. Fritsch. *Gems & Gemology*, **30**(3), 1994, 191–201, 17 illus. in colour.

Botswana. De Beers reported 15.9 million carats produced in 1993 compared with 17.5 million carats in 1992 due to negotiated agreements between Botswana and the CSO.

West Africa. Ghana Consolidated Diamonds plan to double output to 40 000 carats per month at the Akwatia mine.

South Africa. Production in 1993 was 9.8 million carats with Regional Resources, Canadian Overseas and Diamond Field Resources expanding their activities. The situations in other African countries are summarized.

Australia. In New South Wales the lack of lamproites or kimberlites has elicited a new model of formation for diamonds in this region by subduction of carbon-rich marine deposits followed by metamorphism and transport upwards by nephelinites or alkali basalts. The Argyle joint venture is upgrading plant at the Argyle open pit in the Kimberley region of Western Australia and hopes to increase diamond ore production to 8 million tons.

Former USSR. Almazy Rossii-Sakha (ARS) in agreement with De Beers sold its entire quota of diamonds in 1993 and $600 million worth of diamonds in the first half of 1994. R.J.P.

Les autres grands diamants de la Couronne de Saxe.

B. Morel. *Revue de Gemmologie*, **122**, 1995, 3–5, 4 photos.

Following a paper on the Dresden green diamond in *Revue de Gemmologie* 121 the diamonds in the Crown of Saxony are described. They include the Dresden White and the Dresden yellow, weighing 49.71 and 39.46ct respectively. The Rose of Saxony diamond weighs 41.77ct and the Queen Eberhardine diamond 25.11ct. Brief notes are given on their settings. The stones form part of the collections of the Green Vaults, Dresden, Germany. M.O'D.

Fracture filled diamonds.

B. Sechos. *Australian Gemmologist*, **18**(12), 1994,

ABSTRACTORS

M. O'Donoghue	M.O'D.	R.J. Peace	R.J.P.
E. Stern	E.S.		

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379–85, 13 illus. in colour.

After a brief introduction of existing treatments, clarity enhancement or fracture filling using a glass filler with refractive index very close to that of the diamond (Yehuda and Koss methods) was discussed. For the Yehuda treatment the flash effect, using dark ground illumination, a white line on the surface where the fracture emerged, flattened gas bubbles, finger-print inclusions and the cracked mud effect due to partial crystallization were listed whilst for the Koss treatment the purplish flash appeared to be the chief diagnostic feature. Both companies gave lifetime guarantees for their treated stones provided they are kept under normal conditions. Descriptions are given of treated diamonds subjected to extreme conditions including heating to 800°C to simulate jewellery repair conditions and thermal shock by immersion in liquid nitrogen at -185°C. Several examples were quoted of filler instability together with photographs. Declaration of fracture filling is not only important from the legal aspect but diamond jewellery repairers must be able to recognize the treatment. R.J.P.

Gems and Minerals

Tahiti cultured pearl.

M. COEROLI. *Australian Gemmologist*, **18**(12), 1994, 388–94, 6 illus. in black-and-white, 11 illus. in colour.

The Tahiti cultured pearl and its by-products are the most important exports from French Polynesia. Natural black pearls from the black lipped pearl oyster the bi-valve *Pinctada margaritifera* type cumingi were obtained by free-diving in 15–20m yielding only one pearl in 15–20 000 oysters. The first cultured pearls from French Polynesia appeared in 1972. Cultured production really commenced following the establishment of pearl farms in South Marutea and on the Gambier Islands. Advances in technique resulted in establishment of cooperatives during the 1980s. Details of pearl culture are illustrated. Harvest details showed that of 40 pearls obtained from 100 grafted oysters only 15 per cent were round or semi-round. Although the loose pearl market is dominated by Japan and Hong Kong, nevertheless progressive development of the French Polynesian pearl industry should add a prestigious product. R.J.P.

Das Ametrin-Vorkommen von Anay, Santa Cruz, Bolivien.

T. COLLYER, K. FUZIKAWA AND D. SCHWARZ. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 117–26, 1 mpa, bibl., 3 illus. in black-and- white, 2 illus. in colour.

The Anay (Anahi) deposit, located in Santa Cruz along the eastern border of Bolivia near Brazil is the only known deposit of bicoloured purple and yellow quartz (ametrine) of economic interest. The mine is currently being worked by Minerales y Metales del Oriente SRL (M & M), a private Bolivian company, with a steady monthly production of about 400kg of gem quality rough. The amethyst and citrine are associated with hydrothermal quartz veins which cut across the dolomite and limestone formations of the Murcielago group. E.S.

La gravure sur pierres précieuses: les rubis et les spinelles.

M. DUCHAMP. *Revue de Gemmologie*, **122**, 1995, 10–15, 9 photos (3 in colour).

The history and techniques of engraving on ruby and spinel are described with reference to several museum pieces. M.O'D.

Flussperlen in Bayern und Böhmen.

H. HAHN. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 33–8.

River pearls have been found in Europe for many centuries in various rivers in Bavaria, Bohemia, Russia, Scandinavia, Spain, Lorraine (France) Brittany (France) Lüneburg Heath (Northern Germany) as well as Saxony. Because of growing pollution the European pearl fishing industry is very small; in Scotland a few rivers yield some mussel pearls. The author describes the propagation of the mussels and surveys the occurrences of freshwater pearls in Bavaria and Bohemia. Recently some 150 000 mussels from Russia have been placed into Bavarian rivers, not primarily for the production of pearls, but in the hope that the behaviour of the mussels may help to detect various types of pollution. E.S.

Contribution à l'étude des caractéristiques distinctives des saphires du Cachemire (second part).

H.A. HÄNNI. *Revue de Gemmologie*, **122**, 1995, 6–9, 10 photos (5 in colour).

Inclusions characteristic of Kashmir sapphire are described. Rutile needles, green tourmaline crystals, long crystals of zircon and crystals of plagioclase, uraninite and allanite-(Ce) are also found, together with fine lamellae and zoning with exsolved material and fissures. Internal features noted by other writers are listed. M.O'D.

Makusanit – ein klar durchsichtiger Obsidian aus Peru.

U. Henn. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 25–8, 2 illus. in black-and-white, 1 in colour, bibl.

The material comes from Puno in Peru and is found in aluminosilicate bearing ignimbrites of Miocene to Pliocene age. It is a clear brownish transparent rhyolitic obsidian. RI 1.489, SG 2.36. Aluminium silicate inclusions were found in the shape of elongated prisms. E.S.

Saphire von Indaia, Minas Gerais, Brasilien.

U. Henn, H. Bank and F.H. Bank. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 111–16, 1 map, bibl., 4 illus. in black-and-white, 1 in colour.

A new corundum occurrence in Brazil near Indaia in Minas Gerais produces transparent blue sapphires. RI $n\varepsilon$ = 1.760–1.763 $n\omega$ = 1.768–1.771. DR = 0.008 SG = 3.99–4.02. The absorption spectrum shows typical bands of Fe^{2+}/Ti^{4+} and Fe^{3+}. Chemical analysis showed traces of iron and titanium besides aluminium. Mineral inclusions of mica and rutile, healing cracks and distinct growth and colour zoning could be seen under the microscope. E.S.

Gemmologische kurzinformationen.

U. Henn, H. Bank and C.C. Milisenda. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 105–9, 3 illus. in black-and -white, 4 in colour.

Some cuttable peridots were said to come from a new occurrence in Pakistan. The tested faceted examples weighed from 1.99 to 12.41ct. There is also a report of grossular-andradite from Mali; the colour varied from pale to yellow green to brown with a relatively high RI of 1.755–1.774; the SG of the faceted stones was between 3.58 and 4.19. A translucent white beryllonite cat's-eye cabochon with definite cat's-eye effect was said to come from Afghanistan; RI about 1.55, SG 2.80. E.S.

Azurit-Malachit – Verwechslungsmîglichkeiten und Imitationen.

U. Henn and B. Schneider. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 127–32, 1 table, 2 graphs, bibl., 2 illus. in colour.

Azurite-malachite is the result of natural coalescence of the blue azurite and the green malachite, often with chrysocolla, turquoise, quartz and possibly some other components. Gemmological examination is difficult as the various components have varying RI and density. For the laboratory a method using infrared spectroscopy is advised. An imitation often found on the market consists of pressed products of azurite and malachite sometimes with the addition of chrysocolla. Another imitation is made of gibbsite, partially coloured by ultramarine. E.S.

Hsa-Taw green tourmaline.

U.T. Hlaing. *Australian Gemmologist*, **18**(11), 1994, 352–3, 1 illus. in black-and-white, 3 in colour.

The Hsa-Taw tourmaline comes from southeast Myanmar (Burma) close to the Thailand border. Its gemmological properties are standard for elbaite tourmaline and display a variety of inclusions including trichites, colour zoning, possible mica and undetermined solid black inclusions. R.J.P.

Smaragdgrüne Chrom-Titanite aus dem Ural, Russland.

J. Hyrsl and C.C. Milisenda. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 29–32, 1 illus. in black-and-white, bibl.

Faceted green titanites (sphene) were recently offered on the German market. These stones come from the Sarany chromium deposits in the Perm region in the central Urals. The sphenes occur as grass green to dark emerald green crystals up to 8cm in length with definite pleochroism. Transparent pieces are much smaller and cut samples are not bigger than 0.25ct. SG 3.54, RI 1.908–1.912 to 2.07–2.099, DR 0.16–0.19. E.S.

Gem Trade Lab notes.

R.C. Kammerling and C.W. Fryer. *Gems & Gemology*, **30**(3), 1994, 184–90, 16 illus. in colour.

A 'carving' showed an unexplained hole in the base and parallel striations together with cracks which showed no vein-filling materials. X-ray diffraction analysis showed mullite, kalsilite and gehlenite which are rare minerals and not found together in nature, but are found in ceramics. A modified rectangular step cut stone was identified as natural citrine containing a prominent well-formed first-order prism termination which proved to be quartz but of a different orientation to the host.

A handsome mottled white and green rock described as massive grossular garnet was shown to be dominantly white grossular with diopside, vesuvianite and clinochlore. A necklace of highly polished black beads, sold as black jadeite, showed a 'spot' RI of midway between 1.60 and 1.70 and an SG of 3.36 but with an unusual evenness of polish. X-ray diffraction analysis showed the beads to be ferrohornblende an iron-rich member of the amphibole group. Visible light spectroscopy of intense green jadeite beads showed natural colour whilst infrared spectroscopy showed they were not polymer impregnated. The fineness of the aggregate resulted in such high diaphaneity that the stringing cord was clearly visible even in the largest bead. An unusual barrel-shaped black pearl showed both a solid black appearance and distinctive banding. When exposed to long-wave ultraviolet radiation the dark areas fluoresced a very strong red as seen in other black pearls from the Gulf of California whilst X-ray radiography revealed a large dark central core which proved the pearl was natural. A treated-colour black pearl showed the visual damage to the nacre layers and iridescence. EDXRF analysis showed the presence of silver. A blue sapphire was proved to be free from heat treatment on the basis of inclusions which resolved into two phases on cooling. A colour zoned synthetic sapphire appeared a uniform yellow orange face up but from the side all but a small orange area appeared pink. Curved banding in the orange zone proved it was synthetic. An opaque mottled brown and white carving was shown to consist of serpentine and forsterite. A piece of partially polished blue rough was identified as turquoise and a colourless transparent substance on the surface shown to be a polymer by infrared spectroscopy.
R.J.P.

Almandine garnets from Vietnam.

R.C. Kammerling and J.I. Koivula. *Australian Gemmologist*, **18**(11), 1994, 356–8, 1 table, 4 illus. in colour.

A number of garnets from this source were examined referring to the criteria of Stockton and Manson and classed as almandine. Chemical analysis showed the stones to be essentially almandine with minor pyrope, grossular and spessartine components.
R.J.P.

Gem news.

J.I. Koivula, R.C. Kammerling and E. Fritsch. *Gems & Gemology*, **30**(3), 1994, 191–201, 17 illus. in colour.

'Caymanite' from the Grand Cayman Islands was shown by X-ray diffraction to be dolomite found as a banded rock with orange-brown and cream coloured layers. A carving of green beetles on a brown matrix is chrysoprase and chalcedony matrix from the Yerilla district in Western Australia. Iridescent demantoid garnet from Mexico was shown to be very pure andradite with no chromium and only a trace of manganese.'Pearls' from the horse conch *(Pleuroploca gigantea)* showed a clearly visible flame structure. New sources of peridot from Pakistan and rhodonite from the Yukon were reported. The origin of satellite readings on the refractometer from a tourmaline was thought to be the result of thermal shock or overheating when the stone was polished.

Natural gem production in the USA reached a total value of $51 million in 1993 and synthetics were valued at $19 million. Freshwater pearls at $25 million headed the natural list whilst shell inserts for cultured pearls produced $53 million.

Enhancements: A coated jadeite with mottled green varnish together with a clear outer coating gave a positive hotpoint test. The strong chalky blue fluorescence to long-wave UV radiation contrasts with the normal spotty and yellowish-white fluorescence of natural jadeite.
R.J.P.

Schleifwürdige Granate (Grossulare) von einem neuen Vorkommen in Mali.

TH. Lind, H. Bank and U. Henn. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 17–24, 2 tables, 3 graphs, five illus. in colour, bibl.

The article describes chemical and physical properties of a yellow-green to greenish- brown grossular from Mali, but details of the locality are not given. Distinct growth zoning and distinct anomalous double refraction under crossed polars can be observed. RI 1.758 to 1.785, SG 3.63 to 3.72. Spectra show absorption lines of Fe^{3+} superimposed on an intense absorption band with a maximum in the ultraviolet.
E.S.

Gemmologische Kurzinformationen. Short notes from the gemmological laboratory of the German Foundation for Gemstone Research.

C.C. MILISENDA. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 3–8, 8 illus. in colour.

A new occurrence of gem quality sapphires from Madagascar has been found in the southwest of the island, these are pale to dark blue, elongated ditrigonal bipyramids, between 0.49 and 1.32ct, RI 1.761–1.763 to 1.769–1.771, DR 0.008, SG 3.91 to 3.98. Distinct colour and growth zoning with swirls. The most striking inclusions are hollow tubes. Other stones submitted to the laboratory included two ruby cabochons and a rough sample of the same material from China, one of the stones showing distinct asterism due to rutile needles. Blue opals from Peru are greenish-blue to blue with black dendrite inclusions. Fine faceted fire opals from the Shaphane mountains in Turkey are reddish, orange and yellowish-red and comparable to the Mexican fire opals with RI between 1.442 and 1.446 and SG 2.00–2.02. Opal embedded in sandstone matrix from Andamooka in South Australia is similar to the opalised sandstone from Louisiana. The Andamooka material showed yellow, green and blue play of colour. E.S.

Seltene Edelsteine von St. Hilaire, Quebec, Canada.

C.C. MILISENDA, J. SCHLÜTER AND G. GEBHARD. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 133–42, 5 tables, 1 map, bibl., 2 illus. in black-and-white.

The Mont Saint-Hilaire in Quebec lies 20km east of Montreal and is part of the Monteregian Hills; Mont Saint-Hilaire has a diameter of about 3km and is roughly 350m above the St. Lawrence river plain. The most productive occurrence is the Poudrette open mine. Most of the gemstones are found in peralkaline syenites. Among the stones described are a 0.44ct transparent, faceted yellow shortite (a sodium calcium carbonate) and a 0.03ct faceted colourless leifite. Other cuttable gemstones found at Mont Saint- Hilaire include carletonite, eudialyte, hackmanite, katapleite, natrolite, remondite, rhodochrosite, serandite, siderite, sphalerite, villiaumite and willemite. E.S

Heat treated corundums of Sri Lanka; their heat treatment.

T.G. PEMADASA AND M.V. DANAPALA. *Australian Gemmologist*, **18**(11), 1994, 346–7, 1 table.

Before the 1970s the Sri Lankan corundum now known as geuda was often discarded by miners and gem dealers. Thai dealers purchased large amounts and successfully converted poor quality geuda into blue sapphire. Now heat treatment is carried out in over 200 furnaces in Sri Lanka by Sri Lankans. Many use a butane-oxygen mixture. The geuda is divided into two groups. Group I consisted of translucent smoky geuda and partially coloured clear blue corundum known as *otto* which is treated using a reducing flame. Precise temperatures and times are quoted. Group II consisted of bluish ruby and red geuda which yielded ruby and pink sapphire and a third member, Kowangu yellow sapphire, which is slightly yellowish in reflected light due to fine inclusions and yields either yellow or padparadscha sapphire. Oxidizing conditions were used for this group. R.J.P.

Instruments and Techniques

Das Diamond Colorimeter DC 200.

B. GÜNTHER. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 39–43, 4 graphs (1 coloured), 1 illus. in colour.

The Diamond Colorimeter by Gran Computer Industries Ltd is described. Its design is based on colour perception similar to that of the human eye. The diamond is subjected to three colours and those wavelengths which are absorbed by the diamond are measured. The author does not think that its performance matches that of the human eye but that it should be a useful complementary tool. E.S.

Gemlite polariscopes.

T. LINTON, B. NEVILLE AND A. Shields. *Australian Gemmologist*, **18**(12), 1994, 386–7, 1 illus. in black-and-white.

Two models were examined by the GAA Instrument Evaluation Committee. Both were considered good value for money and are of the conventional type. Addition of a X5 lens would have helped in the examination of small stones. Polarized reflections from the aluminium mounting holding the polariser caused some misleading ADR results and the tendency for one of the instruments to fall over in use showed some lack of basic design but all the faults were easily eliminated. The incorporation of an on/off switch would improve the safety aspects. R.J.P.

Synthetics and Simulants

Synthetische Opale aus China und Russland.

U. Henn, L. Ackermann and K. Schoder. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 9–15, 1 table, 3 illus. in black-and-white, 6 in colour, bibl.

Two new types of synthetic opals have come onto the market. First, green and pink opals from China show regular, sharply bounded colour patches with lizard-skin effects and columnar structures. The opals are composed of closely packed silica spheres about 320nm in diameter; there is an ignition loss of about 20 per cent at 1000°C; SG = 1.80– 1.90, RI = 1.450–1.468.

The second type is from Russia and looks very like natural opal. The material is composed of strongly distorted silica spheres with an approximate diameter of 240nm. Ignition loss at 1000°C is about 8 per cent; SG = 1.74–1.86; RI = 1.440–1.450. E.S.

Gemmologische kurzinformationen.

U. Henn, H. Bank and C.C. Milisenda. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **43**(3/4), 1994, 105–9, 3 illus. in black-and-white, 4 in colour.

The Austrian firm Swarovski has marketed a new glass imitation of emerald under the name of 'Swarogreen'. The tested faceted stone weighed 0.22ct RI 1.600 (lower than Swarovski's figures of 1.605–1.615), SG 2.98 (higher than Swarovski's 2.88–2.94). No inclusions could be observed. An intensively yellow brilliant-cut diamond was tested and found to be synthetic. It weighed 0.34ct and was found to be Type Ib. No provenance was given. A new synthetic emerald from the USA was marketed under the name of 'Kimberley created emerald' by the firm Kimberley Inc. NY. The stones were produced by hydrothermal synthesis; the firm plans to produce in future also rubies, sapphires and alexandrites. Another synthetic emerald produced hydrothermally comes from China from the firm Techyears Industries Ltd; this shows very strong red fluorescence. Also from China, there is a new synthetic opal; RI 1.450–1.468 with a distinct lizard skin effect. Another synthetic opal, but without the lizard skin effect, came from Russia; these opals had an RI 1.44–1.45, and an SG 1.74–1.86 which is relatively low due to its obvious porosity. E.S.

Gem news.

J.I. Koivula, R.C. Kammerling and E. Fritsch. *Gems & Gemology*, **30**(3), 1994, 191–201, 17 illus. in colour.

Synthetic phenacite from Russia in the form of transparent bluish-green crystals produced by the flux growth method had the optical and physical properties associated with natural phenacite. Apart from its distinctive colour, flux inclusions provided the most obvious clue to its synthetic nature. These phantom structures appeared to be trapped along growth steps and varied in colour from colourless to a greenish-brown.

The firm Tairus, a joint venture between the Russian Academy of Sciences and Pinky Trading Co. of Bangkok, opened a new facility in Novosibirsk, Siberia, for synthetic gemstone production in late 1994. The prime activity is that of producing hydrothermal synthetic emerald. R.J.P.

Gemmologische kurzinformationen. Short notes from the gemmological laboratory of the German Foundation for Gemstone Research. (in German and English)

C.C. Milisenda. *Gemmologie – Zeitschrift der Deutschen Gemmologischen Gesellschaft*, **44**(1), 1995, 3–8, 8 figs in colour.

Hydrothermally grown synthetic emeralds are marketed by A.G. Japan Ltd. under the name 'AGEE Emeralds, refined and recrystallized' – the rough emeralds are apparently crushed, purified using a laser technique and then recrystallized under hydrothermal conditions. This description is not in agreement with CIBJO nomenclature and the stones should be sold as synthetic emeralds; RI 1.569–1.575, DR 0.006, SG 2.69. Faceted artificial glasses are being marketed under the name of 'lazerite' imitating peridot, citrine, tanzanite, and a blue similar to tourmalines from Paraiba. RI 1.519 to 1.520, SG 2.47 to 2.53. Gas bubbles and swirl marks can be seen under a microscope. E.S.

BOOK REVIEWS

Properties and growth of diamond.

G.Davies (Ed.), 1994. INSPEC/Institution of Electrical Engineers, London. pp xv, 437, illus. in black-and-white, hardback. Price £135.00. ISBN 0 85296 875 2.

Forming no 9 of EMIS Data Reviews series the contents of this large book appeared at first glance to be a set of benchmark papers but the 90-plus papers are all freshly written. I cannot think of a more timely compilation and since, as the foreword says, all the important aspects of diamond science are contained in the volumes of articles edited by Berman (1965), Field (1979 and 1992) and Wilks & Wilks (1991) it has become vital to present the substance of those articles in a form giving the important parameters characterizing all the forms and conditions of diamond.

While most gemmologists will find the topics of diamond physics and diamond growth of great interest many will find the papers written in the rigorous language of physics and chemistry and may not attempt to find the many points which have a direct bearing on diamond as a gemstone. None the less, some will make the attempt and will probably find the most interesting sections to be those dealing with the growth of diamond by chemical vapour deposition, the high-pressure growth of diamond, the decay times of luminescence and laser action in diamond and the properties of nitrogen in diamond. Each paper has its own list of references and there is a subject index. The price is not unreasonable for a book of such size. M.O'D.

Zeolites of the world.

R.W. Tschernich, 1992. Geoscience Press, Phoenix, AZ. pp 563, illus. in black-and-white and in colour, hardback. Price £67.00. ISBN 0 945005 07 5.

Though by their nature few zeolite species are likely to find themselves used ornamentally, readers may none the less find this book useful for details of analcime, pollucite and yugawaralite (all of which I have seen in faceted form) but far more importantly as an example of what such a survey should be. Many gemmologists are mineral collectors too and they should certainly buy the book. The text is well-organized and as comprehensive as possible with references, in the excellent bibliography, up to 1991. M.O'D.

The history of mineral collecting, 1530–1799, with notes on twelve hundred early mineral collectors.

W.E. Wilson, 1994. Mineralogical Record, 25(6), pp 1–264, illus. in black-and-white and in colour.

Priced at US$24.00, this monographic issue of the *Record* introduces mineral collectors from the mid-sixteenth century to the end of the eighteenth, with notes on their collections and reproductions, many in colour from their works where appropriate. Among the collectors celebrated for their cabinets of gem minerals are Jacob van der Näll, Abraham Gottlob Werner (Germany), Sir Hans Sloane and Alexander Crichton (Great Britain) René-Just Haüy and Jacques de Bournon (France). I know of no comparable account and details of European collectors and their specimens are especially hard to come by. There are several very full lists of references and the standard of colour reproduction from early books is particularly good. Title-pages of many of the books concerned are reproduced in black-and-white. M.O'D.

Gem reference guide for the GIA colored stones, gem identification and colored stone grading courses.

Gemological Institute of America, 1993. Santa Monica. pp ix, 270, illus. in black-and-white and in colour, hardcover.

Stones forming part of the GIA identification courses are described with full listing of properties and coloured representations of absorption spectra where appropriate. Entries also include notes on care and cleaning, market availability, sources and recommended disclosures of treatment where applicable. Key separations point out the major possibilities of confusion with other species and with artificial products. Particularly welcome and shown in no comparable book are the colour photographs of specimens, mostly cut stones. Notes on mode of occurrence are not given but in all this is a most attractive and useful guide. M.O'D.

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Hohe Tauern: Mineral & Erz.

1994. Naturhistorisches Museum, Wien. pp 149, illus. in black-and-white and in colour, softcover. Aus.Schg. 1,250. ISBN 3 900 27548 3.

Useful information on emerald from Habachtal is given in this survey of the Hohe Tauern area of Austria. The book deals not only with geology and mineralogy but also with fossils and with the National Park which occupies much of the area.

M.O'D.

Gems, their sources, descriptions and identification.

R. WEBSTER, 1994 (fifth edition). Butterworth-Heinemann Ltd, Oxford. pp xxviii, 1026, illus. in black-and-white and in colour. Price £75.00. ISBN 0 7506 1674 1.

The revision of a work such as this cannot be undertaken lightly. Those who accepted the challenge are to be congratulated for effectively and sympathetically updating a mammoth work.

The book has been revised by a number of specialist contributors under the able editorship of Peter Read and the text has a welcoming appearance as the former long paragraphs have been divided into more readable length. The bibliography contains a pleasingly high proportion of up-to-date gemmological literature of an authoritative nature. Additional specialist volumes are mentioned in the text where appropriate.

Revision has in general been conservative. However, the results of the latest research, newly discovered deposits, recently developed equipment and changes in techniques have been included, and some heaviness of historical detail has been reduced. Where substantial rewriting has occurred, it is mostly succinct and light in style.

Given that this weighty tome is a specimen well worth collecting, it is to be expected that at a cost of well under 1p per carat, there will be some imperfections.

Illustrations: Some of the black-and-white photographs can be said to be of historical interest but the continued use of others, now of poor definition, cannot be justified. Some changes are purely cosmetic: a photograph of a lone pearl fisher, standing in a Scottish river and peering into his glass-bottomed tub has been removed, and although of more pleasing artistic composition, the replacement photograph leaves much to the imagination! Unfortunately, in the same section, the Lauegram patterns produced by natural and cultured pearls have been printed above one another's captions.

The frontispiece neither excites nor educates and overall the selection of colour plates lacks imagination. Plates 9 to 14 inclusive are out of focus and the spectrum diagrams need updating for proportion and realism. Several photographs in the text intending to demonstrate relative sizes of items have no scale and are, therefore, of limited value. Students unacquainted with certain crystal specimens will not be enlightened by some photographs contained in the text. A good line drawing of a star sapphire would convey more than its dismal photograph.

Text: In the diamond chapter previous theories regarding its origin have been omitted, but unfortunately the results of important research still in progress during the preparation of this edition have not been included.

For the ruby and sapphire chapter the rearrangement of the presentation works well. Unfortunately, where additions have been made, colloquial expressions have been introduced. These will date and may be a problem where English is not the reader's first language. The review of this topic is a highly individual one and these passages do not blend sympathetically with the general tone of the work. A work of this nature is no place for political statements and the editor might usefully have wielded his blue pencil more heavily here. On the other hand, in this chapter, inclusions are now dealt with by type rather than provenance, and pertinent references are made, where confusion might arise between inclusions of similar appearance, in both natural and synthetic stones. This is a distinct improvement.

In places there is some inconsistency of information and for instance on the topic of trapiche emeralds, the 4th edition reported them as found in 1946, the 5th edition in 1964, while in *Emerald and other beryls* (Sinkankas, 1989) relates a detailed history beginning with their first notice in 1879.

In the chrysoberyl chapter, the spectrum of alexandrite is described as resulting from an anomaly. Not so. It has all the characteristics of a good chromium spectrum. Evenly balanced transmission of wavelengths, in the red and green, causes the characteristic colour change depending on the nature of the incident light. The ubiquitous use of fluorescent lighting today means that reference to colour-changes in gems could better be made using the words 'incandescent light', rather than 'artificial light'.

Some 24 extra items have been included in 'Lesser known ornamental and gem materials' but the generally available sogdianite is still only mentioned in passing under sugilite.

J.R.H. Chisholm would have been pleased to note that 33 years after his review of the first edition, the crystal axes of the monoclinic system have now been defined correctly. However, some picturesque errors from that edition are still evident. Those who expect to see the mean refractive index of malachite at 1.85 on the refractometer, are sure to be disappointed; likewise those who hope to see a single vagrant extraordinary ray shadow edge, when a dark brown tourmaline is rotated on the refractometer prism.

Strangely, there is still considerable emphasis on the use of Clerici solution. As this is not available for general testing, and should only be used at all in controlled laboratory conditions, the coverage of its use in such details seems inappropriate. Perhaps Rohrbach's solution could have been mentioned.

There are some inevitable inconsistencies of fact where different reviewers have dealt with the same subject under different headings. Calculations comparing the weight of a diamond and a strontium titanate of equal size could more usefully have been adapted for CZ. The expression 'in recent years', used variously throughout, seems to indicate, as far as could be ascertained, a span of anywhere between the mid-eighteenth century and the start of the present decade!

Some terms, such as 'Liesegang bands', explained in previous editions are now without explanation. Other terms, such as 'Nomarski interference contrast techniques', appear for the first time but without explanation or reference. Name-dropping of technical terms 'which are not our concern here' could have been eliminated without detriment to the text and a glossary of relevant specialist terms would be helpful. A few examples are banket, Joplin jig, aureole, aplite, coenosarc and tenebrescence. Some of the terms used are not even in standard geology, mineralogy, physics or science dictionaries.

Table 1 is a consolidation of the main gem constants in mean RI order. The other tables of separate constants are much as before, suitably updated, although the list of suggested permissible names has been omitted. An additional appendix giving all the causes of colour of gems, where known, would have been most welcome.

Compiling and revising an index is by no means the least of the tasks required for a new edition. An exhaustive test of the index has not been possible and although some headings are still ambiguous, so far all references sought have been found.

My copy of the work has had one careful owner and already the spine is beginning to separate from the body of the book. The board used for the cover is less substantial than that of previous editions. For a volume which will undoubtedly receive much use, this is a pity.

The content represents an extra 9.3 per cent in the text, having over 10 per cent more words to the page than the 4th edition. The weight has been reduced by just under 3 per cent and is about 1.94kg. All units of measurement now conform to international standards.

When not actually on the desk, this 5th edition of Webster's 'magnum opus' needs to be readily accessible as it will undoubtedly be indispensable to the enthusiastic gemmologist and voracious student alike. G.M. Green

Turmalin: der Edelstein des Regenbogens. Neueste Nachrichten von der Turmalin-Gruppe.

[extraLapis. no.5], 1994. Christian Weise Verlag, München. pp 96, illus., in black-and-white and in colour, softcover. Price DM 29.80. ISBN 3 921656 31 1.

At an absurdly low price here is one of the very finest illustrated books on a single gem species (a mineral group, of course) that I have yet seen. With colour photographs on nearly every page the book would delight anyone and especially the beginner in gemmology. Particular topics covered include early work on the properties of tourmaline, on its crystal forms, how the different colours are accounted for and details of historical and new discoveries. The book is designed to be read right through and I recommend readers to do so, as fresh stimuli to your gem studies will be received every time the page is turned. Everyone has their favourites but look at the blue Paraíba specimens on page 47 – even better are the Mount Mica crystals on page 78. Several illustrations from the mammoth book by Benesch (1990) are included. The book forms part of the series extraLapis and, like its five predecessors, is not included in the subscription to the main journal *Lapis*. M.O'D.

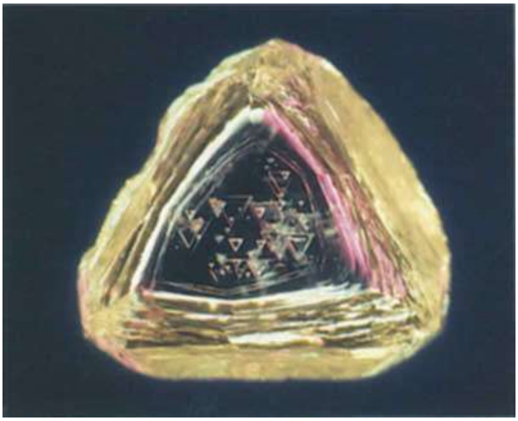
Proceedings of the Gemmological Association and Gem Testing Laboratory of Great Britain and Notices

PHOTOGRAPHIC COMPETITION

The second GAGTL Photographic Competition again stimulated some exceptional pictures on the theme 'The spectrum of gemstones'.

The winner, with a picture of the interference colours from cleavage in gem sphalerite (see cover picture), was Wilma van Opstal of Tilburg, The Netherlands. Second prize was won by Michael J. Crowder of Camberley, Surrey, for a phase-contrast picture of a diamond crystal (submitted while he was studying for the Gem Diamond Diploma). Third prize was won by David Minster of Pretoria, South Africa for a close-up of the iridescent colours of paua shell.

The three prize winners receive awards of £100.00, £75.00 and £50.00 respectively and plans are advanced to include these pictures and a selection of other fine entries in the 1996 GAGTL calendar.



Second Prize. Trigons on a diamond crystal.
Photograph by Michael J. Crowder.

Third Prize. Paua shell from New Zealand.
Photograph by David Minster, FGA.

OBITUARY

Mr Claude B. Jones FGA, DGA (FGA 1972, DGA 1973), Northampton, died on 30 December 1994.

Mrs Marja L.A. Pitkanen FGA (D.1987), Kukkila, Finland, died on 1 January 1995.

Mr John Reginald Shaw, FGA (D.1968), Birstwith, near Harrogate, died suddenly on 4 May 1995.

Mr Douglas N. Wilson, FGA (D.1963), Paradise, South Australia, died recently.

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GIFTS TO THE ASSOCIATION

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

Gerhard Becker, Idar-Oberstein, Germany, for the book *Führer durch das Deutsche Edelsteinmuseum* by H. Bank.

George Lindley & Co Ltd, London, for a parcel of mixed diamond simulants.

Thomas M. Schneider, San Diego, California, for rough samples of blue and greenish-blue apatite for teaching purposes.

The Scottish Branch of the GAGTL for the book *The Honours of Scotland* by C.J. Burnett and C.J. Tabraham (1993), Historic Scotland, Edinburgh.

Swarovski, Switzerland, for five synthetic rubies.

Wu Chao-Ming, Taiwan, for a garnet crystal and a piece of rough serpentine.

MEMBERS' MEETINGS

London

On 12 June in the Gem Tutorial Centre at 27 Greville Street, London EC1N 8SU, the Annual General Meeting was held, followed by the Reunion of Members and Bring and Buy Sale. A full report appears on page 527.

On 16 June at the Royal Automobile Club, Pall Mall, London SW1, the Annual Trade Luncheon was held. The speaker was Mr Jeremy Richdale, a Director of the Central Selling Organization, and a report of his address will appear in the September 1995 issue of *Gem and Jewellery News*.

Midlands Branch

On 28 April at Dr Johnson House, Bull Street, Birmingham, the Annual General Meeting of the Branch was held, at which Jim Porter was re-elected Chairman and Mandy MacKinnon and Neil Rose were elected to share the post of Secretary. The AGM was followed by a talk by Mrs Carson on the work of the Assay Office.

Gem Clubs were held on 16 April, 21 May and 18 June.

North West Branch

On 17 May at Church House, Hanover Street, Liverpool 1, Eric Emms gave an illustrated talk entitled 'Diamonds in the Laboratory'.

On 21 June at Church House, Dr John Franks gave an illustrated talk on 'Geological jewellery and souvenirs'.

Scottish Branch

On 19 May at the Assay Office, Goldsmiths Hall, 39 Manor Place, Edinburgh, the inaugural meeting of the new Branch was held, at which Joanna Thomson was elected Chairman. Ana I. Castro gave an illustrated talk entitled 'Gem testing in the Laboratory'.

ANNUAL REPORT

The following is the report of the Council of Management of the GAGTL for 1994.

The Gemmological Association and Gem Testing Laboratory of Great Britain (GAGTL) is a company limited by guarantee and is governed by the Council of Management. This year Eric Bruton was elected President at the Annual General Meeting in June. The activities of the company benefited enormously from the contribution of other major councils and committees and in September Dr G. Harrison Jones took over as Chairman of the Board of Examiners from E.A. Jobbins, C. Winter took over as Chairman of the Members' Council from R. Velden and J. Kessler continued as Chairman of the Trade Liaison Committee. In addition, the Education Review Meeting provided a very useful forum to exchange information between teachers, examiners and staff of the Association which helped in developing the path of gemmological education.

During 1994 the GAGTL continued to expand its major activities and can report a successful financial year. In the laboratory, growth in diamond grading continued and additional staff were recruited to deal with the extra work. In addition to CIBJO and GIA diamond reports, the Laboratory now

FORTHCOMING MEETINGS

London

1 October	GAGTL Annual Conference to be held at the Scientific Societies Lecture Theatre, New Burlington Place, London W1. The theme will be *Gemmology in Britain.*
16 October	**Recent developments in the diamond industry.** Howard Vaughan. To be held in the GAGTL Gem Tutorial Centre, 2nd floor, 27 Greville Street (entrance in Saffron Hill), London EC1N 8SU. The charge for a member is £3.50. Entry will be by ticket only, obtainable from the GAGTL.

Midlands Branch

29 September	**Jewellery valuations and their attendant problems**	Philip Stocker
27 October	**Pearls - production and identification**	Stephen Kennedy
24 November	**Jewels in the hand**	James Gosling

The meetings will be held at Dr Johnson House, Bull Street, Birmingham. Further details from Mandy MacKinnon on 0121-444 7337 or Neil Rose on 0161 832 2551

North West Branch

20 September	**Natural history of jewellery**	Dr John Franks
18 October	A gemmology evening – no charge, open to members and friends	
15 November	Annual General Meeting	

Meetings will be held at Church House, Hanover Street, Liverpool 1. Further details from Joe Azzopardi on 01270 628251.

Scottish Branch

19 September	A visit to the British Geological Survey, Edinburgh
20 October	A talk by Doug Garrod to be held at Newliston House, Edinburgh

Further details from Ruth Cunningham on 0131-225 4105 issues the London Diamond Report using harmonized colour and clarity grades. Pearl testing continues to be an important part of the Laboratory's work and after producing a report on the Hope Pearl a full description of this famous jewel was published in *The Journal of Gemmology*. On the coloured stone front, origin opinions on rubies and sapphires were much in demand. Laboratory staff also hosted the first CIBJO Recognized Laboratories meeting in London which provided an international forum to discuss identification and description of gemstone treatments.

The GAGTL staff member seconded to the Gem and Pearl Testing Laboratory of Bahrain also reports increased activity. A large proportion of the testing concerns pearls but other interesting gems are also encountered and 'Notes from the Bahrain Laboratory – 3' was published in *The Journal of Gemmology*.

For the first time, GAGTL offered its own on-site comprehensive courses leading to the Diploma in Gemmology and in September one course held on two full days per week and a second course held on two evenings per week were established. The former enables a student to obtain the Diploma in nine months and has proved attractive particularly to overseas students wishing to qualify quickly.

An increased programme of trade, student and general tutorials was held in the Gem Tutorial Centre – now expanded to two floors in the building – and courses were also held in Birmingham, at centres in Ireland and in Hong Kong.

The number of students entering the GAGTL examinations in gemmology increased by more than 20 per cent compared with 1993 and 45 per cent of candidates obtained the Diploma. The examinations were offered in seven languages and this opportunity was welcomed by many students. The Gem Diamond qualification is increasingly sought after worldwide and 67 per cent of the students who sat for the examination were successful in 1994.

Gemmological Instruments Ltd now occupies a designated area on the second floor of the Greville Street building where visitors can investigate and receive advice on the instruments, stones and books on display. Stock and records are now fully computerized and this will assist in better service both for visitors and for the mail order customers. The 1994 turnover was 8 per cent higher than that for 1993 and with further improvements in the instruments stocked the prospects are bright for the future.

The GAGTL again exhibited at the American Gem Trade Association Fair at Tucson and, for the first time, joined the British group of companies exhibiting at the International Jewellery Fair in Basle. At the GAGTL Annual Conference entitled 'Diamonds and modern gem developments', Professor I. Sunagawa was the keynote speaker in a full day's programme attended by members and visitors from over 20 countries. The following day, the President Eric Bruton chaired the Presentation of Awards in Goldsmiths' Hall where the successful gemmological and gem diamond students received their prizes and diplomas from Vice- President Alec Farn.

Both the Midlands and North West Branches of the GAGTL mounted successful programmes of lectures and meetings in 1994 and plan increased activities in 1995.

The first GAGTL photo competition produced a very good response and the best contributions were reproduced in the 1995 GAGTL calendar distributed free to all members. Membership increased in 1994 and the future prospects to expand the membership are good.

The Council of Management wish to pay tribute to the efforts of all the staff for their enthusiasm and professionalism in developing the activities of the organization throughout the year.

ANNUAL GENERAL MEETING

The Annual General Meeting of the GAGTL was held on 12 June 1995 at 27 Greville Street, London EC1N 8SU.

Terry Davidson chaired the meeting and welcomed those present. The Annual Report and Accounts were approved and signed.

It was reported that following approval of the amendments to the Memorandum and Articles at the 1994 Annual General Meeting, our solicitors, Paisner and Co., had further clarified the wording in some paragraphs and had recommended the addition of two paragraphs. Paisner and Co. pointed out that in the Memorandum and Articles it would be advisable to specify the right of the company to obtain insurance cover for certain categories of risk, including the legal responsibilities of directors (Council of Management). The following additions to the Memorandum and Articles were proposed and approved.

> Paragraph 3(t)
> To purchase and maintain insurance for the benefit of any person who is or was, within a period of six years, a member of the Council of Management of the Company or of any other company which is its holding company or in which the company or such holding company has any interest whether direct or indirect or which is in any way allied to or associated with the Company or of any subsidiary undertaking of the Company including (but without prejudice to the generality of the foregoing) insurance indemnifying such persons against liability for negligence, default, breach of duty or breach of trust or any other liabilities which may lawfully be insured against; for these purposes 'holding company' and 'subsidiary undertaking' shall have meanings ascribed to them in the Companies Acts.
>
> Article 71
> The members of the Council shall have power to purchase and maintain insurance for the benefit of any person who is or was, within a period of six years, a member of the Council or other officer of the Company or of any other company which is its holding company or in which the company or such holding company has any interest whether direct or indirect or which is in any way allied to or associated with the Company or of any subsidiary undertaking of the Company.

Christopher R. Cavey and Ian Thomson were re-elected to the Council of Management.

It was announced that R. Velden had expressed the wish to retire from the Members' Council. Tony Allnutt, Patrick Daly, Robert Fuller and Brian Jackson were re-elected to the Members' Council.

Messrs Hazlems Fenton were re-appointed Auditors.

Reunion of Members and Bring and Buy

The AGM was followed by the Reunion of Members and a Bring and Buy Sale. The sale proved very popular with a wide variety of new and second-hand books, gems, minerals and instruments being offered.

During the evening the winners of the 1995 Photographic Competition were announced (see p.523) and a selection of entries displayed.

MEETINGS OF THE COUNCIL OF MANAGEMENT

At a meeting of the Council of Management held on 12 April 1995 at 27 Greville Street, London EC1N 8SU, the business transacted included the election of the following:

Transfers – FGA to FGA, DGA

Bedwell, Victoria Lynsee, London, 1995
Chen, Kesheng, Wuhan, China, 1995
Chen, Meihua, Wuhan, China, 1995
Chung, Yam Ming (Daly), Hong Kong, 1995
Li, Yali, Wuhan, China, 1995
Liu, Zhoa, Wuhan, China, 1995

Mok, Dominic Wai Kei, Kowloon, Hong Kong, 1995
Osmond, Catherine, London, 1995
Xue, Qinfang, Wuhan, China, 1995

Transfers – Ordinary membership to DGA
Gedeon, Leila, London, 1995
Kaskara, Tatiana, London, 1995
Yoshida, Miyuki, Hong Kong, 1995

Fellowship
Bagai, Deepak, Bombay, India, 1995
Cheung, Losanna Lai Ha, Wan Chai, Hong Kong, 1995
Cracco, Alexia, London, 1994
Kan, Wing Lok, Kowloon, Hong Kong, 1995
Ki-Jung, Kim, Taegu, Korea, 1995
Levonis, Helen, Toowoomba, Qld, Australia, 1995
Mangun, Colleen C., Manila, Philippines, 1995

Transfers – Ordinary membership to FGA
Ferrell, Ronald L., Deland, Fla., USA, 1995
Lee, Chiu-Hsia, Taipei, Taiwan, 1995
Lundsrud, Berit, Sandvika, Norway, 1995
Shu, Xingying, Wuhan, China, 1995
Tsai, Pei-Lun, Taipei, Taiwan, 1995
Tzou, Jyh-Jeng, Keehung City, Taiwan, 1995
Van Goethem-Tytgadt, Anne, Johannesburg, S. Africa, 1995

Ordinary Membership
Booth, Roderick McKenzie, Greenwich, London
Chan, Wai Chu, Wan Chai, Hong Kong
Cheong, Stephanie Mun Fong, Kuala Lumpur, Malaysia
Davey, John Richard, Rainham
Head, Christopher, Bournemouth
Lim, Victor K.K., Singapore
Ma, Annie Yiu-Chu, Hong Kong
Owens, Suzanne, Dublin
Ryder, Peter Ian, Tunbridge Wells
Sakurai, Akane, London
Sunnak, Jugal Kishore, Bristol
Tai, Man Tak William, Hong Kong
Williams Jnr, Hodson Adeoye, London
Zilvold, Mirjam, Bridel, Luxembourg

At a meeting of the Council of Management held on 14 June 1995 at 27 Greville Street, London EC1N 8SU, the business transacted included the election of the following:

Diamond Membership
Chan, Tony Chung Sing, Kowloon, Hong Kong, 1995
Chan, Yik Pun, Hong Kong, 1995
Nottsbusch, Jürgen Uwe, Appel, Germany, 1995

Fellowship
Campbell, Robert Desmond, Wallington, 1995
Ketomaki, Tapio, Jokela, Finland, 1994
Park, In Sook, Seoul, Korea, 1994
Park, Kinam, Seoul, Korea, 1995
Samson, Ma Teresita, Quezon City, Philippines, 1995
Sherman, Suthita, Makati, Philippines, 1995
Sokhal, Baljender, Birmingham, 1987
Vlahos, Nikolaos, Pireas, Greece, 1995

Ordinary Membership
Chen, Jyh-Shyang, Taipei, Taiwan
Chonan, Rie, London
Daalmeyer, Trudy, Oegstgeest, The Netherlands
Ho, Hsiung-Chien, Taipei, Taiwan
Horne, Timothy, Aylesbury
Lam, Chui-Hung David, Kowloon, Hong Kong
Mackay, Colin Alexander, Edinburgh
Shaw, Gillian Ann, Nairobi, Kenya
Smallenburg, Maud Alice, Amsterdam, The Netherlands
Streit, Veronica, Manila, Philippines
Theodorou, Antonia, Limassol, Cyprus
Young, Sigrid, Billingshurst
Zini, Grazia, Ferrara, Italy

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ADDENDUM

Declinometer

Explanation of symbols shown in 'The declinometer for refractometers: the latest developments' by A. Moliné i Sala (*Journal of Gemmology*, 1995, **24**, 6, 405–9) Figure 3, p. 408.

The following symbols refer to the optic character of the gem and optic orientation of the facet of the gemstone being studied:

MX : Singly refractive, facet cut in any orientation
UC : uniaxial, cut at 90° to the optic axis
UP : ″ cut parallel to the optic axis
UI : ″ tilted facet
BNC : biaxial, cut at 90° to γ
BNA : ″ ″ to α
BNB : ″ ″ to β
BPC : ″ cut parallel to γ
BPA : ″ ″ to α
BPB : ″ ″ to β
BPE : ″ ″ to an optic axis
BI : ″ facet tilted to every optic axis

The geometric symbols draw attention to patterns where extra care should be taken in interpretation:

Δ : To determine the optic sign of a gem from a facet cut at 90° to the uniaxial optic axis

❑ : To distinguish the facet of a uniaxial negative gem from that of a biaxial gem cut at 90° to γ

O : To distinguish the facet of a uniaxial positive gem from that of a biaxial gem cut at 90° to α

For further information, the reader should consult the monograph by J. Figueras Calsina, details of which are given in the References section p. 409.

ADVERTISING IN THE JOURNAL OF GEMMOLOGY

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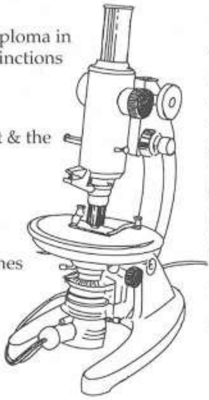

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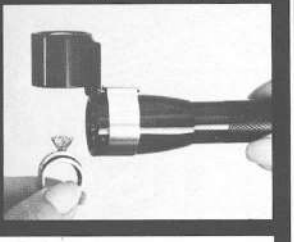

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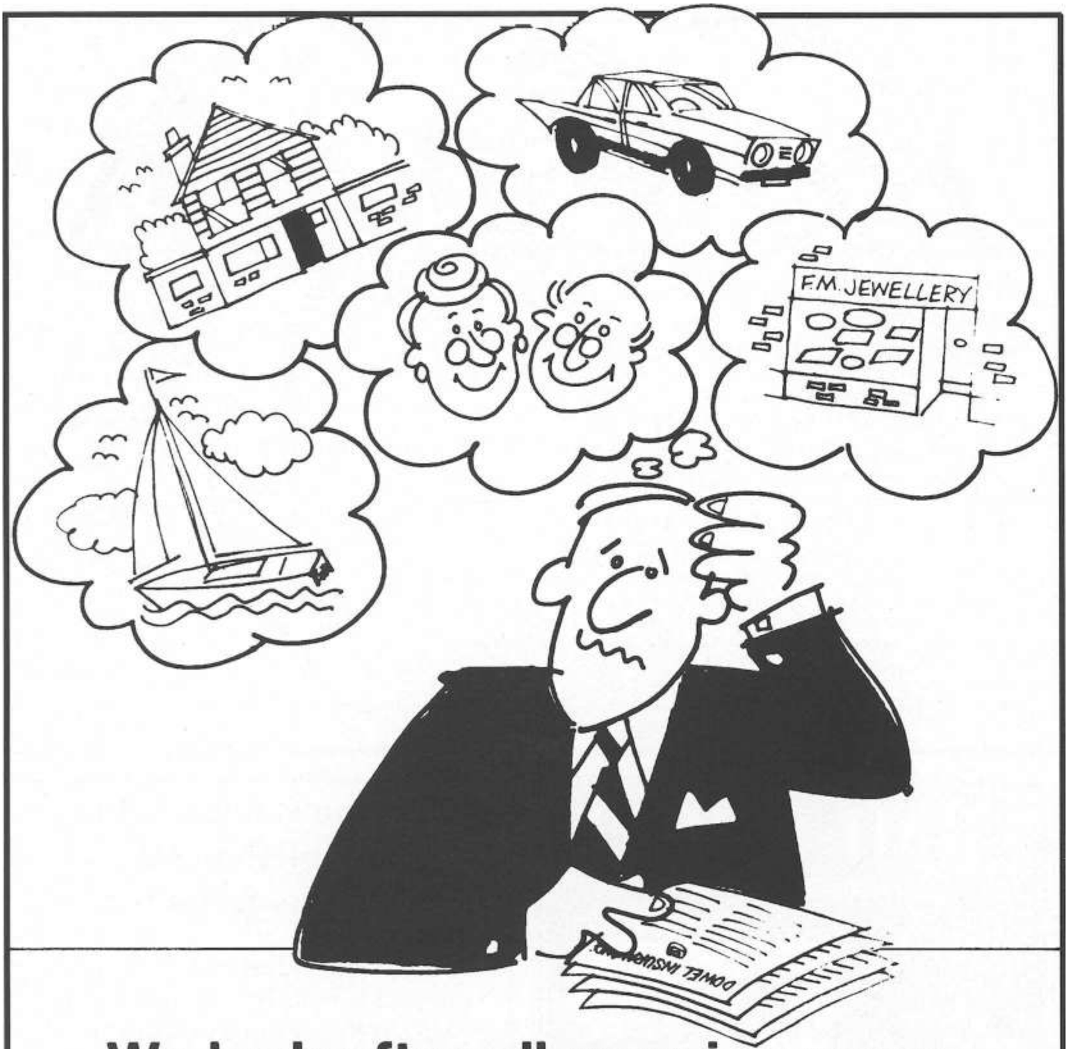
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Guide to the preparation of typescripts for publication in *The Journal of Gemmology*

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

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

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

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

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Notes and References Authors may choose one of two systems:

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

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

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

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

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

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

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Contents

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