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## Cover Picture

Amerindian named 'Joseph' collecting jasper in the Ireng River
at one of the Orinduik falls in Guyana, South America – see page 91.

*Photograph by J.G. Gosling, F.G.A.*

# New developments in spectroscopic methods for detecting artificially coloured diamonds

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## Introduction

Four parameters ('the four Cs') normally determine the value of a polished diamond gemstone: the carat weight, the cut, the clarity and the colour. For a diamond of a given weight, with a well-proportioned cut and a high clarity grade, the colour has a profound influence on the value of the stone.

Diamonds which appear completely colourless are very rare and command the highest prices. However, a large proportion of gem quality diamonds, belonging to the so-called Cape Series, exhibit various degrees of yellowness down to a pale straw colour. Even a hint of this yellow coloration – so faint that a layman would not notice it – significantly reduces the value of the diamond. As the yellow colour becomes more and more pronounced, so that it becomes obvious even to the untrained eye, the value of the diamond falls further. Occasionally, however, diamonds are found in nature which are of excellent gem quality and which have a *full-bodied* yellow, golden or amber colour. Such stones are termed 'fancies'. These diamonds, when properly cut and polished, are on grounds of both rarity and attractiveness generally more valuable than those with the less definite pale yellow colours of the lowest categories of the Cape Series. In Fig. 1 we represent in a schematic way how market forces determine the value of diamonds having different depths of yellow coloration. We notice that, although the strongly-coloured yellow fancy diamonds are nowhere near as valuable as otherwise comparable colourless stones, they can command a price well above some of the diamonds near the middle of the distribution.

Research work on diamond during the 1950s, notably by Dugdale[1] and Clark and co-workers[2,3], showed that it was possible artificially to colour diamonds yellow or golden by subjecting them to radiation damage in a nuclear reactor, or in a van de Graaff accelerator, or by using very intense γ-ray sources, and then heating the specimens to about 800°C. This pioneering work led to three very fruitful decades of fundamental research on physical
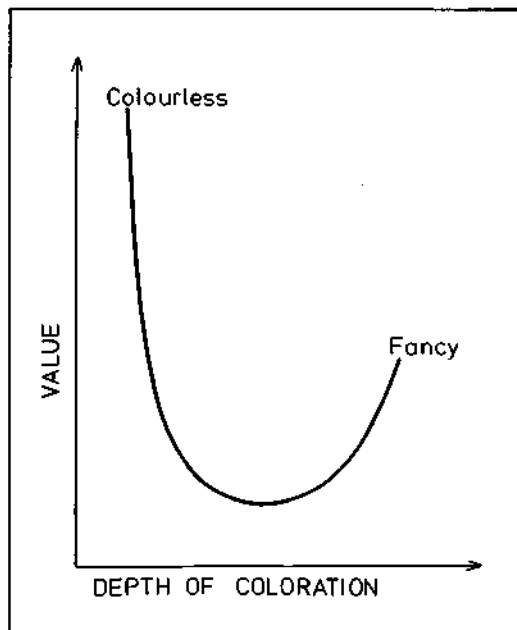


Fig. 1. This diagram illustrates, in a schematic way, how the value of a cut and polished diamond varies with the depth of yellow coloration.

properties of diamond, including investigations of the point defects which are the origins of colour, and this is still an active field of investigation in many laboratories.

The colour produced by irradiation and heating (called 'treatment' in the gem trade) adds to that already present in the diamond. Hence, considering diamonds from near the minimum point in Fig. 1, the effect of treatment is to intensify their colour, and thus potentially to enhance their value. Although many customers would be unable to tell, by eye, whether a fancy yellow diamond was naturally or artificially coloured, market forces decree that the natural product is more valuable than the artificial one. (Indeed, this is true for most gem materials.) A

further advantage of treatment in increasing the value of a stone is that the deeper colour can hide small cracks and inclusions, and so diamonds with a relatively low clarity grade can be selected in the first instance.

These points were, of course, all appreciated at an early stage by the gem industry: consequently gem-testing laboratories world-wide now often have the responsibility of deciding whether a particular diamond has been treated. It should be noted that many treated diamonds are in fact legitimately sold as such, with certificates stating that the colour is artificial. However, problems arise when attempts are made to pass off treated stones as natural yellow fancy diamonds.

### Spectroscopic techniques

Although many diamonds may appear to have a similar yellow colour, the way in which they absorb light may be very different. These differences can be partially revealed using a simple hand-held spectroscope, and very considerable advances in examining diamonds were made by Anderson[4] with such an instrument. Absorption lines in diamond become much sharper if the diamond is cooled to about $-150°C$ or lower, and Scarratt[5] obtained far greater sensitivity with a hand spectroscope when the diamonds were at low temperature. The hand spectroscope, how-ever, has many limitations, and the major gem-testing laboratories now use spectrophotometers which provide a plot, or spectrum, showing how strongly the diamond is absorbing over a wide range of wavelengths. It is often advantageous to record a spectrum with the diamond cooled to liquid nitrogen temperature $(-196°C)$ or slightly above.

In Fig. 2 we show absorption spectra, recorded at room temperature, of four different yellow diamonds – a canary yellow, a deep Cape yellow, an amber yellow and a treated yellow. At first sight two things may seem surprising. The first is that the diamonds have a similar hue; and the second is that there should be any problem in detecting the treated stone.

The reason for the similarity of colour is related to the response of the human eye, which has its maximum sensitivity at about 550 nm and can detect virtually nothing at wavelengths below 380 nm or above 750 nm. Moreover, the colour receptors in the eye respond only to the average light level and cannot sense sharp absorption lines or subtle variations in the light level. As far as the eye is concerned, therefore, all four diamonds are simply absorbing light at the blue/violet end of the visible spectrum and so appear yellow.
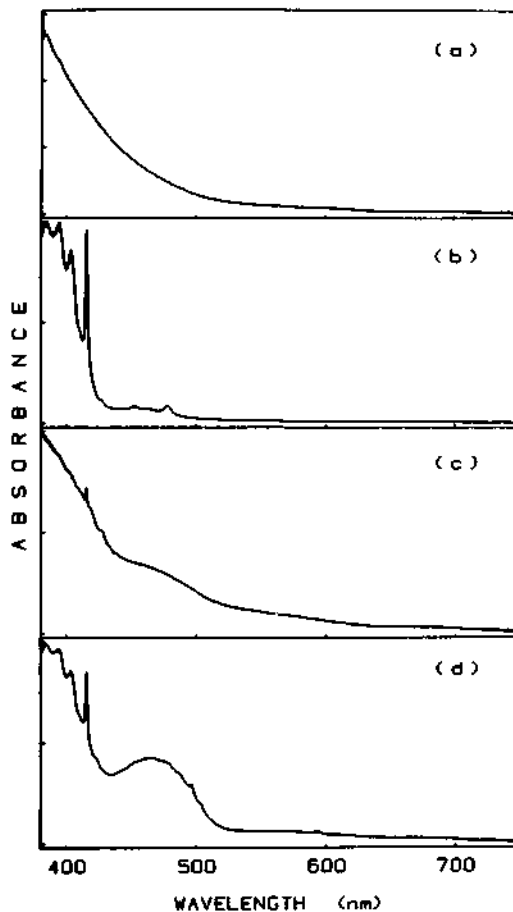


Fig. 2. Absorption spectra of four yellow diamonds, recorded with the samples at room temperature. (a) is a type Ib diamond classified as canary yellow, (b) is a Cape series diamond, (c) is an amber diamond and (d) is a treated diamond.

A precise assessment of the colour can be obtained by taking the data of Fig. 2 and calculat-ing the chromaticity coordinates[6]. These are numbers which locate the colour in a two-dimensional colour space, and which are an objective measurement of the colour of an article, as would be recorded by a standard observer under standardized conditions of illumination. (The interested reader is referred to books by Billmeyer and Saltzman[7], Graham[8] or Wyszecki and Stiles[9] for a more thorough discussion of this topic than can be given here.) The chromaticity coordinates would again show the similarity between the colours of the four diamonds, placing them in fairly close proximity in colour space.
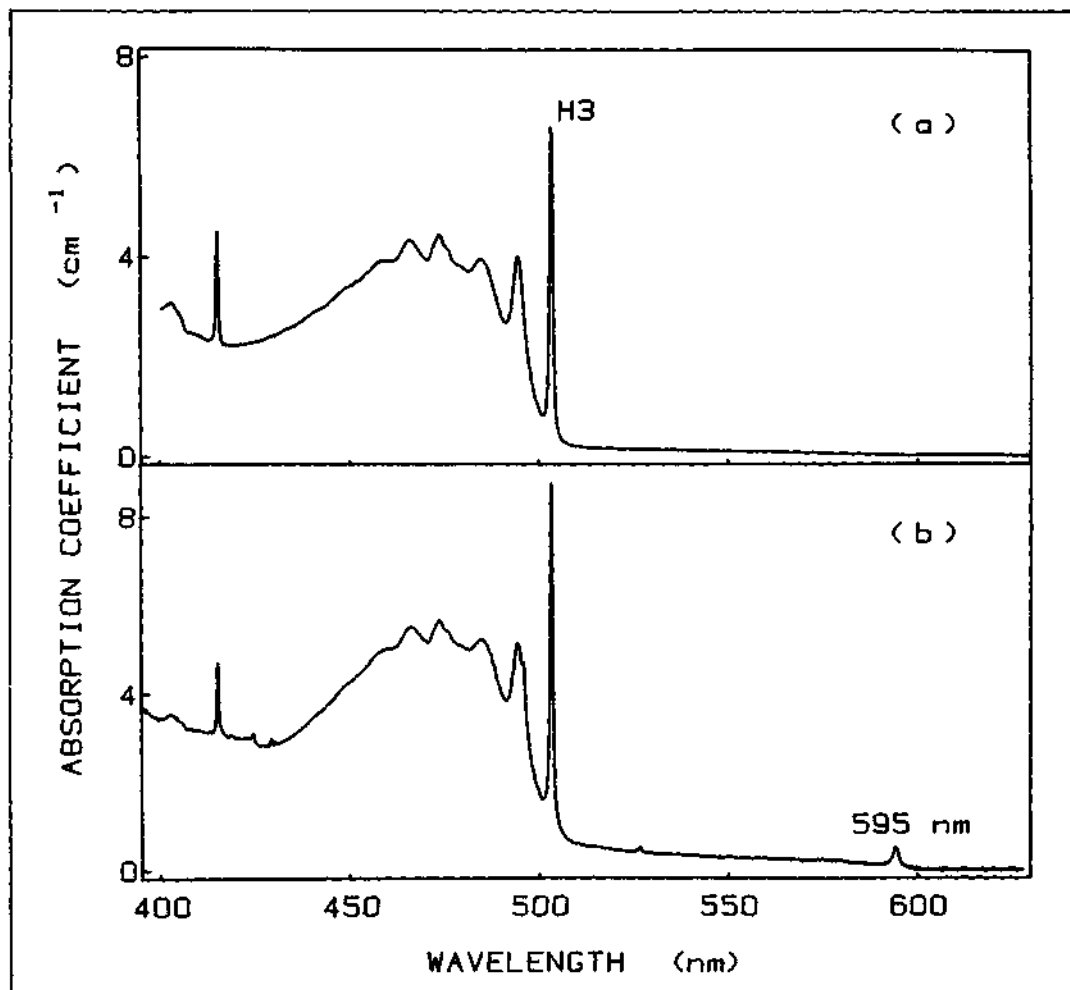
Fig. 3. Absorption spectra, recorded with the samples at liquid nitrogen temperature, of (a) a natural fancy yellow diamond and (b) a treated yellow diamond.

As noted above, the differences between the spectra shown in Fig. 2 should make it very easy to identify a treated diamond. The problem which arises is that the dominant absorption band produced in some diamonds by treatment is also found to occur naturally in certain stones[10]. In Fig. 3 we show absorption spectra, recorded at liquid nitrogen temperature, of a natural fancy yellow diamond and an artificially coloured diamond. In both cases the colour is caused by the H3 absorption band which has a sharp line at 503 nm. It is diamonds containing this absorption band which can pose the greatest problem to gem-testing laboratories. Inspection of Fig. 3 shows that there is an absorption line at 595 nm in the spectrum of the treated diamond that is not present in the naturally coloured stone. Studies

by Crowningshield[11] in 1957 on a large number of treated and untreated diamonds indicated that the presence or absence of this absorption line could be used to indicate whether the colour of a cut and polished diamond was artificial or natural. However, in 1978, high temperature annealing studies by Collins[12] showed that the 595 nm absorption line can be destroyed (by heating treated diamonds to about 1000°C) without significantly changing the colour. It is possible that this phenomenon has been known for many years by those operators who colour diamonds artificially and try to sell them as natural fancy stones. The fact that the 595 nm absorption line is not a reliable indicator of the history of a diamond has caused considerable anxiety, since 1978, in the gem-testing centres.

Research work on treated diamonds has continued in our laboratories, and as a result of this work we can now set out a series of spectroscopic measurements which will indicate with a very high degree of reliability whether a yellow or brown fancy coloured diamond is naturally or artificially coloured. In the rest of this paper we deal with the relevant point defects in diamond, summarizing previous work and incorporating our present results at the appropriate points. Useful background reading may be found in articles by Anderson[13], Collins[14] and Woods[15].

## Point defects in diamond

In this section we shall be concerned with the nitrogen impurity which is present in most diamonds, with the vacancies and interstitials which result from irradiation and with the effects of heat treatment. It is believed that nitrogen is first incorporated in the diamond crystal, as it grows, in the form of single nitrogen atoms on substitutional lattice sites (i.e. at those points in the diamond lattice normally occupied by carbon atoms). For a small proportion of natural diamonds most of the nitrogen is still present in this form, and the crystals have a characteristic yellow colour. These are classified as type Ib diamonds and in some cases the colour may be described as a canary yellow[16]. The absorption spectrum in the visible region for type Ib diamonds is typified by that shown in Fig. 2a.

For most diamonds the high temperatures (around 1000–1200°C) experienced over geological time-scales result in the nitrogen atoms moving around in the crystal, ultimately forming small aggregates. The first stage of aggregation produces A-centres, which are made up of two nearest-neighbour nitrogen atoms. The next dominant stage of aggregation is the formation of B-centres, which are believed to contain four nitrogen atoms. Neither the A-aggregates nor the B-aggregates produce absorption in the visible region, so neither contributes to colour; however the conditions that result in the formation of B-centres also produce N3 centres. It is the N3 centre, believed to contain three nitrogen atoms, which, when present in different concentrations, produces the yellow colours of the Cape Series stones. The spectrum of the N3 centre is that shown in Fig. 2b.

From this brief summary, we can make an important generalization: pale yellow diamonds selected for treatment almost certainly have some nitrogen present in the B form.

### Radiation damage

Immediately after damage by high energy electrons or fast neutrons, diamonds have a blue or green colour, primarily associated with absorption in the GR1 band[14], due to the vacancy. As the diamonds are heated at progressively higher temperatures for a standard time interval (typically one hour) the following behaviour of certain absorption bands is noted:

a. At about 275°C the 595 nm line is first detected. So, too, is an absorption line at 1450 cm$^{-1}$ (6897 nm) in the infrared spectral region. The interstitial atom produced by the irradiation is believed to be involved in the formation of both of these centres. As the temperature is raised the 595 nm line reaches its maximum intensity by about 800°C, and is reduced to zero after heating to about 1000°C[12]. The 1450 cm$^{-1}$ line reaches its maximum intensity at about 400°C and remains at this strength until about 1300°C. Prolonged heating at temperatures around 1400°C is necessary to eliminate this absorption[15].

b. At about 500°C the vacancies begin to move and the GR1 absorption begins to decrease, finally disappearing after heating at about 800°C. As the intensity of GR1 decreases, so, in a complementary fashion, do the intensities of the H3 (503 nm) and H4 (496 nm) lines increase. Spectra of diamonds containing the H3 and H4 bands have been shown previously in reference 14, and it was emphasised there that it is necessary to make measurements at high resolution with the diamond at low temperature if the H4 line is to be distinguished from the side-band of the H3 absorption system. The H3 centre is a vacancy trapped at a nitrogen A-centre and the H4 centre is a vacancy trapped at the nitrogen B-centre, and, for diamonds heated at temperatures up to 1200°C, the ratio of the H3:H4 line strengths is proportional to the ratio of the A:B nitrogen concentrations. It has been reported previously, and confirmed in the present investigation, that the relative strength of the H4 line may be substantially reduced by heating the diamond at temperatures above about 1200°C. Four hours heating at 1400°C can completely eliminate the H4 band in some diamonds.

c. The most important finding to emerge from our research[17], as far as gem-testing laboratories are concerned, follows on from the preliminary work of Woods[15] on the H1b and H1c lines in irradiated and annealed diamonds. These absorption lines in the near infrared spectral region, at 2024 and 1936 nm respectively, are shown in Fig. 4. The value of these lines in the examination of treated diamonds stems from their annealing behaviour. Fig. 5a shows the decay of the GR1 and the growth of the H3 band as the diamond is heated at temperatures between 400°C and 800°C, and we see that the intensities of these bands behave in a comple-
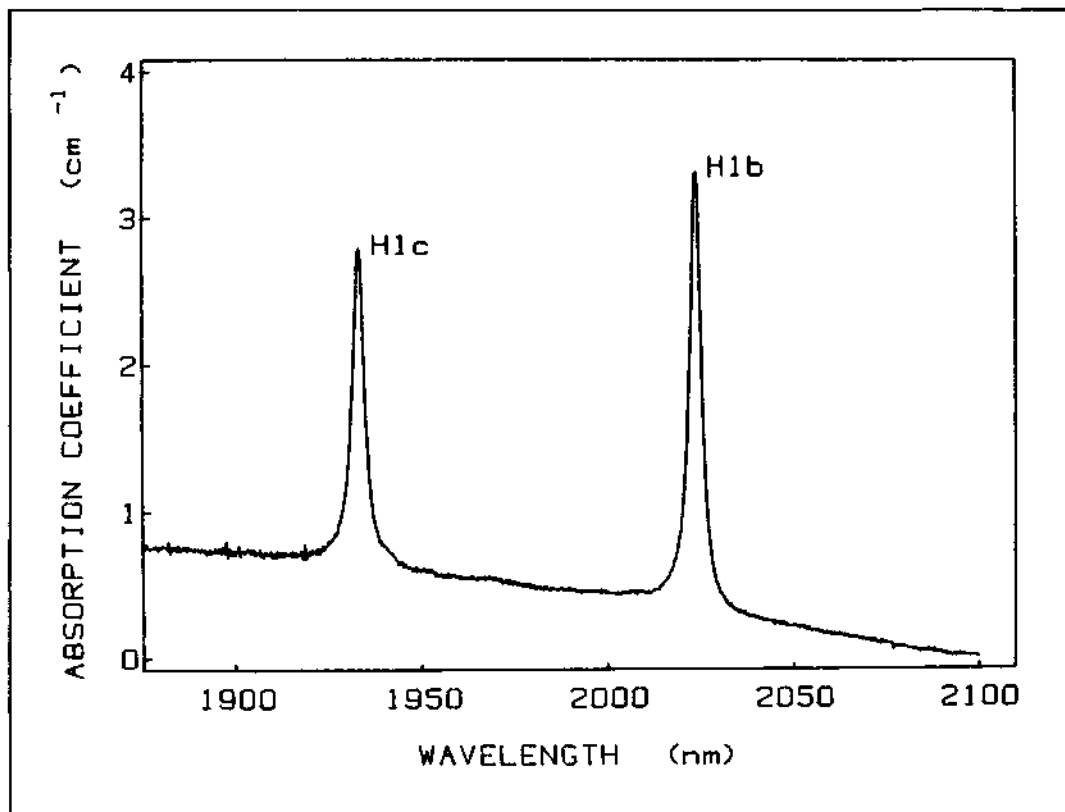
Fig. 4. Absorption spectrum, recorded with the sample at liquid nitrogen temperature, showing the H1b and H1c lines in a treated diamond.

mentary fashion. The H4 band, although not shown for the sake of clarity, behaves like the H3 band. Fig. 5b shows that, at a somewhat higher range of temperatures, exactly the same complementary effect is observed for the decay of the 595 nm band and the growth of the H1b line (the H1c line behaves identically). In particular we note that for annealing temperatures up to 1325°C it is not possible to produce a treated yellow or brown diamond that has not present either the 595 nm line on the one hand, or, on the other, the H1b and/or H1c lines.

Our work[17] shows that the ratio of the H1b:H1c line strengths is proportional to the ratio of the H3:H4 line strengths. However there is no relationship between the intensities of H1b and H3, nor of H1c and H4. These results indicate that H1b and H1c centres are formed when some or all of the constituents of the 595 nm centre become trapped at the A-form or B-form of nitrogen, respectively.

Prolonged heating at 1400°C substantially reduces, or eliminates, the H1b and H1c lines. However, we have found that this drastic treatment results in an unattractive appearance of the diamond, partly because of an absorption often produced at the red end of the spectrum (illustrated in Fig. 6) which imparts a drab, unappealing green colour; and also because of internal graphitization often occurring at micro-inclusions. Moreover, it is very difficult to prevent the polished facets on the stone from becoming frosted. Thus, although it is possible, with care, to heat a treated diamond to 1000°C to destroy the 595 nm line, it is not possible to destroy the H1b or H1c lines without ruining the diamond as a gem.

*Natural fancy diamonds*

We have examined a large number of diamonds in which the H3 band occurs naturally and, apart from one diamond which we discuss later, we find the following:

a. There is little evidence for an absorption line at 1450 $cm^{-1}$ in any of the diamonds;

b. None of the diamonds showed an H4 line, regardless of the A to B nitrogen ratio;

c. None of the diamonds had a 595 nm line;

d. None of the diamonds had an H1b or H1c line.
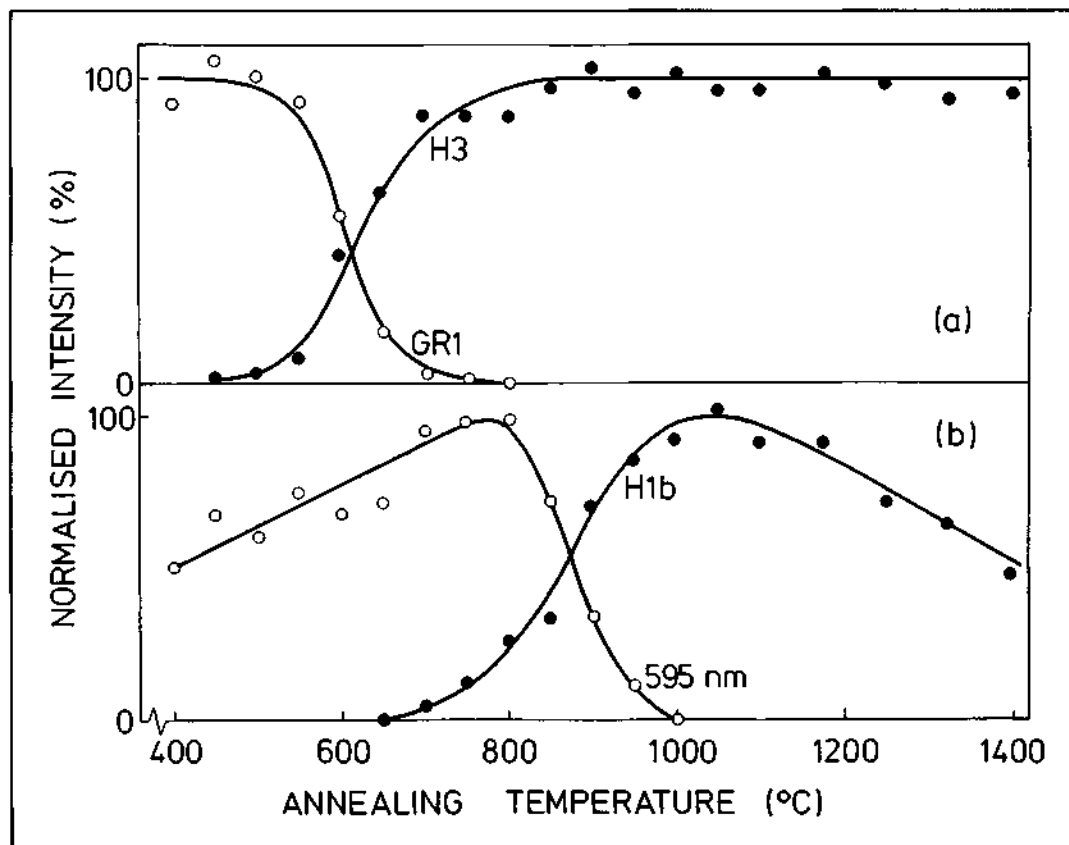
Fig. 5. Annealing curves showing (a) the decay of the GR1 absorption and the growth of the H3 (503 nm) absorption, and (b) the decay of the 595 nm absorption and the growth of the H1b line. The diamonds were heated for one hour at each temperature.

As we have noted above, the 1450 cm⁻¹, H4, 595 nm, H1b and H1c lines can be virtually eliminated in a treated diamond by heating for about four hours at 1400°C, although only at the cost of spoiling the diamond as a gem. In nature the lower temperatures acting for millions of years, on stones in which vacancies have been produced by natural processes, also result in diamonds showing only the H3 absorption band: in this case, however, the stones will not have suffered the deleterious effects which we have described as being a result of the higher temperatures used in the laboratory.

**Spectroscopic assessment of diamonds**

The presence or absence of the 1450 cm⁻¹ infrared line, taken on its own, is not a satisfactory indicator of the origin of the colour of a diamond. Some diamonds which have not been irradiated have an absorption which may be confused with the radiation-induced 1450 cm⁻¹ line. Furthermore, Woods[15] found that this line was *not* present in one of his treated stones, for reasons not yet fully understood. However, a clearly defined 1450 cm⁻¹ line would strongly suggest that a diamond had been artificially coloured.

The absence of the H4 line does not unambiguously mean that a diamond has not been treated. It is perfectly possible, starting with a diamond which does not contain B-centres, to produce an artificial colour with no H4 absorption present. (See Fig. 3b for example.) However, as we have noted earlier, diamonds selected for treatment generally have at least some nitrogen present in the B-form, and the H4 line will therefore be present after treatment. The presence of this line would again strongly suggest that the diamond has been artificially coloured.

The most reliable indicator of the lack of authenticity of the colour of a diamond turns out to be the 595 nm line used until 1978, *taken in conjunction with* the H1b and/or H1c lines. Fig. 5 shows that for an annealing temperature around 700°C, the 595 nm line would be near its maximum strength, but the H1b and/or H1c lines would be
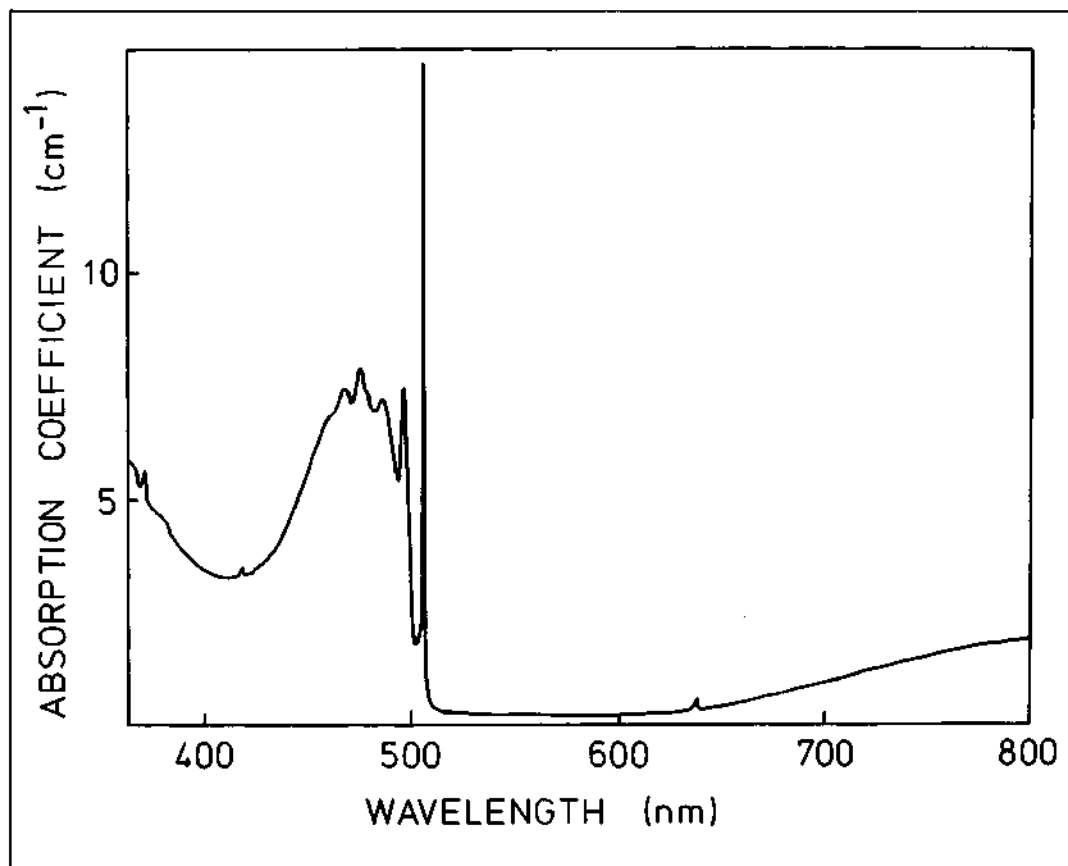
Fig. 6. Absorption spectrum, recorded with the sample at liquid nitrogen temperature, of a treated diamond that has been heated at 1400°C for four hours to destroy the H1b and H1c absorption lines. Note the absorption at the red end of the spectrum (wavelengths above 630 nm) which gives the diamond a drab, unattractive appearance.

barely detectable; whereas for an annealing temperature greater than 1000°C the 595 nm line would be completely absent, but the H1b and/or H1c lines would be relatively strong. An intermediate situation is observed for temperatures between 700 and 1000°C.

*An exception*

A diamond owned by the late Basil Anderson has been referred to previously in this journal[14]. Because it was purchased before 1950 Anderson was certain that the colour was natural. However, the diamond has both H3 and H4 absorption bands with the H3:H4 ratio proportional to the A:B nitrogen ratio, and a well-defined 595 nm line. In our present measurements we have shown that, for this stone, the H1b and H1c lines are very weak indeed, and the spectra are, at face value, all characteristic of a treated diamond that has been annealed at about 750°C.

We must assume that the natural annealing received by this diamond was relatively mild compared with that received by all the others we have examined (in much the same way as type Ib diamonds have experienced a milder degree of heating and nitrogen aggregation than the vast majority of type Ia diamonds). Diamonds like Anderson's are however extremely rare and we believe our method of assessing the origin of the colour of diamonds will be correct in 99% of cases examined. No treated diamonds should be mistaken as naturally coloured, but it is possible that very occasionally a naturally coloured diamond may be classified as treated.

**Conclusions**

Latest developments in research on artificially coloured yellow and brown diamonds have been described. We have shown that it is not possible to colour a diamond artificially using radiation damage

and heat treatment, without producing at least one of the absorption lines at 595 nm, 1936 nm (H1c) or 2024 nm (H1b). When all three are absent the diamond may safely be categorized as 'naturally coloured'. It is desirable to measure the spectra in the visible region with the sample cooled with liquid nitrogen. The H1b and H1c lines, however, are reasonably sharp at room temperature, and in many cases cooling will not be necessary to record the near infrared spectrum.

Very occasionally one or more of the above lines may be present in a naturally coloured stone. In any diamond in which the 595 nm band is absent, but the H1b and H1c lines are present, the strengths of the latter should therefore be compared with those of a known treated diamond which has an H3 band of similar intensity to that of the stone being investigated. If the H1b and H1c lines are very weak compared with the standard stone, then the colour of the diamond under test is probably of natural origin. This conclusion could be firmer if the H4 line is absent or very weak.

Even after completing a detailed series of tests there may be very rare occasions when a naturally coloured diamond is wrongly classified, but it should not in future be possible fraudulently to obtain a 'naturally coloured' certification for a treated diamond that has been heated at 1000°C to destroy the 595 nm line.

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# Green aventurine quartz: mineralogical characterization

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## Introduction

Quartzite, a metamorphic rock consisting of interlocking grains of quartz, may contain small crystals of mica or other minerals. When these accessory minerals impart an appealing colour, sheen or glitter to the quartzite, then it is known as aventurine quartz. Green aventurine quartz is one variety reportedly containing platey crystals of a green chromium-bearing muscovite mica, fuchsite[1]. It is commonly used for beads or set in rings, brooches and other articles of jewellery as well as being used in making bowls, vases and other ornamental objects. Most of the green aventurine comes from India; hence the misnomer, Indian jade. Some localities where it occurs are Belvadi in the Hassan district of Mysore and the Coimbatore,
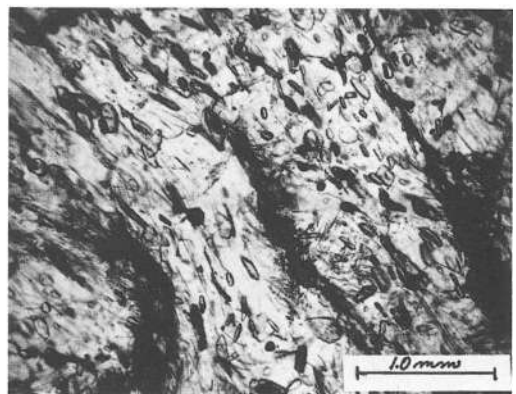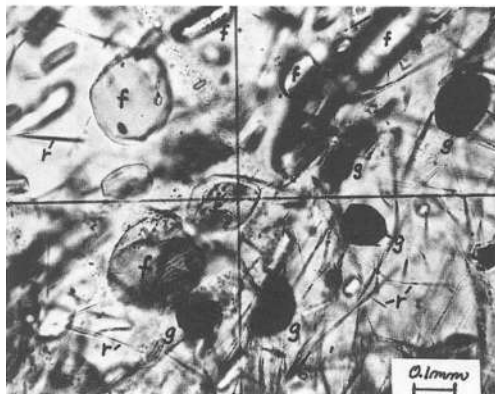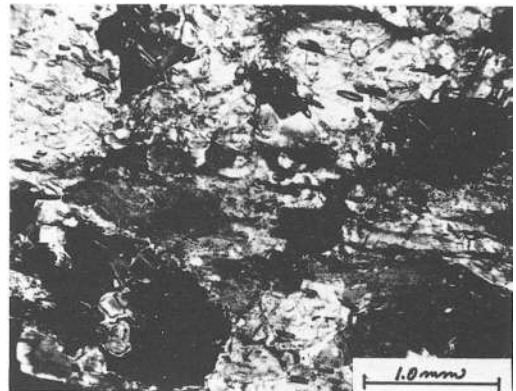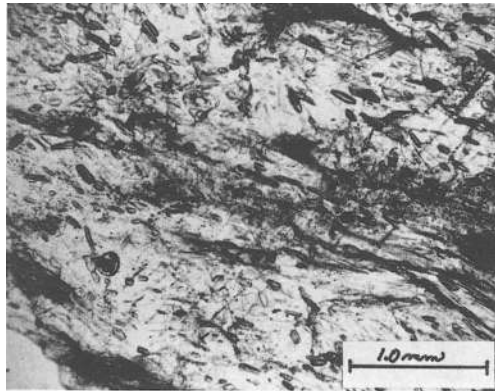


Fig. 1. Transmission light micrograph of a thin-section of green aventurine showing the various mineral components.
1a. Normal light.
1b. Crossed-polarized light.
1c. Normal light. f=fuchsite, g=garnet, r=rutile.
1d. Normal light.

Bellary and Nellore districts of Madras. Other sources are Siberia, Tanzania, China, and Rutland County, Vermont, USA.[1,2]

Previous studies on the mineral description of green aventurine were not found to be reported in the literature. However, Webster[1] states that this material gives a chromium-type optical absorption spectrum, but with the lines in the red rather vague and the broad absorption in the yellow-green region not pronounced.

Green aventurine from the Bellary district, India, was studied in order to determine the mineral constituents present and their microstructural arrangement. These analyses were conducted by means of petrographic microscopy, scanning and transmission electron microscopy, X-ray diffraction and electron microprobe spectroscopy.

## Petrographic microscopy

Thin sections showed the aventurine to be composed of a complex array of four crystalline minerals. Interlocking, irregularly-shaped grains of quartz, $SiO_2$, formed the bulk of the specimen. Associated with the quartz were three accessory minerals, fuchsite mica, $K(Al, Cr)_2(AlSi_3O_{10})(OH)_2$; rutile, $TiO_2$; and almandine garnet, $Fe_3Al_2(SiO_4)_3$.

Figs. 1a and 1b show this microstructure using normal light transmission and the same field using cross-polarized light. The relatively large polyhedral quartz grains can be seen best in Fig. 1b where some of these grains up to about 1.0 mm in size are at partial or complete extinction (black). The smaller 0.1–0.2 mm transparent green euhedral crystals of fuchsite are in abundance as are the grey hair-like fibres of rutile which are aggregated into

bundles in some areas. Small dark red crystals of garnet, less than 0.1 mm, occur with less frequency. At the higher magnification of Fig. 1c some of these minerals are marked with identifying labels. The subparallel texture of the rutile fibres and fibre bundles as well as the platey fuchsite mica crystals imparts a schistosity to this metamorphic rock which is readily observed in Fig. 1d.

## Electron microscopy

Transmission and scanning electron microscopes were used to examine fracture surfaces of the aventurine. These instruments revealed the granular texture of the quartz along with the accessory crystals of mica. The rutile and garnet crystals were not identified by these methods.

Fig. 2a shows the granular texture of the quartz on a fracture surface of the aventurine observed by scanning microscopy. A fracture crevice travelling through the quartz contains fuchsite mica.

Transmission electron microscopy using the replication method also revealed the granular nature of the specimen. Fig. 2b shows one region at high magnification where a small crystal of fuchsite mica is located at the grain boundaries of three relatively large grains of quartz. The mica crystal displays a parallel step-like topography reflecting the perfect cleavage inherent in this mineral.

## X-ray diffraction

The powder X-ray diffraction pattern of aventurine obtained using a diffractometer showed peaks assignable to quartz and mica. Although almandine garnet and rutile were indicated by light microscopy, their volume percentage in the
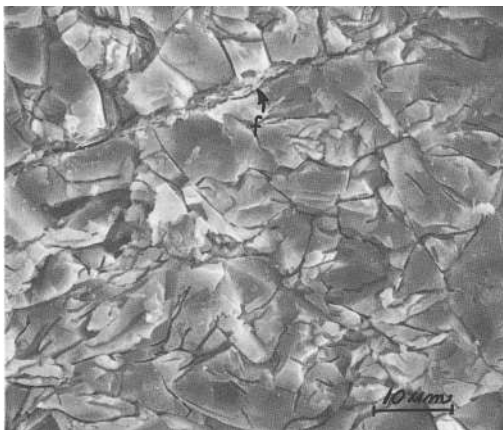


Fig. 2a. Scanning electron micrograph of the surface of green aventurine. Etched with NaOH. The grains of quartz are clearly discernible. Fuchsite (labelled f) occurs in a fracture crevice.
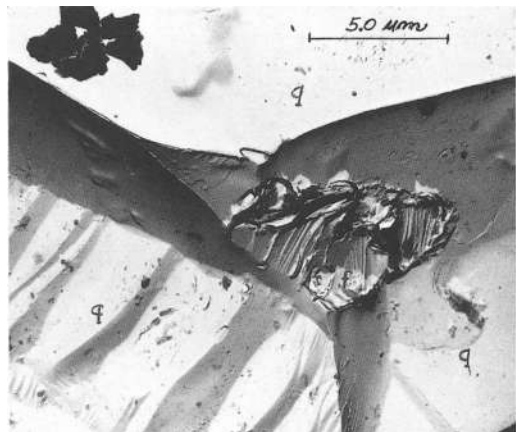
Fig. 2b. Transmission electron micrograph of the surface of green aventurine. Replication. Crystals of quartz and fuchsite mica are present in this field. q=quartz; f=fuchsite.
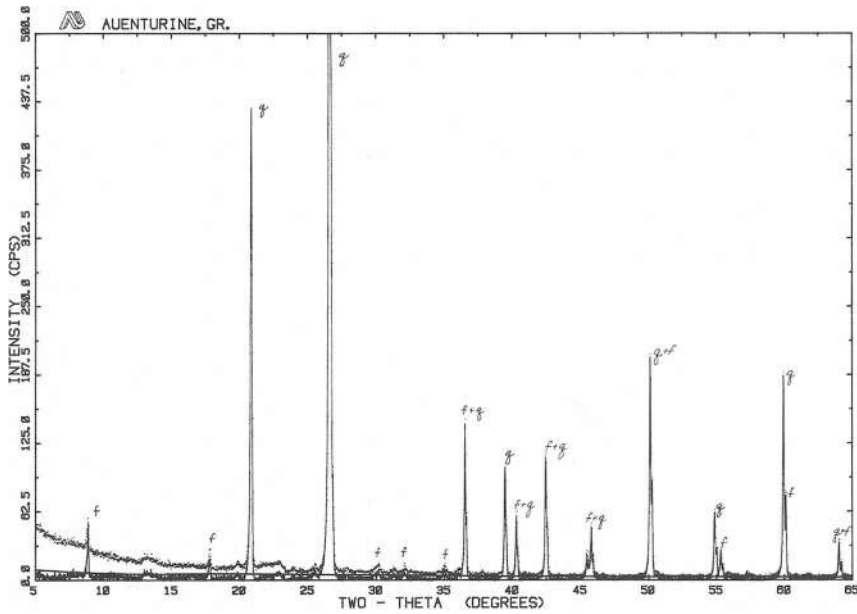
Fig. 3. X-ray diffraction pattern of green aventurine. CuKα radiation. Diffraction maximas identified by q=quartz and f=fuchsite mica.
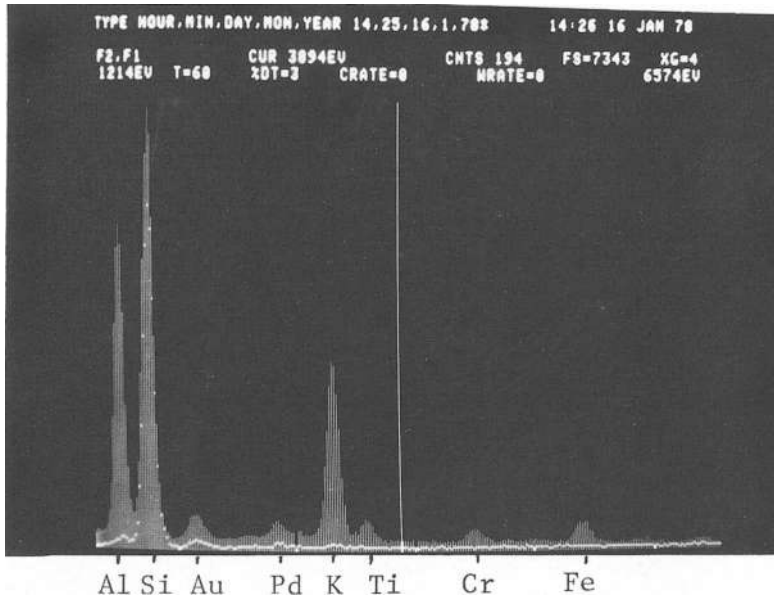


Fig. 4. X-ray spectrum emitted from green aventurine during electron microprobe analysis. Elements corresponding to the X-ray peaks are given by chemical symbols.

aventurine was too low to be detected by X-ray diffraction. These X-ray results are presented in Fig. 3.

**Electron microprobe spectroscopy**

Chemical analysis of the elements present in the aventurine was carried out by identifying the X-rays emitted from the sample when bombarded by an electron beam.

Fig. 4 shows the X-ray spectrum which was obtained. The various X-ray peaks are identified as to their corresponding chemical element. With the exception of the elements of gold (Au) and palladium (Pd), which were derived from the electron-conductive metal coating that was applied to the aventurine surface, all the elements detected corresponded to the various mineral species present.

Taking the elements in the order they appear on the graph in Fig. 4, aluminium (Al) occurs in

almandine garnet, $Fe_3Al_2(SiO_4)_3$, and in fuchsite mica, $K(Al, Cr)_2 (AlSi_3O_{10})(OH)_2$. Silicon occurs in quartz, $SiO_2$, as well as in the garnet and mica. Potassium is found in the mica, titanium occurs in rutile, $TiO_2$, chromium occurs in the mica and iron occurs in the garnet.

**Acknowledgement**

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# Locating gem deposits by computer

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The information explosion about which so much is heard today is no passing phenomenon. The range and amount of literature (not always in book or journal form) with relevance to gemstones is surprisingly large and often appears to be growing exponentially. After nearly twenty-six years in national libraries, during which time I have examined virtually every piece of information on gemstones ever published, I am no closer to claiming close acquaintance with the whole field. The growth of information is matched, too, by growth in those interested in it and the interest shown manifests itself at a number of levels. As Curator of the largest European collection of earth science books and journals one of my chief tasks is to supply precise or general information from the collections as well as to build it up and maintain its eminence.

## Sources of information

The readership of such an institution as the Science Reference Library (part of the British Library) has changed since its physical separation from the British Museum in the early 1970's. Readers even in those days would have been content to check gemmological points in the standard text-books of the time and though there were in fact many other sources to which they could turn even then, few were aware that much useful data could be found in physical and chemical texts and journals as well as in mineralogical and geological ones. There seems to have been an unwillingness on the part of writers on gemmological topics to refer to outside sources, so that until very recently even the better monographs provided inadequate bibliographies with few citations of pieces other than those which most readers would already have known about. Even today almost all the gemmological texts are found wanting in this area. This may partly be due to the readership aimed at, since if a book can be addressed to the beginner, time and scholarship do not need to be spent on extensive literature searching. Another explanation may be that many writers are themselves unfamiliar with

the scale of the resources now available and it is true that, unless a conscious effort is made to find out what is there, useful, even vital material will be missed.

Much of the elusive material is concerned with the location of minerals since many finds are first communicated to those needing to know and for obvious commercial reasons publication in high-relief texts would not be contemplated. Again, many gem minerals are found during prospecting for something else – a good example is the discovery of gem spodumene in the lithium mines of southern California. Recovery of strategic minerals may pay for the recovery of otherwise uneconomic gem specimen material and only the mineral may be thought worth recording. Those who do the recording will send details to a mineralogical or economic geology journal and may not think of *The Journal of Gemmology*.

## Maps

Further useful information can be found in geological maps and in the maps produced for a limited and specific purpose. Again, access to maps is a specialized skill and finding out who actually holds a particular map is not always easy. Major libraries hold standard surveys, including geological ones, but many gem locations are not shown, either because they are too insignificant as places or the name used by miners is too local to get further than the immediate area. Many gem locations are known by more than one name and when a name is used it may refer to the nearest place of significance which may be some miles away from the actual mine (e.g. Sandawana). Where a name is used on a map and the deposit is described in the literature it ought to be possible to locate both even when the two names used are different. How this can be done will be seen later.

In the absence of definite detail about existing gem locations, possible ones can also be predicted if the right map is to hand. This will in all cases be a geological map since these are the only ones upon which elements are shown. If beryllium is seen on a

map (usually as Be) then the possibility of the presence of one of the beryl gemstones is there.

The overall picture then is one of a mass of information, much of it fairly easily predictable and obtainable but with an underlying mass of data which is at once both valuable and unsuspected. The value of this type of information is that it is usually more specific and first-hand, being taken from workers in the field.

As anyone who has used *Chemical Abstracts* will know to their cost, the fear that something important may be overlooked through inadequate searching technique can be considerable and it is now unreasonable to expect anyone to search an increasingly large footage of small-type paperwork. To be sure of finding all there is on a particular topic at least a dozen journals need to be consulted and although *Mineralogical Abstracts* covers the earth science side well, many searchers for details of gem deposits may need to look in mining or economic sources or even in general science journals such as *Nature*.

Clearly some form of mechanized retrieval system is as necessary in the location of gem deposit information as it is in subjects with a wider background.

**Databases**

Fortunately today we have at least two databases concerning themselves with geology, mineralogy and allied topics. The databases GEOREF and GEOARCHIVE (American and British-based respectively) can be accessed through the Lockheed DIALOG host which itself is easily obtainable by subscribers to British networks with access to PSS (Packet Stream Switching). The technique of searching is not hard to master, but the real skill comes in avoiding unnecessary expense, since a lot of time can be spent pondering the next move while the system is actually live. There are ways of getting round this, as will be seen below. For greater ease of understanding, search qualifiers are not included in the descriptions below. Intending searchers will need to learn the qualifiers appropriate to the database host they select.

**Searching**

Searching for a topic means that the computer will look for given words, phrases, map coordinates or the names of authors and present them to the user in the form of "hits". A large number of hits is not necessarily helpful since the word GEOLOGY will appear so often in a geological database that to ask for it is a waste of time. We need to know how to avoid this waste by giving the system more specific words and combinations so that it will be able to narrow the search, remembering also that the

material loaded into the system may be in different languages: if we expect a paper in German about emerald to include the word EMERALD rather than SMARAGD we may lose that paper. One way to bear this in mind is to reflect on the history of the country in which we are interested: former French colonies will be more likely to have papers written about them in French (EMERAUD). Again, the computer is literal and if you ask it for references including the word RUBY it will ignore RUBIES.

The two main databases are loaded (stored) with material in the form of abstracts so that the searcher's hits will include not only the title of relevant papers but abstracts of them. The most economic way to check whether or not a paper will be worth printing out is to get the system to type the title or the paper in précis form; only after this need the searcher opt for the full abstract (which is more expensive). It is hoped that *Mineralogical Abstracts* will be loaded on to GEOARCHIVE during 1986.

It is relatively easy to locate a paper on a particular gemstone; the name of the species can be keyed in accompanied by country name where known or by the name of the author (be careful with spelling) in addition:

RUBY AND MOGOK AND IYER

will give any paper whose keywords include the three (not any other paper and not any which contain only two or one keywords out of the three). For less certain searches it would be preferable to key

RUBY OR MOGOK

so that the system would look for papers with either keyword. Should the searcher already know about the Iyer paper and therefore not want to spend money on it he would key

RUBY OR MOGOK AND NOT IYER

The use of AND, OR and AND NOT is known as Boolean logic and is familiar to all computer users: without this conditioning searches would be hugely unwieldy, producing vast amounts of repetitive information.

If we wish to range in our search for ruby a little more widely we can key

RUB?

– this device is known as a truncation and will give hits for ruby, rubis (French) and rubies. A similar strategy for diamond might be

DIAMON?

but this would lead to an oversize response, since the terms diamond, diamondiferous and even Diamonair would be retrieved. In the latter case the use of AND NOT is indicated. In the same way PERIDOT? would give both the gem of that name and peridotite.

For more general concepts we need to be able to use the term that a system prefers. What these

terms are can be found in a dictionary-like work produced by the originators of the database and known as a thesaurus. Here we can find whether the database recognizes the term 'synthetic' in the sense that gemmologists give to it or whether 'man-made' is preferred. All thesauri are large because they contain so many cross-references and in addition some may carry numerical codes for geographical areas as well as for some general concepts.

Many papers are written for the more popular journals and in such cases may have rather fanciful titles. The searcher will not be able to guess that a paper on peridot has the title *Green gems from the Red Sea* but RED SEA is acceptable as a phrase, as is MAFIC ROCKS. Keying in RED SEA OR MAFIC ROCKS OR GEM? would give us the Gübelin paper on Zabargad, the spelling of which is romanized in different ways, this making it an uncertain search term on its own.

### Searching coordinates

There is no detailed map of world gemstone deposits apart from that produced in the 1960s by the French Bureau de Recherches Géologiques et Minières. This uses an equiareal projection and a scale of 1:40 000 000. This does not allow for much distinction between rock types, and in fact eight different types of gem deposit are distinguished:

    deposits enclosed in volcanic rocks and their vents
    decay deposits of volcanic rocks
    pegmatite deposits
    lode deposits
    metamorphic deposits
    endomorphic deposits
    decomposition deposits
    other types.

A careful study of the deposits as shown on the map will show where they fit into the map coordinates (latitude and longitude). The two main databases will accept map coordinates as search terms and these can be combined with country names, deposit type names as listed above (consult the thesaurus to see if these are acceptable phrases for your database) and species names:

    Lat. 22° 50′ 45″ N to 23° 5′ 15″ N and Long. 96° 19′ to 96° 35′ E would give us the Mogok Stone Tract in Burma: they should be combined with GEM? or RUB? or SAPH? or CORUND? or KORUND

to give one search. Results of this (the number of hits) could be combined with shifts in the coordinates to see if further corundum gems were reported from neighbouring areas. On the whole these areas are well reported and stones from them have been the subject of papers for many years. A deposit of significance for strategic elements as well as for gem material can be found by searching on

    Lat. 15° to 25° 8′ S and Long. 22° to 28° E and adding the term MANGAN? (for both English and German spellings of manganese). The deposit is the Kalahari manganese orefield from which magnificent orange-pink rhodochrosite has been recovered. As the ore is likely to be of more importance than the gem material it may be worthwhile using a metals database rather than a geological one. Since this deposit was located partly at least by the use of remote sensing using the LANDSAT satellites, a look at the 16 mm browse film produced from their orbits will show useful areas with coordinates worth inputting.

For those interested in getting the most up-to-date information on a prospect the date of publication of particular papers can be significant, and when the subject is a popular one a cut-off date can eliminate large quantities of paper. In most databases this is done by keying in PY = 1960–1980, for example, so that any paper with a publication date not falling in that range is not brought up.

Likely prospects for gemstones can be checked by inputting the names of features which have been found to be common accessories to known deposits of the desired species. For a deposit similar to that in the Pala area of southern California we could try coordinates plus GRAPHIC GRANITE OR SCHORL OR MUSCOVITE to see if these have been reported as occurring together (it would be surprising if they did not). We could add lithium as a concept by typing Li? or the full word.

### Chemical data

Chemical formulae can in fact be entered in addition to the terms already mentioned, providing that they are mentioned in the papers abstracted. Normally chemical searches would take place in *Chemical Abstracts* (which contains a good deal of geological information), but this is a very large database which needs skilful handling. We know that there are 2 331 890 possible quaternary compounds (i.e. having four elements) and 109 736 ternary ones. As the total number of known mineral species is only about 3000 some kind of selection is clearly operating and possible compounds can easily be found by using the computer. A paper describing calcium and oxygen will not normally mention that no CaO forms naturally on earth since Ca and O combine more efficiently with $CO_2$ to form $CaCO_3$ but once such sources as *Chemical Index to Minerals, Glossary of Mineral Species* and lists of new and discredited minerals are loaded into a database it will be possible to search on various elements and their compounds to see which combine.

In a similar way optical and physical constants

will be able to be searched in conjunction with species names, place names and chemical terms to see whether there can be a red tourmaline with abnormally high refractive index; whether there can be gem materials which include boron and whether this is linked with any particular type of rock formation.

I should like to encourage gemmologists to visit the Science Reference Library to see what we can already provide and to conceive what may be possible in future. Anyone who has regularly scoured the tiny print of the hard-copy *Chemical Abstracts* or *Index Medicus* will know how much easier it is to use the computer, and it does provide opportunities for bringing together concepts which no hard-cover work could afford to do.

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# A description of the jasper found at the Orinduik Falls in Guyana, South America

*(Cover photograph)*

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In the north-east of South America between Venezuela and Surinam and to the north of Brazil lies Guyana. The name comes from an Amerindian word which means 'Land of Waters', and this is an apt description since great rivers dominate the country.

One of these is the river Ireng which is the natural boundary between Guyana and Brazil. On this river lies the tiny community of Orinduik with its air strip, two stores and Amerindian settlement where guides and helpers may be hired. On these settlements live Wapisianas and Macusi Indians, who are a sturdy, small built people with a tremendous capacity for hard work and fun.

From the early days of geological exploration it has been recorded that certain areas of Guyana had a wide range of ornamental stones. Among these was a very handsome red jasper that was found in large quantities around Orinduik in the Pakaraima Mountains. In the early 1970s both the quantity and quality found encouraged the Ministry of Energy and Natural Resources to set up a new industry based on the utilization of these materials. This project was assisted by British Technical Aid arranged by the Ministry of Overseas Development and the author was privileged to carry out the scheme for the people and Government of Guyana.

To reach Orinduik from Georgetown could take about two weeks by river and land since much of the journey would be through miles of the most beautiful jungle scenery, which is still largely unexplored. Normal access with Georgetown is by Guyana Airways, which takes only a few hours, and once there overland communications are good.

The area is the habitat of a small fly called locally Kaboura, which produces a maddeningly itchy bite – fortunately it yields to insect repellents.

Orinduik lies in the south-western part of the Pakaraima Mountains, which are underlain by the geological unit known as the Roraima Formation.

This consists of a great thickness of current-bedded, pink and red ferruginous sandstones and arkroses together with shales and conglomerates. Mount Roraima is not too far from Orinduik and rising sheer out of the jungle gave Sir Arthur Conan Doyle the geological basis for his popular classic 'The Lost World'.
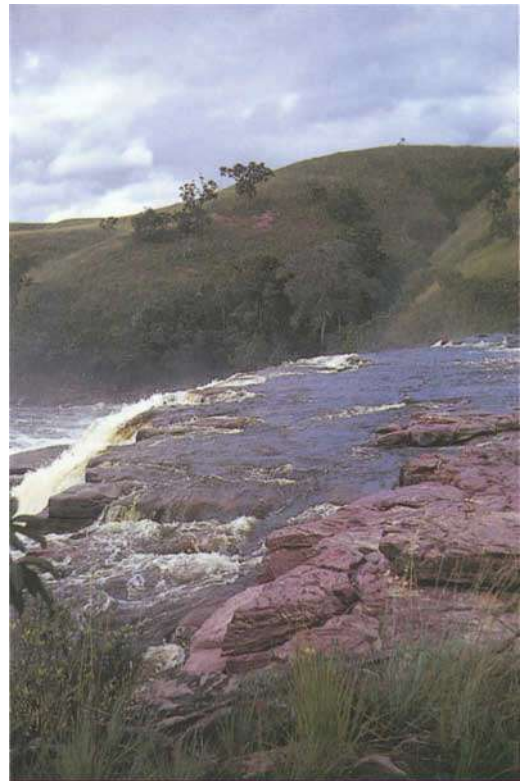


Fig. 1. Falls at Orinduik showing red jasper and blocky sandstone outcrop. *Photograph by J.G. Gosling.*

At first sight from Orinduik the Falls appear as a series of vast steps at the head of the valley, but from the air one is aware of three major falls and about a dozen minor drops. The overall effect is one of breath-taking beauty, since all the rock faces of the falls are formed of dusky red quartzitic sandstone and interbedded jaspers. These quartzitic sandstones are fine to very fine grained and often break with conchoidal fractures but are fairly easily distinguished from the true micro- to crypto-crystalline jasper used as an ornamental stone.

Large boulders are also found rolled along in the

insects in the area, but the fireflies, or candleflies as they are called locally, leave a lasting impression because of the brilliance of their blue-green light emission at night.

Farther away from the Ireng river and out on the savannas another interesting jasper formation is to be found. Here strange forms are created by wind erosion. In this type of erosion sand is whipped up by the wind and cutting its way into the jasper produces weird shapes and strange angular castles of all sizes.

In other areas of the Roraima Formation many



Fig. 2. Searching for red jasper pebbles by a brownish-red sandstone outcrop, Orinduik Falls. *Photograph by J.G. Gosling.*

Ireng river and were particularly fine above the last major fall, and it was discovered that the best jasper for tumbling or cutting was found just below the last major fall. (Photograph on front cover.)

This seemingly idyllic spot can hide a few dangers, as just above the Falls are beautiful sheltered pools but one must be aware of the deep holes there, since these may host a very powerful electric eel, which has a sting sufficiently powerful to stun a man and allow him to drift over the edge of the Falls.

There are many interesting animals, birds and

varieties of jasper have been found including grey, purple, brown, green, spotted and banded forms.

After these materials had been collected and sorted, they were transported back to the small industrial unit in Georgetown and fashioned into clockfaces, paperweights, jewellery units and a host of other objects for sale locally and for export.

This project continues to flourish and has been expanded to other areas in the interior.

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# Notes from the Laboratory – 6

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On occasions, because of his cunning and artistry, the perpetrator of an attempt at gemmological skulduggery might be thought of as a person deserving a little of our admiration. This should be far from the case. Any intended dishonesty must be looked upon in the light of the knowledge that the been made up from several parts of old rings and one section included part of a hallmark with a date letter similar to that used for the period 1916–17 (Fig. 3) – many years before the production of synthetic opal!

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Fig. 1. A synthetic opal in a ring made up from several parts of old rings.



Fig. 2. A synthetic opal in a ring made up from several parts of old rings (side view).

person involved is attempting to sully the reputation of the gemmologist and others who handle jewellery.

An example of this cunning and artistry was seen when we were asked to examine the marquise-shaped opal set in the ring seen in Figs 1 and 2. The stone was clearly a synthetic showing the typical 'lizard skin' structure and columns of colour. In fact there cannot be a gemmologist who would have been in any doubt as to its identity. On this occasion the attempted deceit was, we believe, aimed at the 'antique' dealer/collector who perhaps has only a limited knowledge of gemstones, rather than the pure gemmologist who might not have much knowledge of old jewellery. The ring had



Fig. 3. The hallmark in the shank of the ring seen in Figs 1 and 2.

Fig. 4. Natural opal 11.49×8.31×2.11 mm (see Figs 5, 6 and 8 for structure).
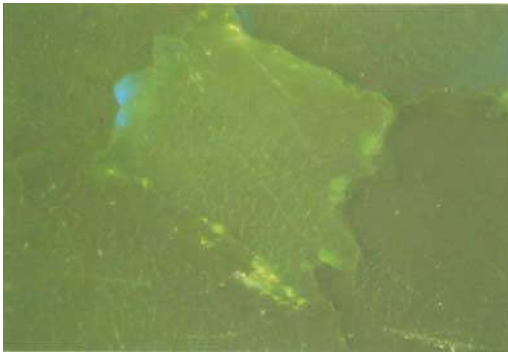


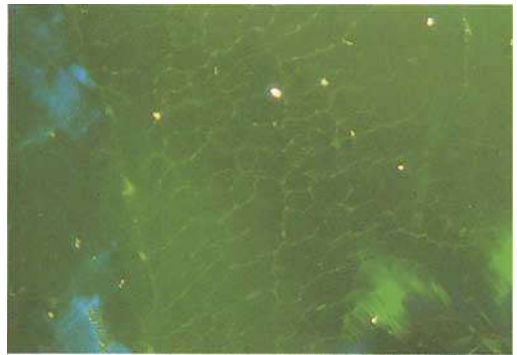Fig. 5. 'Chicken wire' type structures in the natural opal seen in Fig. 4.



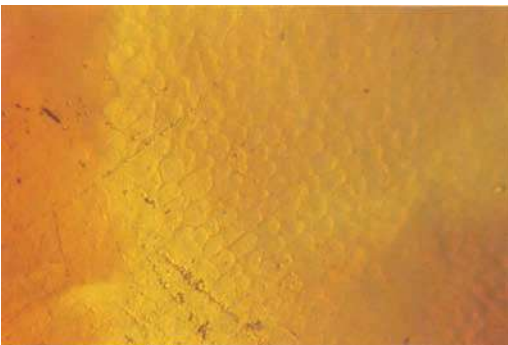Fig. 6. A closer view of the 'chicken wire' type structures seen in Fig. 5 in a natural opal.



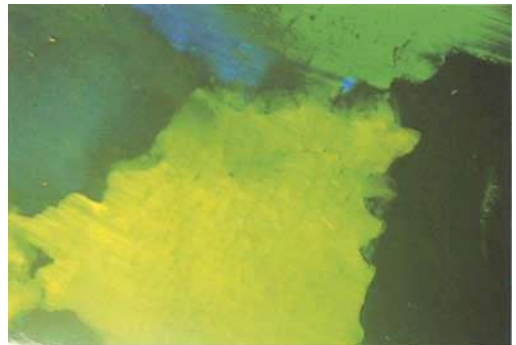Fig. 7. 'Chicken wire' structures in Gilson synthetic opal.



Fig. 8. Dark matrix veins in the natural opal in Fig. 4 giving an appearance similar to an opal that has been sugar-acid treated.

Some years ago when the first papers were published detailing the diagnostic structures of synthetic opal[1,2], an eminent British gemmologist stated that he had seen similar structures in natural opals. In the intervening period we have noted a number of peculiar structures in natural opals. Many of these have resembled the structures seen in sugar-acid treated opals but have revealed themselves to be, for example, oolitic opal. We have never seen a natural opal in which the structures are identical to those seen in the Gilson material.

Amongst those which we have examined the closest we have come to a synthetic-like structure in a natural opal was seen towards the end of 1985. The structure was seen in the 1.50 ct stone depicted in Fig. 4. The stone measured $11.49 \times 8.31 \times 2.11$ mm and was backed by its matrix. The matrix travelled through the opal in veins and these were arranged in a pattern (Figs. 5 and 6) which was similar in some ways to the 'chicken wire' structure seen in transmitted light in some synthetic opals (Fig. 7). In reflected light (Fig. 8) the dark colour of the matrix in the veins gives the impression that the stone has been sugar-acid treated, which it has not.

\*       \*       \*

In 1984[3] details of a large hollow baroque pearl were reported upon in which the cavity had been 'filled' with a number of beads. The beads had 'an opacity to X-rays comparable with that of the setting'.

Two further examples of large hollow pearls with their cavities filled with artificial materials have been examined recently. The first pearl measured approximately $18 \times 15$ mm and, as can be seen in Fig. 9, had a very large internal cavity. The pearl had been drilled in one place and through the drill hole the cavity had been filled with what appears on the radiograph to be wire. Upon looking into the drill hole some form of adhesive substance could also be seen in the cavity.
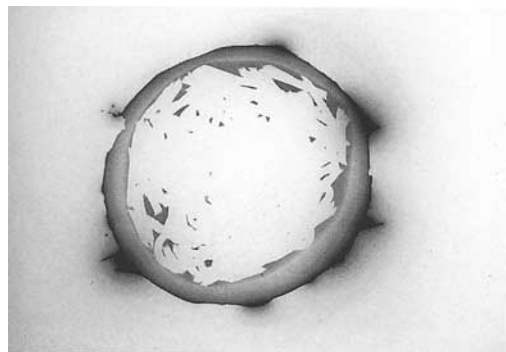


Fig. 9. Radiograph of a large hollow pearl in which the void appears to have been filled with wire.
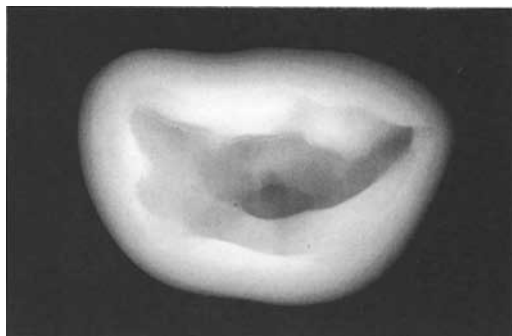


Fig. 10. Radiograph of a large hollow pearl in which the void appears to have been filled with a resin-like substance.

The second example weighed 28.58 ct and as can be seen in Fig. 10 it also had a large internal cavity. The pearl had been drilled in one place and this time the cavity had been filled with a soft substance similar in appearance to a dry resin. The substance was heated with a hot point and the odour produced was similar to a burning plastic when smelt in close proximity, but at a greater distance the smell was similar to frying bacon.

\*       \*       \*

If one looks back through the gemmological journals of recent years it will be realized that quite a number of manufacturers are either producing or have the capability of producing synthetic rubies. Mostly if these manufacturers market their stones they do so openly and make various announcements about them. It is quite unusual to have placed before you a number of obviously synthetic ruby crystals, the manufacturer of which nobody seems to know.

This happened recently when we were shown the crystals depicted in Figs 11 and 12. The crystals in Fig. 11 had a lot of included orange flux and those in Fig. 12 had platinum wire protruding from them.

\*       \*       \*

An interesting and effective amber 'treatment' was brought to our attention during the latter part of 1985. A dealer who purchased an 'amber' drop with a view to repolishing it was surprised to find that the colour of the material was located in the surface area only and that beneath the surface it was colourless (Fig. 13). The colour penetrates the colourless material along flaws (Fig. 14) and these when viewed side on (Fig. 15) bore a close resemblance to the stress figures seen in much clarified amber[4].

The material has an SG of 1.04 and an approximate RI of 1.55–1.56. There are numerous included
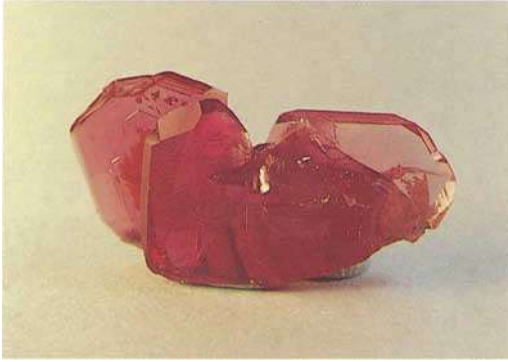
Fig. 11. A group of synthetic ruby crystals with included orange flux.



Fig. 12. Two synthetic ruby crystals with platinum wire protruding.
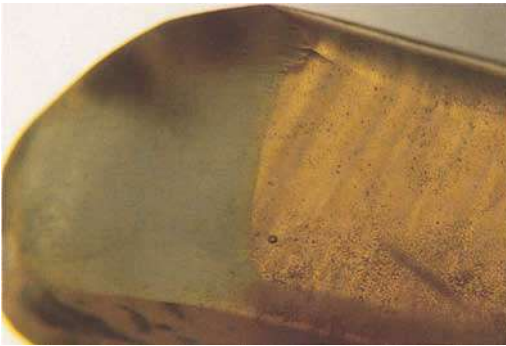


Fig. 13. Amber in which part of the surface yellow colour has been polished away revealing the colourless material beneath.
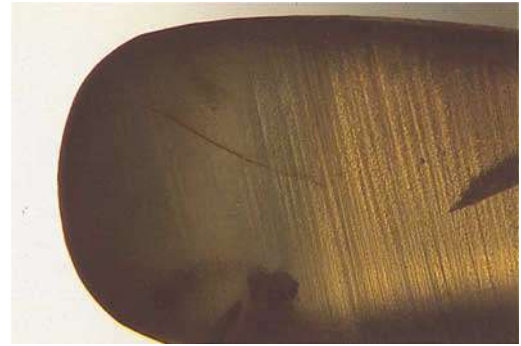


Fig. 14. Amber in which the surface coloration (see Figs 13 and 15) also penetrates the colourless underlying material along flaws.



Fig. 15. A flaw in the amber of Figs 13 and 14 which resembles the stress figures seen in much clarified amber.



Fig. 16. A 4 mm broken natural pearl.

bubbles, the greater number of which are just under the surface (see Figs 13 and 15). The colour is not a discrete coating on the surface, such as a paint or a varnish, but appears to have been diffused into the surface of the material by gentle heating. The colourless area in Fig. 13 fluoresces a bright light blue under ultraviolet light whilst the yellow area fluoresces a mustard-yellow/green. The material is very soft, sectile, and when heated with a hot point produces a smell similar to that produced by amber. Additional pieces of this material are now being examined and more details will be published in a future number.

<div align="center">*    *    *</div>

The 4 mm broken pearl in Fig. 16 was strung in a necklace of natural pearls. The owner of the necklace assumed that the apparent 'bead' revealed by the break indicated that it was a cultured pearl. In fact radiographs of the pearl proved it to be natural.

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# An unusual needle-like inclusion in gem sinhalite from Elahera, Sri Lanka

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Elahera, the north-east gem field of Sri Lanka is well known for the occurrence of near colourless, yellowish, brownish or greenish-brown sinhalites of gem quality. The internal paragenesis of these sinhalites often exhibit mineral inclusions such as zircon, apatite and mica, and liquid feathers including two-phase cavities. However, to date sinhalite with rutile or similar needle-like inclusions is not known. While collecting sinhalites from this gem locality it was evident that one sample contained needle-like inclusions which are orientated in certain crystallographical directions of the host gem (Fig. 1).

Since it was the opinion of some gemmologists that the inclusion was rutile, further investigations were needed to confirm the nature of these needle inclusions.

The gem microscope provided noteworthy information during the investigations. It revealed the orientation of the needles parallel to the three main rhombic crystal axes. Under cross-section examination the needles were of tetragonal symmetry (Fig. 2). However, the distinct surface lustre of rutile was absent when observed under reflected light. Along the length of these needles there were portions transparent enough to show the enclosed iron oxide concentrations (Fig. 3). This is not the case in rutile inclusions seen in many other gemstones. Further, immersion microscopy revealed the clear transparent nature of the needles.

A suitable optical flat was available on one of the rear facets with an exposed portion of the inclusion. Under these conditions the electron
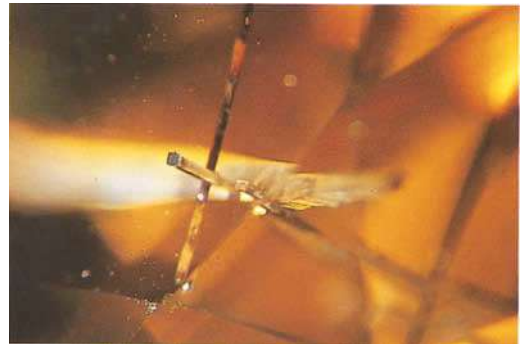


Fig. 2. Apparent tetragonal symmetry of the needle-like inclusion under cross-section examination. Dark field 40x.



Fig. 1. Gem sinhalite of 8.43 ct from Elahera, Sri Lanka, with orientated needle-like inclusions.
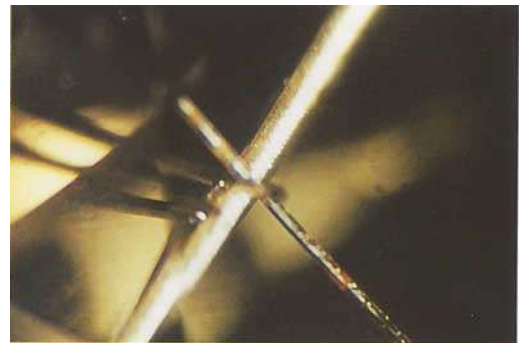


Fig. 3. Transparent areas of the needles clearly showing the iron-oxide concentrations. Dark field 55x.

beam of the microprobe signalled the Fe and Si peaks. However, these chemical components did not show any crystalline nature nor any X-ray diffraction patterns.

Both the gemmological and chemical investigations have contributed in recognizing the needle-like inclusions in Elahera gem sinhalite. Neither the microscope nor the microprobe provided any clue that the inclusion was rutile. Furthermore, the chemical component without any crystalline nature suggested that the inclusion was a secondary cavity filled with iron oxide. These hollowed needles probably formed in the gem sinhalite during growth and were related to the main crystallographical directions of the host. They were then filled with iron oxide and other chemical components from the neighbouring rocks.

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# Gem hornblende from Baffin Island, NWT, Canada

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## Introduction

Baffin Island is situated north of the province of Quebec, on the southern fringe of the Arctic region, in the District of Franklin, Northwest Territories, Canada. Field parties from the National Museum of Natural Sciences and the University of Ottawa have investigated mineral deposits on southern Baffin Island with an emphasis on lapis lazuli. D.D. Hogarth (1971) studied the lapis lazuli deposits in detail as a potential source of gem material. These deposits have been known to the local Inuit (Eskimos) for decades, and are presently under claim with them, but there has been no development of the property. The paper 'Lapis Lazuli from Lake Harbour, Baffin Island, Canada' (Grice and Gault, 1983) gives a good overview of the situation regarding travel and collecting in the area, and describes some of the minerals that have been collected. Travel is difficult because it is an isolated area with only a short ice-free period (July and August), and variable weather including erratic fog banks.
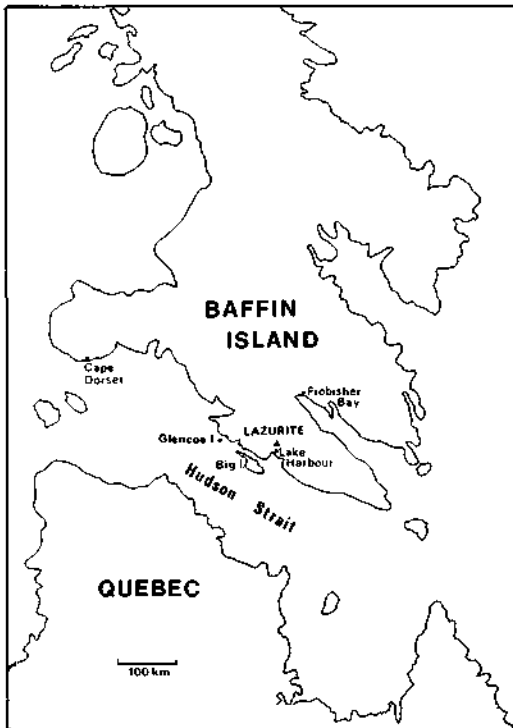


Fig. 1a. Location map for southern Baffin Island.
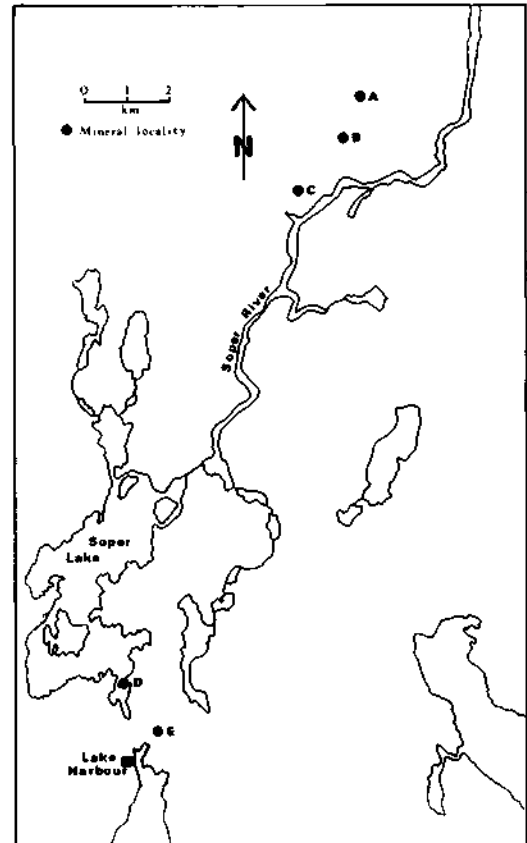
Fig. 1b. Soper River mineral localities: B – north lapis lazuli deposit; C – south lapis lazuli deposit and hornblendes.
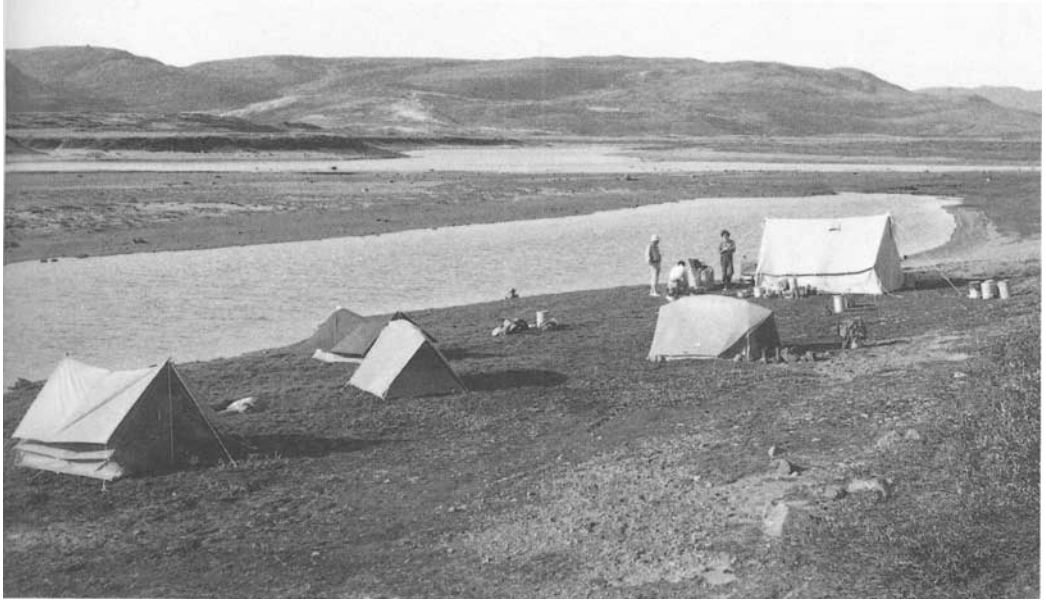
Fig. 2. Camp at Soper River, Baffin Island, NWT, looking north to the lapis lazuli deposits (in white marble).



Fig 3. Phlogopite mica pit near the south lapis lazuli occurrence where facetable hornblende was found in 1980.

## Geology

The lapis lazuli of southern Baffin Island lies within a series of highly metamorphosed sedimentary rocks, the most abundant being garnet-biotite gneiss and marble. The dolomitic marble, which is coarse grained and almost white in colour, commonly contains diopside, amphiboles, phlogopite and clinohumite, as well as lazurite deposits. Other minerals such as meionite, uvite, spinel, graphite, forsterite and titanite occur more rarely in the marble.

## Hornblende occurrence

One of the areas visited by Grice and Gault in 1980 was along the Soper River some 15km north of Lake Harbour (see Figs. 1 and 2), near the previously known 'south lapis occurrence' and 'north lapis occurrence'. Hornblende is common there in the marbles as stubby, prismatic, greenish-brown crystals averaging 2–3 cm long. Fragments of large crystals were found in a phlogopite mica pit a short distance from the south lapis occurrence (Fig. 3). Some of these fragments were transparent enough to facet.

## Gem hornblende

Hornblende is a monoclinic, calcium magnesium aluminium silicate in the amphibole group. Chemical analysis is essential to determine the identity of a particular member of the amphibole group since there is much overlap in values of physical and optical properties; even X-ray data are inconclusive. See the 'Amphiboles-General' section of this article for an explanation of this most complicated group of minerals.

Chemical analyses on specimens from several locations on Baffin Island (Grice and Gault, 1983) showed minor variations in composition, but all were within the edenitic to pargasitic hornblende range, using Leake's (1978) amphibole classification. The faceting-grade fragments are pargasitic hornblende (NMNS 46664). Analyses are given in Table 1. Note that the facetable hornblende contains traces of vanadium and chromium. The presence of vanadium was unexpected, as it was absent in analyses of other minerals from the same area. Vanadium is not usually reported in amphiboles (Deer, Howie and Zussman, 1963; Hawthorne, 1983). In this case, the vanadium and chromium (along with low iron content) are likely to contribute to the pleasing greenish-brown colour, since most hornblendes are very dark and unattractive.

Four gems were faceted for the National Gem Collection by Mr Arthur T. Grant, a noted faceter

### Table 1. Composition of Baffin Isalnd Hornblendes

|  | Pargasitic Hornblende 46664 | Pargasitic Hornblende 46677 | Edenitic Hornblende 46608 |
|---|---|---|---|
| $SiO_2$ | 45.0 | 43.8 | 46.5 |
| $TiO_2$ | 0.73 | 0.45 | 1.1 |
| $V_2O_5$ | 0.11 | 0.0 | 0.0 |
| $Al_2O_3$ | 14.1 | 14.7 | 11.7 |
| $Cr_2O_3$ | 0.10 | 0.08 | 0.0 |
| FeO* | 0.62 | 1.3 | 0.31 |
| MnO | 0.0 | 0.0 | 0.0 |
| MgO | 20.1 | 19.3 | 20.7 |
| ZnO | 0.0 | 0.0 | 0.0 |
| CaO | 12.1 | 12.7 | 12.1 |
| $Na_2O$ | 3.0 | 2.3 | 3.4 |
| $K_2O$ | 1.3 | 1.6 | 0.50 |
| F | 1.4 | 1.6 | 1.1 |
| Cl | 0.07 | 0.12 | 0.01 |
| $H_2O$** | 2.0 | 2.6 | 3.0 |
|  | 100.00 | 100.00 | 100.00 |

*total iron expressed as FeO
**by difference
A simplified chemical formula derived from analysis of 46664 is $(Na, K)(Ca, Na)_2(Mg, Al)_5(Si, Al)_8O_{22}(OH, F)_2$.
Calculated density 3.09 g/cm³.

with considerable experience in handling unusual gem materials. He used silicon carbide laps for cutting, and chromium oxide on an ultralap for polishing. The pavilion main facet was placed at 41°; the crown main angle was 42° with 5° splits when possible. Some difficulty arose when cutting across the cleavages, as fraying tended to occur. The material chipped easily during polishing. Orientation of the rough required careful consideration of the cleavage planes and the pleochroism. Mr Grant's opinion is that faceting this material is 'not terribly difficult'. The four stones are fashioned in various styles and weigh between 1.62 and 3.03 ct:

NMNS 20896 emerald step cut 3.00 ct
10.4×6.8×6.3 mm
NMNS 20897 marquise step cut 1.62 ct
16.9×4.1×3.9 mm
NMNS 20900 octagonal step cut 1.91 ct
12.2×5.0×4.0 mm
NMNS 22129 pear-shaped brilliant 3.03 ct
12.5×7.5×5.4 mm
One (NMNS 20897) appears a more greenish-brown than the others, because of pleochroism. See Figs 5 and 6.

minerals make the precise correlation of their chemical composition and optical properties practically impossible.

### Identification

If gem hornblende is encountered unexpectedly, it is quite likely to be mistaken for brown tourmaline (dravite or uvite). The refractive indices, birefringence and specific gravity are very similar, and they both show strong pleochroism. However, tourmaline is uniaxial, not biaxial, and shows only two dichroic colours.

Other gems that may appear in shades of brown have either lower refractive indices e.g. quartz, or much higher indices. Grossular (hessonite) garnet, sphalerite, and diamond are singly refractive. Cassiterite, scheelite, titanite (sphene), and zircon are all over the limits of a standard refractometer, and are not likely to be mistaken for hornblende. A number of other brown gemstones with which hornblende could be confused are listed in Table 2.

### Description of gem hornblende

Crystal system: Monoclinic.

Habit: Stubby, prismatic.

Inclusions: Veils of healing feathers; colourless crystal inclusions.

Colour: Greenish-brown.

Lustre: Vitreous.

Fluorescence: Moderate – yellow in shortwave ultraviolet; inert in longwave.

Hardness: 5½–6.

Tenacity: Brittle.

Cleavage: Two good, {110} at 56°; {100} {001} parting.

Twinning: {100} simple, lamellar, common.

Specific gravity: 3.09 ±0.01.

Optical properties

Refractive index: $\alpha$ 1.625–1.627
(sodium light, $\beta$ 1.632–1.633
Rayner Dialdex $\gamma$ 1.644–1.647
refractometer)
average 1.626–1.645

Birefringence: 0.020 Biaxial positive.

Pleochroism: Strong; green/orange/brownish-orange.

Absorption spectrum: Weak; a line in the blue.

Note the wide range of values listed for common hornblendes in Deer, Howie and Zussman (1963): $\alpha$ 1.615–1.705; $\beta$ 1.618–1.714; $\gamma$ 1.632–1.730; birefringence 0.014–0.026; optic sign positive or negative; SG 3.02–3.45.

Generally, refractive indices of amphiboles are increased by the substitutions of ferrous iron for magnesium, and aluminium for silicon. The varied and extensive substitutions in the hornblende



Fig. 5. Hornblende gem: 3.00 ct, emerald cut (NMNS 20896) from Baffin Island, NWT, Canada.



Fig. 6. Hornblende gems: 3.00 ct, emerald cut (NMNS 20896) and 3.03 ct, pear-shaped brilliant cut (NMNS 22129), from Baffin Island, NWT, Canada.

### Table 2. Identification of Gem Hornblende

| Gemstone | RI | DR | SG | Pleochroism | Other |
|---|---|---|---|---|---|
| Pargasitic Hornblende | 1.625–1.645 | 0.020 B(+) | 3.09 | S: G/O/Br-O | low dispersion |
| *Very similar, and likely to be confused with hornblende* | | | | | |
| Tourmaline (Dravite or Uvite) | 1.62–1.64 | 0.020 U(−) | 3.06 | S: Y-Br/dk Br | |
| Vesuvianite | 1.70–1.71 | 0.005 U(−) | 3.3–3.5 | S: G/O-Br | abs. spectrum |
| *Similar, but less likely to be confused* | | | | | |
| Topaz, brown | 1.630–1.638 | 0.008 B(+) | 3.53 | D: Br-Y/Y/O-Y | |
| Andalusite | 1.63–1.65 | 0.016 B(−) | 3.15 | S: Y/G/R | |
| Barite | 1.636–1.648 | 0.012 B(+) | 4.3–4.6 | Wk: Y/Y/V | |
| Danburite | 1.630–1.636 | 0.006 B(−) | 3.00 | None | |
| Siderite | 1.633–1.873 | 0.240 U(−) | 3.8–3.9 | | |
| Enstatite- | 1.65–1.66 | 0.008 B(+) | 3.25 | D: G/Y-G/Br-G | abs. spectrum |
| Hypersthene | 1.69–1.70 | 0.012 B(−) | 3.4 | Pink to G | |
| Series | to | to | to | | |
| | 1.76–1.77 | 0.021 | 3.5 | | |
| Peridot, brown | 1.65–1.69 | 0.036 B(+) | 3.4 | Weak | abs. spectrum |
| Diopside- | 1.664–1.694 | 0.024 B(+) | 3.29 | Weak or none | |
| Hedenbergite | to | to | to | | |
| Series | 1.72–1.75 | 0.031 | 3.56 | lt G/G-Br | |
| Sinhalite | 1.67–1.71 | 0.038 B(−) | 3.48 | D: lt Br/G-Br/dk Br | abs. spectrum |
| Axinite | 1.678–1.680 | 0.01 B(−) | 3.29 | S: Br/V/G | high dispersion |
| Epidote | 1.736–1.770 | 0.034 B(−) | 3.4 | S: G/Br/Y | abs. spectrum |
| Chrysoberyl, brown | 1.75–1.76 | 0.01 B(+) | 3.72 | D: Y/Br | abs. spectrum |

D distinct; lt imperceptible; S strong; Wk weak.
Colours by initial letters.
Data extracted from Webster, 1983, and Arem, 1977.

Vesuvianite (idocrase) from Laurel, Quebec has a similar golden-brown colour, but its refractive indices are significantly higher. Topaz has an RI in the same region, but it has a higher SG and a lower birefringence. Andalusite might be tricky, but it is usually more greenish or reddish in appearance.

**Conclusions and future prospects**

The number of Canadian gemstones in the National Gem Collection of Canada has been augmented significantly in recent years by arranging to have suitable pieces of field-collected minerals faceted into gems. This increase has been both in number and, more importantly, in the number of species. The Mineral Sciences Division of the National Museum of Natural Sciences has continued a long tradition of collecting in the field – one that was begun by the Geological Survey of Canada in the 1880s at the beginning of the development of Canada. Very few mineral museums today have personnel who actually go out to collect mineral specimens.

The pargasitic hornblende from Baffin Island, when properly cut to take advantage of its pleochroism, is an attractive gemstone with its warm brown colour showing glints of green and orange. Additional material may very well be obtained on future field trips to look specifically for faceting material. It was simply a lucky chance that some of the small amount brought back in 1980 was suitable for faceting.

Although faceted hornblende will never be a commercial success with its relative softness and limited supply, it is definitely a mineralogical rarity, a desirable collector's stone, and another contribution to Canada's mineral and gemstone heritage.

**Amphiboles – General**

The amphibole group consists of extremely important rock-forming minerals, occurring in a wide variety of igneous and metamorphic rocks throughout the world. Because they are so common, these silicate minerals are present in most mineral

collections, and have been rigorously investigated by mineralogists.

The name 'amphibole' is derived from the Greek, *amphibolos*=ambiguous. It was used first by Haüy in 1801, referring to the great variety in composition and appearance of these minerals. Many of the amphiboles share common physical properties and appear alike externally, but internally there is great diversity in chemical composition, with many atomic substitutions possible giving rise to extensive solid solution series. Many amphiboles are, therefore, often misidentified, since a visual identification based on the usual characteristics of colour, crystal habit, specific gravity etc. is invalid. Even optical and X-ray data may be inconclusive because of overlapping values between various members of the group. Amphiboles are one of the most complicated groups of minerals, and are a challenge to all who encounter them.

The advent in the 1960s of the electron microprobe enabling rapid, accurate chemical analysis of small samples of minerals did much to promote understanding of the amphiboles, because knowledge of their chemistry is essential. A general classification of the amphiboles, based on crystal chemistry, was compiled by Leake (1978), after years of work by a committee of the International Mineralogical Association. A précis of this highly technical work was presented by Robinson (1981) for mineral collectors, with particular reference to a number of well-known amphibole localities in Ontario and New York. General background information on amphiboles is given by Deer, Howie and Zussman (1963).

Until now, gemmologists have not had much reason to be concerned about the amphibole group. The only group members commonly known in gemmological circles are tremolite and actinolite, mostly because nephrite jade is a variety of them. Tremolite-actinolite-ferroactinolite form a solid solution series varying from tremolite ($Ca_2Mg_5Si_8O_{22}(OH, F)_2$), with increasing amounts of ferrous iron substituting for magnesium, to ferroactinolite ($Ca_2Fe_5Si_8O_{22}(OH, F)_2$). These are simple amphiboles.

The essential feature of the structure of amphiboles is the presence of $(Si, Al)O_4$ tetrahedra linked to form double chains with the composition $(Si_4O_{11})_n$. These double chains are oriented parallel to the *c*-axis, and run 'lengthwise' in most amphibole crystals (see Fig. 7). This helps explain the prismatic crystal habit and the splintery 56° and 124° cleavage commonly found in amphiboles. The chains are separated and bonded laterally by planes of cations plus hydroxyl radicals. The crystal system may be either monoclinic or orthorhombic. When aluminium substitutes for
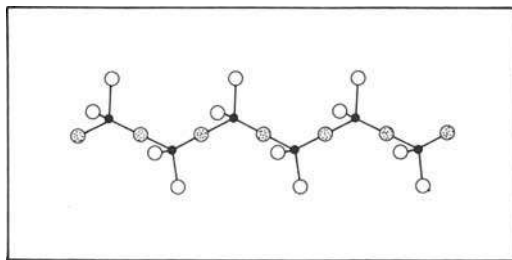


Fig. 7a. Each silica tetrahedron ($SiO_4$) may share two oxygen atoms to form a chain. This single chain $(SiO_3)_n$ is found in pyroxenes.
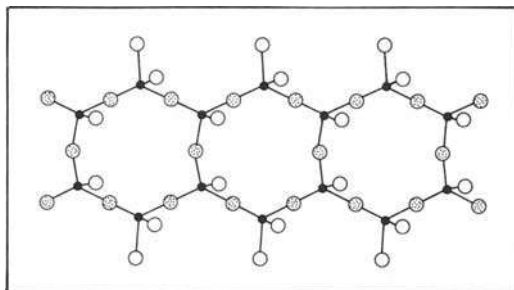


Fig. 7b. A double chain $(Si_4O_{11})_n$ occurs in amphiboles. Two parallel single chains may form a double chain by sharing oxygen atoms between alternate tetrahedra.

some of the silicon in the $Si_4O_{11}$ chain, the net charge balance is usually maintained by substitution of the type $Mg^{2+}Si^{4+} \leftrightarrows Al^{3+}Al^{3+}$.

The general formula of an amphibole is given in Leake (1978) as $A_{0-1}B_2C_5^{VI}T_8^{IV}O_{22}$ (OH, F, Cl)$_2$. We are concerned here with hornblendes, which are monoclinic, and in the calcic amphibole sub-group (one of four), which contains substantial calcium in the B position. Then, most commonly,

   A is sodium or potassium
   C is magnesium, with some ferrous iron, etc. in six-fold co-ordination.
   T is silicon, aluminium, ferric iron, etc. in four-fold co-ordination.

The classification is made on the basis of which elements are in B, the number of silicon atoms (silicon/aluminium ration), the magnesium/iron ratio, and other chemical considerations, resulting in 57 recognized end-members.

A simplified version of Leake's classification of calcic amphiboles is shown in Fig. 8. Note that common usage of the term hornblende includes calcium-rich amphiboles having a wide range in proportions of magnesium/iron and silicon/aluminium. The formula of our Baffin Island amphibole was determined from its chemical analysis to be ($Na_{0.65}K_{0.23}$) ($Ca_{1.81}Na_{0.16}$)

A: low alkali
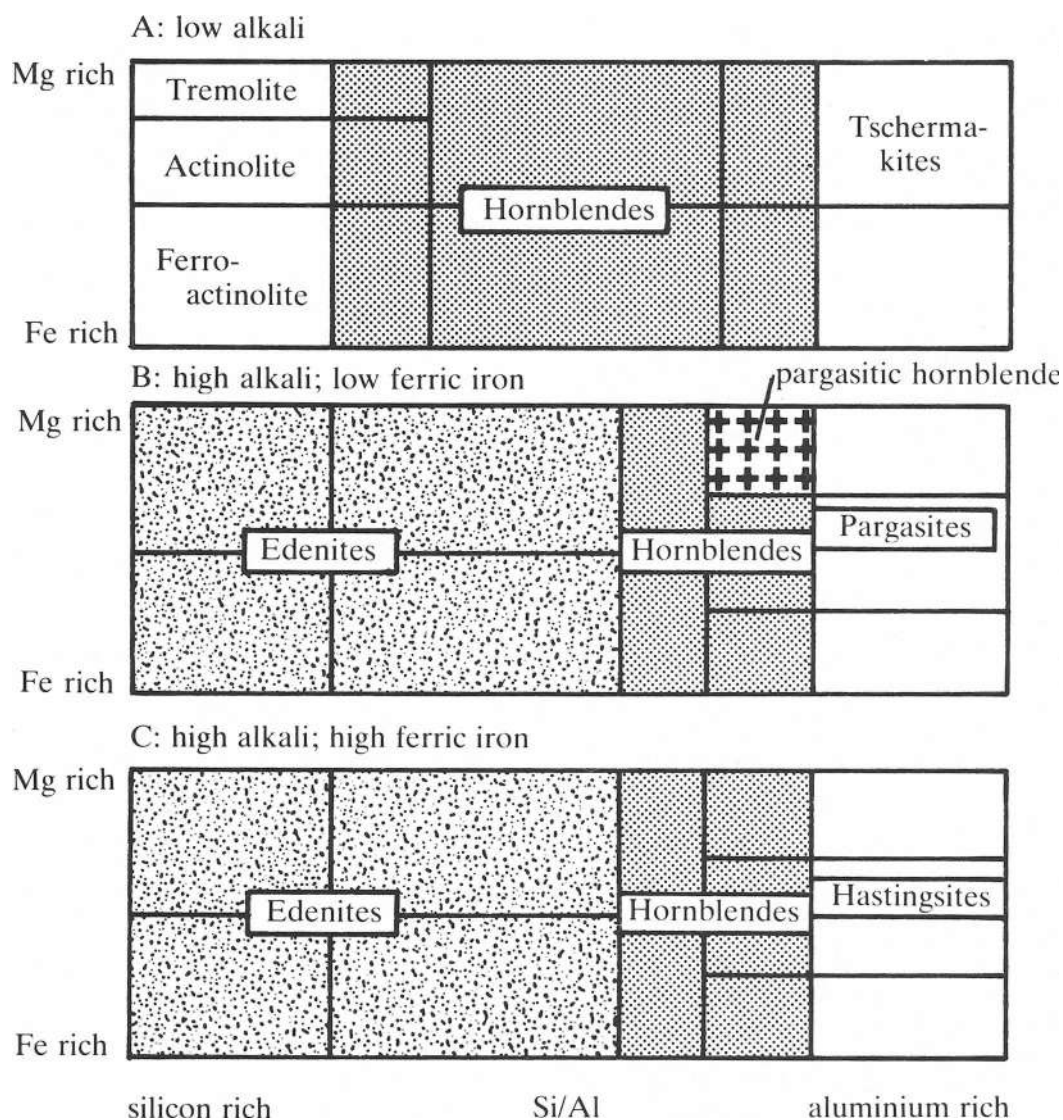


Fig. 8. Classification of calcic amphiboles (after Leake, 1978).

$(Mg_{4.17}Fe_{0.07}Al_{0.58}Ti_{0.08}Cr_{0.01}V_{0.01})$ $(Si_{6.27}Al_{1.73})$ $O_{21.52}$ $(OH_{1.84}F_{0.62}Cl_{0.02})$. Because its water content was determined only by difference, the value for OH is probably too high. Vanadium was arbitrarily assigned to position C based on its ionic radius. The calculated density for this formula is 3.09, compared to the observed density of 3.088 g/cm³. This formula places our amphibole in the pargasitic hornblende region, as shown by the + in Fig. 8, since it contains very little iron, and moderately high aluminium versus silicon. Because such complicated calculations are necessary to pinpoint the exact identity of an amphibole, there will still be many occasions when a broader terminology will have to be used.

## Acknowledgements

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# On the problems of using the gallium content as a means of distinction between natural and synthetic gemstones

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**Abstract**

In the past Ga-contents have been used to distinguish natural and synthetic gemstones. The Ga contents of 32 emeralds, 18 corundums and 16 chrysoberyls have been analysed by neutron activation analysis (NAA). It is shown that a distinction of natural and synthetic gemstones on the basis of their Ga contents is not possible.

**Introduction**

The title of this paper may already imply the kind of equipment which is currently used to distinguish natural and synthetic gemstones. The continuous development of techniques and the methods of production of synthetic gemstones necessitate new methods of distinction. In particular gemstones need special treatment, in that methods transferred from geochemistry have to work without destroying the stone. In spite of this limitation the trace element analysis, for example, can be extremely useful. This kind of analysis is able to indicate the environment of the origin of a gemstone, whether it be natural or synthetic. The crystal growth in a crucible of platinum means that in many cases very small traces of this element (Pt) are incorporated in the synthetic crystal, and, in few favourable cases, microscopically small plates of platinum.

Investigation by trace element analysis of gemstones containing aluminium indicate various contents of gallium. This fact is not surprising, for it has been known for some years that in nature gallium is camouflaged by aluminium. The similar ionic radii and the same state of valence of aluminium and gallium explain this behaviour. The amount of gallium in the earth's crust is very small compared with aluminium, and Rösler and Lange (1976) give a proportion of $Al:Ga = 4235:1$ for an average composition of the Earth's crust. This ratio differs in some rocks because gallium can be enriched at the end of a magmatic cycle. Table 1 shows the theoretical gallium contents of some gemstones.

Certain investigations (Ottemann *et al.* 1978, Horiuchi 1979, Ohguchi 1981, Hänni and Stern 1982, Schmetzer 1985) on synthetic and natural gemstones yielded the following 'rules', whose accuracy should be tested:

- corundum: gallium contents greater than 50–200 ppm prove a natural origin,
  gallium contents smaller than 50–200 ppm indicate a synthetic origin,
- alexandrite: 'measurable' gallium contents signify a natural origin.

**Method**

Requirements of methods used to investigate gemstones include:

- the method has to work without destruction;
- the method must not cause any alterations such as discoloration.

Normally the following methods are applicable:

- X-ray-fluorescence-analysis (XFA) with wavelength-dispersive and energy-dispersive measurements;
- electron microprobe analysis (EPMA) with wavelength-dispersive and energy-dispersive measurements;

**Table 1: Gallium contents of some gemstones theoretically calculated on the geochemical proportion of Al:Ga of the Earth's crust:**

| | | | |
|---|---|---|---|
| Emerald | $Be_3Al_2(Si_6O_{18})$ | 10.2% Al | 24 ppm Ga |
| Corundum | $Al_2O_3$ | 52.9% Al | 124 ppm Ga |
| Chrysoberyl | $BeAl_2O_4$ | 42.5% Al | 100 ppm Ga |
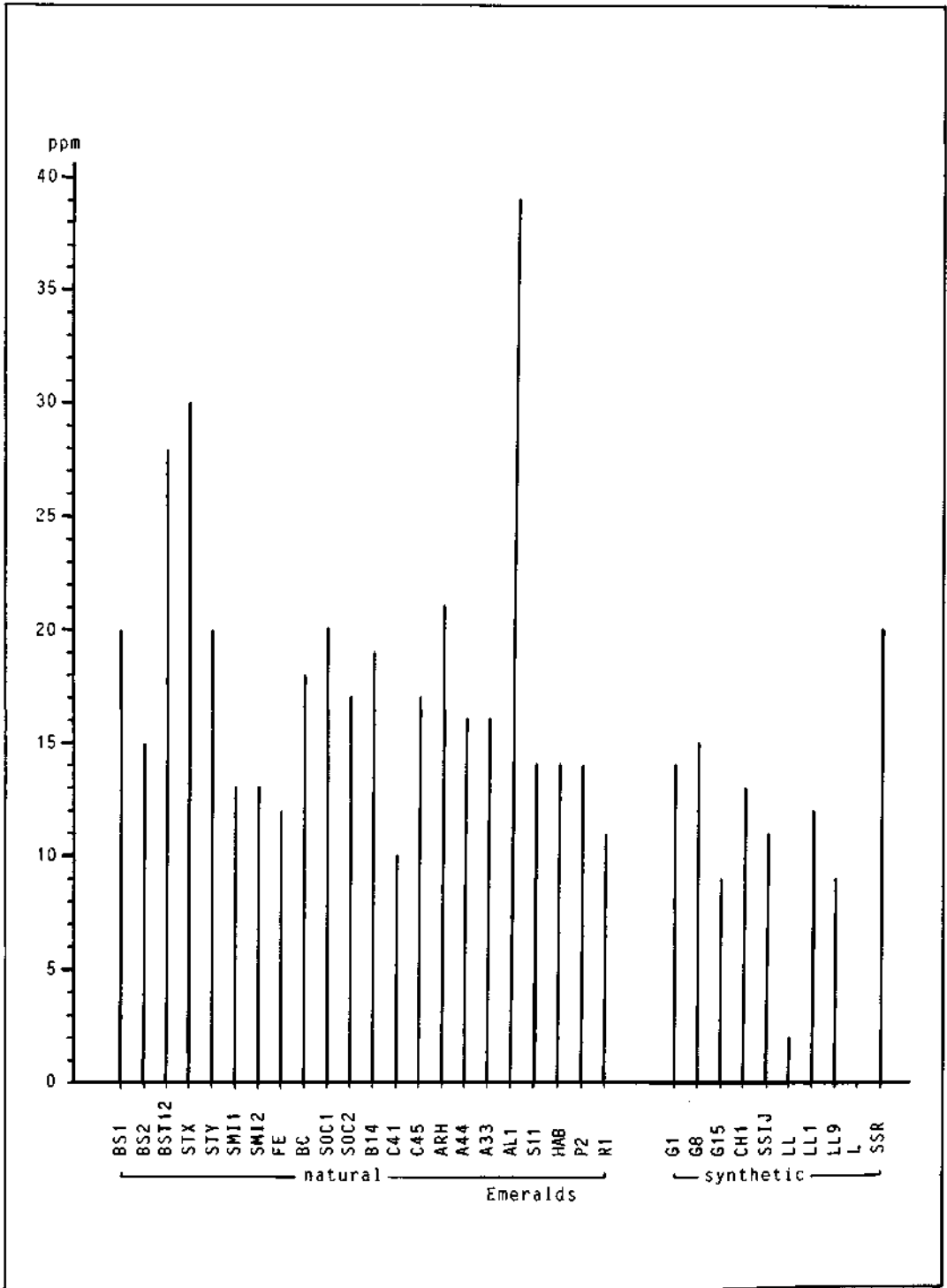
Fig. 1 : Gallium contents of natural and synthetic emeralds
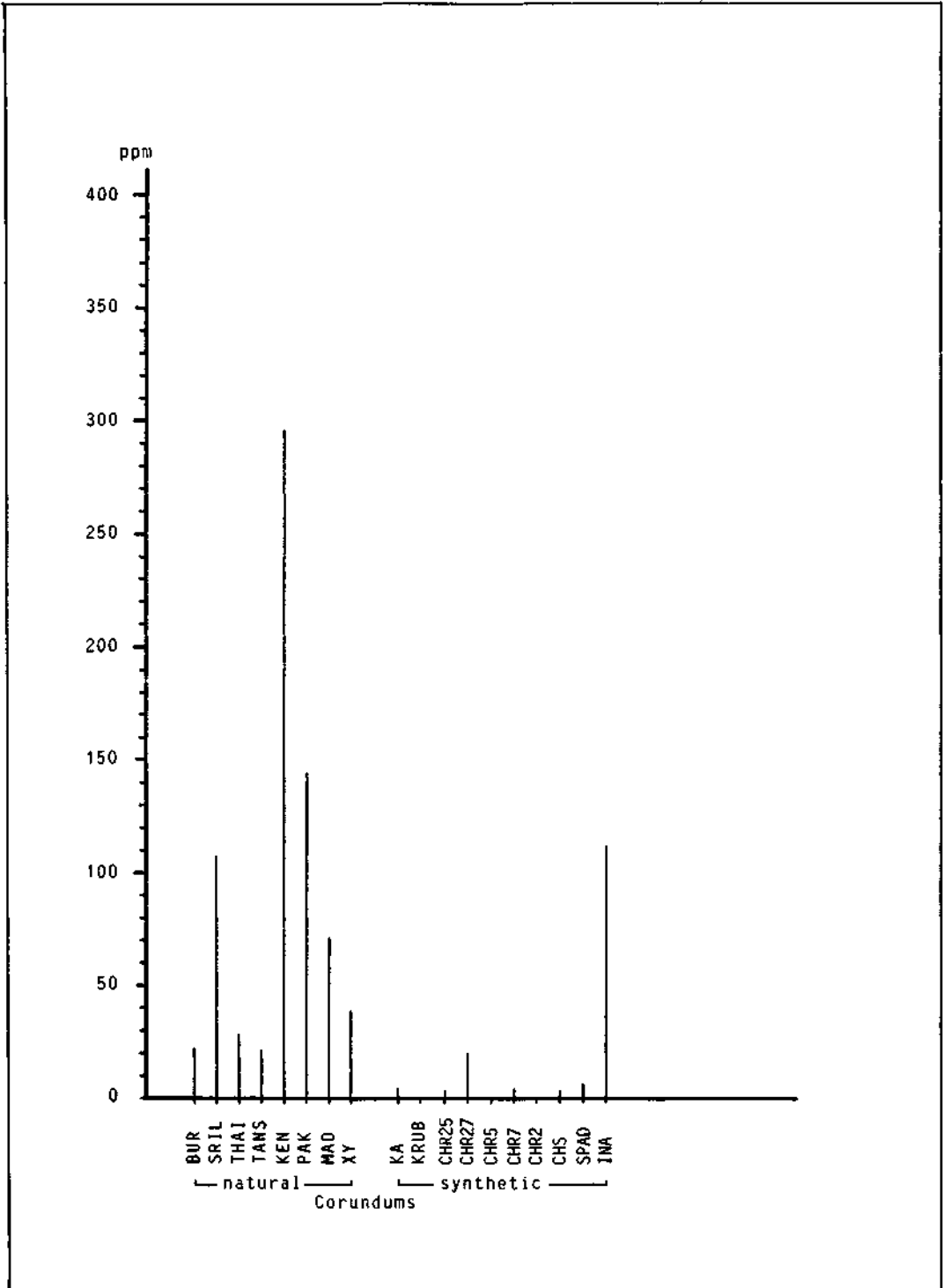
Fig. 2 : Gallium contents of natural and synthetic corundums
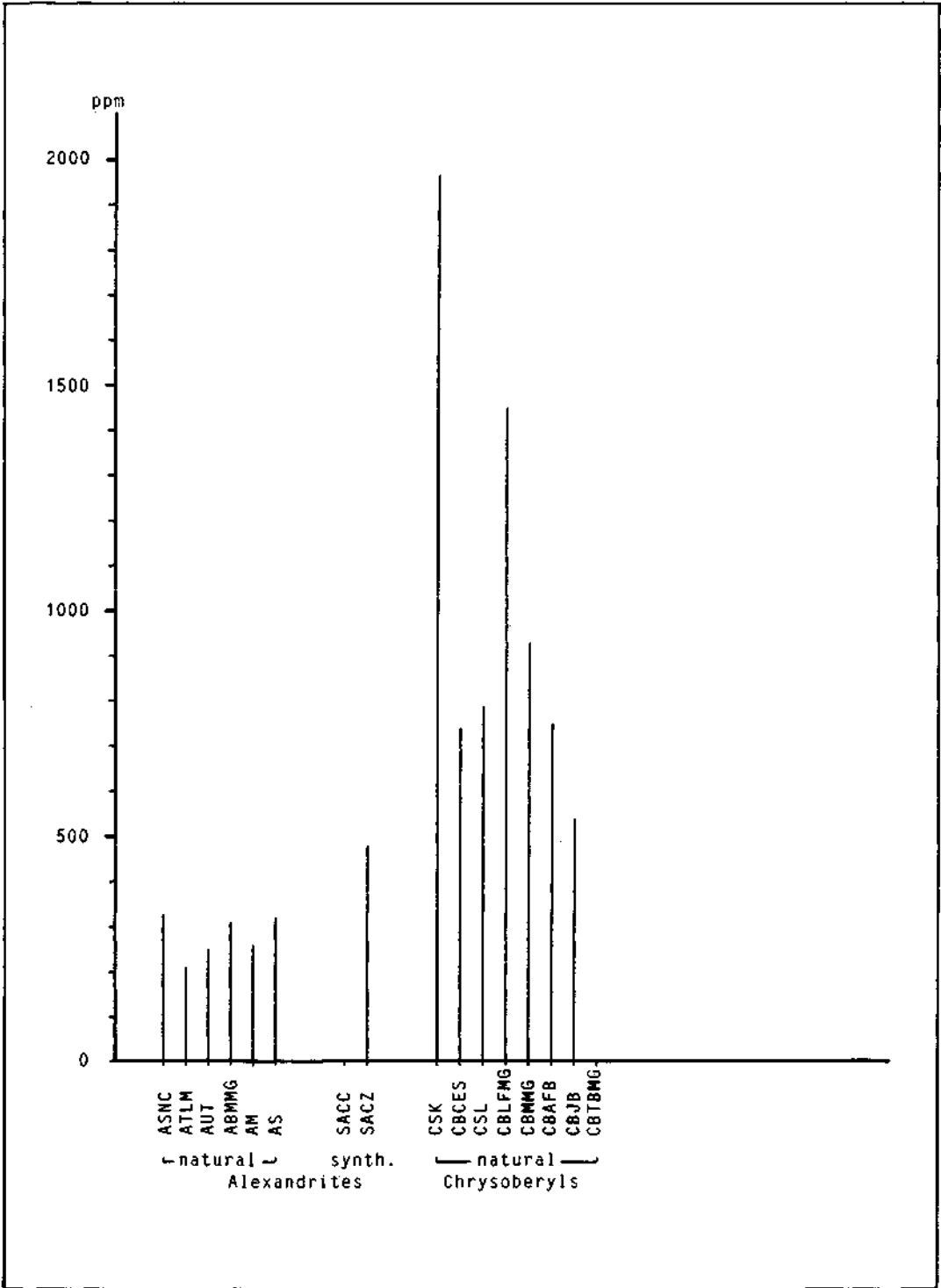
Fig. 3 : Gallium contents of natural and synthetic chrysoberyls

Table 2: Samples investigated by NAA gallium contents from Figs 1 to 3:

| BS1 | Emerald, Salininha, Brazil | 20 ppm |
|---|---|---|
| BS2 | Emerald, Salininha, Brazil | 15 ppm |
| BST12 | Emerald, Sta Terezinha de Goias, Brazil | 28 ppm |
| STX | Emerald, Sta Terezinha de Goias, Brazil | 30 ppm |
| STY | Emerald, Sta Terezinha de Goias, Brazil | 20 ppm |
| SMI1 | Emerald, Sta Maria de Itabira, Brazil | 13 ppm |
| SMI2 | Emerald, Sta Maria de Itabira, Brazil | 13 ppm |
| FE | Emerald, Ferros, Brazil | 12 ppm |
| BC | Emerald, Carnaiba, Brazil | 18 ppm |
| SOC1 | Emerald, Socotó, Brazil | 20 ppm |
| SOC2 | Emerald, Socotó, Brazil | 17 ppm |
| B14 | Emerald, Brazil | 19 ppm |
| C41 | Emerald, Chivor, Colombia | 10 ppm |
| C45 | Emerald, Chivor, Colombia | 17 ppm |
| ARH | Emerald, Zimbabwe | 21 ppm |
| A44 | Emerald, Cobra Mine, Transvaal, South Africa | 16 ppm |
| A33 | Emerald, Cobra Mine, Transvaal, South Africa | 16 ppm |
| AL1 | Emerald, Leydsdorpdistrict, South Africa | 39 ppm |
| S11 | Emerald, Zambia | 14 ppm |
| HAB | Emerald, Afghanistan | 14 ppm |
| P2 | Emerald, Pakistan | 14 ppm |
| R1 | Emerald, Takowaja, Siberia, USSR | 11 ppm |
| G1 | Synthetic emerald, flux-method, Gilson | 14 ppm |
| G8 | Synthetic emerald, flux-method, Gilson | 15 ppm |
| G15 | Synthetic emerald, flux-method, Gilson | 9 ppm |
| CH1 | Synthetic emerald, flux-method, Chatham | 13 ppm |
| SSIJ | Synthetic emerald, flux-method, Inamori | 11 ppm |
| LL | Synthetic emerald, hydroth.-method, Lechleitner | 2 ppm |
| LL1 | Synthetic emerald, hydroth.-method, Lechleitner | 12 ppm |
| LL9 | Synthetic emerald, hydroth.-method, Lechleitner | 9 ppm |
| L | Synthetic emerald, hydroth.-method, Linde | 0 |
| SSR | Synthetic emerald, hydroth.-method, USSR | 20 ppm |
| BUR | Corundum, ruby, Burma | 23 ppm* |
| SRIL | Corundum, ruby, Sri Lanka | 107 ppm* |
| THAI | Corundum, ruby, Thailand | 28 ppm* |
| TANS | Corundum, ruby, Longido, Tanzania | 22 ppm* |
| KEN | Corundum, ruby, Kenya | 295 ppm* |
| PAK | Corundum, ruby, Pakistan | 144 ppm* |
| MAD | Corundum, ruby, Madagascar | 71 ppm* |
| XY | Corundum, ruby, unknown origin | 39 ppm |
| KA | Synthetic ruby, Kashan | 5 ppm |
| KRUB | Synthetic ruby, Kashan | 0 |
| CHR25 | Synthetic ruby, Chatham | 4 ppm* |
| CHR27 | Synthetic ruby, Chatham | 20 ppm* |
| CHR5 | Synthetic ruby, Chatham | 0.6 ppm* |
| CHR7 | Synthetic ruby, Chatham | 5 ppm* |
| CHR2 | Synthetic ruby, Chatham | 1 ppm* |
| CHS | Synthetic sapphire, Chatham | 4 ppm* |
| SPAD | Synthetic sapphire, Chatham | 7 ppm |
| INA | Synthetic ruby, Inamori | 112 ppm |
| ASNC | Alexandrite, Novello Claims, Zimbabwe | 330 ppm |
| ATLM | Alexandrite, Lake Manyara, Tanzania | 210 ppm |
| AUT | Alexandrite, Takowaja, USSR | 250 ppm |

* after Schneider (1979)

| ABMMG | Alexandrite, Malacacheta, MG, Brazil | 310 ppm |
|-------|--------------------------------------|---------|
| AM | Alexandrite, Madagascar | 260 ppm |
| AS | Alexandrite, Zambia | 320 ppm |
| SACC | Synthetic alexandrite, (flux) Creative Crystals | 5 ppm |
| SACZ | Synthetic alexandrite, Czochralski | 480 ppm |
| CSK | Chrysoberyl, Kapoi, Zimbabwe | 1970 ppm |
| CBCES | Chrysoberyl, Colatina, Espirito Santo, Brazil | 740 ppm |
| CSL | Chrysoberyl, Sri Lanka | 790 ppm |
| CBLFMG | Chrysoberyl, Lonego de Fogo, MG, Brazil | 1450 ppm |
| CBMMG | Chrysoberyl, Malacacheta, MG, Brazil | 930 ppm |
| CBAFB | Chrysoberyl, Agua Fria, Bahia, Brazil | 750 ppm |
| CBJB | Chrysoberyl Jaqueto, Bahia, MG, Brazil | 540 ppm |
| CBTBMG | Chrysoberyl, Tres Barras, Brazil | 2 ppm |

– scanning electron microscope (SEM) with energy-dispersive measurements;
– neutron activation analysis (NAA) with energy-dispersive measurements.

Investigation of gemstones by wavelength-dispersive XFA is risky because the high excitation energy may cause irreversible discoloration of gemstones (Bank, 1982).

Energy-dispersive measurements by SEM and EPMA have a relatively high detection limit of about 2wt.% for Ga and are not sensitive enough to measure the Ga contents of gemstones. Energy-dispersive XFA and wavelength-dispersive EPMA may detect the levels of Ga present in some gemstones (EDS-XFA: ±200 ppm, WDS-EPMA: ±100 ppm). However, these values are close to the detection limits, so inaccurate figures must be accepted. Besides this, in both methods only the surface of the sample can be analysed and so possible variation in content caused by the structure or zoning in the material are not detected. Currently the best method for measuring Ga is NAA as its detection limit is 0.5 ppm and accuracy is 3–10% of the Ga value. However, this kind of analysis is not suitable for a large number of investigations because radioactivity decreases slowly, and a lot of time is needed for the whole investigation and thus the costs are consequently high.

**Results**

Gallium contents have been obtained by the authors and Schneider (1979) using NAA for:
32 emeralds (22 natural, 10 synthetic);
18 corundums (8 natural, 10 synthetic); and
16 chrysoberyls (6 natural alexandrites, 2 synthetic alexandrites, and 8 natural chrysoberyls).

The results are given in Table 2 and displayed in Figs. 1–3. Four natural corundums were found with Ga <50 ppm, and only one with >200 ppm. One synthetic alexandrite with high Ga and one natural chrysoberyl with only 2 ppm Ga were found. In the emerald analyses the range of Ga contents is similar for both natural and synthetic stones.

These results indicate that the proposals concerning use of Ga content for distinguishing between natural and synthetic gemstones, put forward by authors listed above, must be treated with caution, and any conclusions indicated by Ga contents should be corroborated by further tests.

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# Possibilities and limitations in radiographic determination of pearls

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## Abstract

The main types of pearls available at present in the trade are characterized by radiographic features. Systematic investigations of pearls were conducted using direct radiography as well as X-ray diffraction techniques. In addition the luminescence under X-ray excitation was examined. A simple diffraction camera was developed which enables the investigation of diffraction patterns of pearls in exactly defined angles to each other. By use of an additional sample holder the production of diffraction patterns of one single pearl from a necklace is possible. During the investigation of freshwater pearls (natural and cultured freshwater pearls) with X-ray diffraction techniques a dark spot is generated on the pearl's surface by radiation defects.

Using a combination of all three radiographic techniques available at present, an unambiguous identification of almost every type of pearl found in the trade is possible. Due to overlapping of their characteristic radiographic features it is difficult to distinguish some Keshi cultured pearls from natural seawater pearls and some non-bead-nucleated cultured freshwater pearls from natural freshwater pearls.

Schematic diagrams for determining pearls of unknown origin using the three radiographic methods are presented.

## Introduction

Since the middle of the 1920s radiographic techniques have been used extensively for the distinction of natural and cultured pearls. By use of the X-ray diffraction method, which is also known as the Laue-technique, natural pearls are distinguishable from bead-nucleated cultured pearls. Using direct radiography internal structures of pearls may become visible on the X-ray film which lead to a conclusive identification of the pearl's origin. The luminescence of pearls under X-ray excitation depends on the growth environment of the pearl (freshwater or seawater).

Detailed descriptions of systematic investigations of pearls with radiographic techniques were recently published by Hänni (1982, 1983) and Brown (1979, 1983). Hänni (1982, 1983) investigated the diffraction patterns of natural and bead-nucleated cultured pearls, and studied the influence of the external shape of non-spherical pearls on the diffraction patterns of the pearls, especially the relationship between the direction of the primary X-ray beam with respect to the external shape of the pearl, i.e. the direction in which a non-spherical pearl is placed in the X-ray beam (cf. also Webster, 1957; Schiffman, 1971; Duroc-Danner and Yvon, 1983). Brown (1979, 1983) gave a systematically arranged compilation of direct radiographs of natural pearls, cultured pearls and imitation pearls (cf. also Webster, 1957; Brown, 1980, 1981a, 1981b; Brown and Mendis, 1984).

In the literature dealing with identification of pearls by radiographic techniques – including gemmological textbooks – one finds only few hints on possible ambiguities in radiographic results of pearl investigation, i.e. on possible overlappings of diagnostic features of pearls of different origin. The aim of the present paper is to make a contribution to this important and still problematic field of pearl identification. The applicability of different radiographic techniques on the characterization of pearls of unknown origin is discussed in regard to overlapping diagnostic features of different types of pearl which are available on the international market.

The composition and internal structure of pearls is described in detail by different authors, e.g. Wada (1970), Korago *et al.* (1976), Götting (1979) and Simkiss and Wada (1980). Only those types of pearls which mainly consist of small tubular crystals of aragonite (nacre) exhibit those optical properties which are the precondition to use the pearls for jewellery, i.e. for necklaces or rings. Pearls which mainly consist of organic matter (conchiolin) or of prismatic crystals of aragonite or calcite are not useful for jewellery and are therefore of no commercial value.

## Experimental details

At present the types of pearls given in the summary below are found on the international market:

*Natural pearls*
1. spherical, pear-shaped, button-shaped or baroque-shaped from seawater
2. spherical, pear-shaped, button-shaped or baroque-shaped from freshwater
3. blister pearls (removed from the shell of the oyster, with or without shell fragments) from seawater

*Cultured pearls from seawater ·*
1. bead-nucleated cultured pearls
2. cultured blister pearls (e.g. Mabe composite cultured pearls)
3. non-bead-nucleated, non-tissue-implanted cultured pearls (Keshi cultured pearls); pearls of this type (adventitious pearls) are accidentally formed in bead-nucleated oysters (cf. Brown, 1980).

*Cultured pearls from freshwater*
1. bead-nucleated cultured pearls
2. cultured blister pearls
3. non-bead-nucleated cultured pearls
   a) tissue-implanted cultured pearls ('first crop' Biwa cultured pearls, Chinese cultured freshwater pearls)
   b) non-tissue-implanted cultured pearls ('second crop' Biwa cultured pearls) (cf. also Farn, 1975; Brown, 1981a, 1981b).

For the present paper several necklaces and single pearls (not mounted in jewellery) of each type mentioned above were examined:

The following numbers indicate (a) necklaces used for direct radiography and luminescence tests (pearls from necklaces used for X-ray diffraction), (b) single pearls used for direct radiography and luminescence tests (single pearls used for X-ray diffraction).

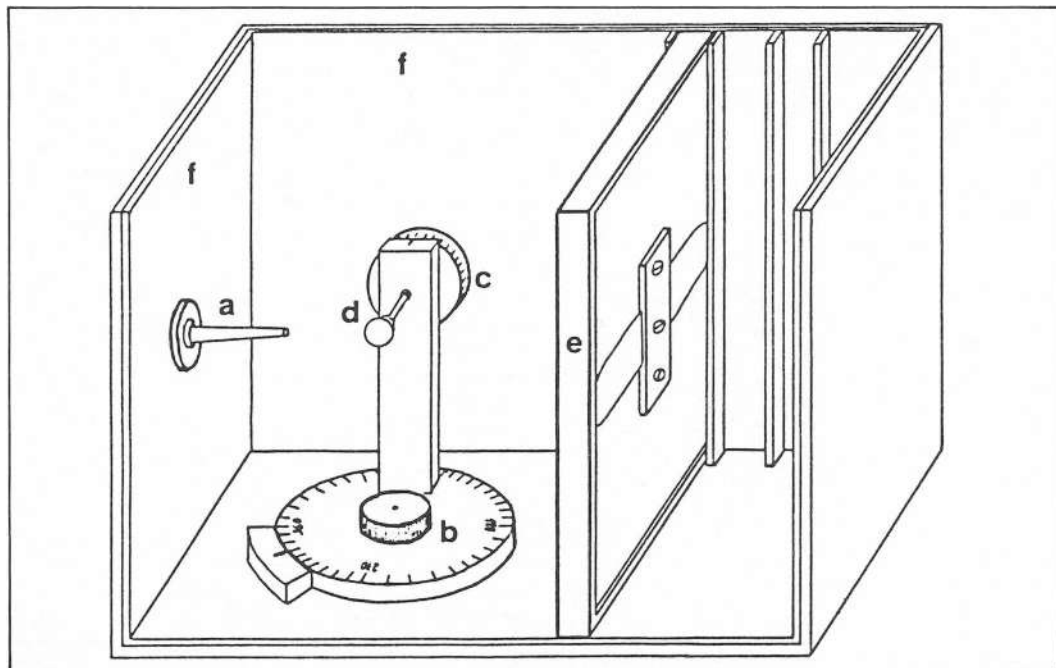| *Natural pearls* | (a) | (b) |
|---|---|---|
| from seawater | 12 (10), | 90 (8) |
| from freshwater | – –, | 24 (4) |
| blister pearls from seawater | – –, | 2 – |
| | | |
| *Cultured pearls, seawater* | | |
| bead-nucleated pearls | 25 (15), | 55 (10) |
| blister pearls | – –, | 2 – |
| Keshi pearls | 2 –, | 30 (8) |
| | | |
| *Cultured pearls, freshwater* | | |
| bead-nucleated pearls | – –, | 2 (2) |
| blister pearls | – –, | – – |
| non-bead-nucleated pearls | 30 (5), | 20 (8) |



Fig. 1. X-ray diffraction camera (Laue-camera) for pearls; (a) collimator, (b) vertical rotation axis with a dial having 360° subdivisions, (c) horizontal rotation axis with a dial having 360° subdivisions, (d) pearl, (e) film cassette, (f) camera box covered inside with lead sheet; length of the camera approximately 25 cm.

Direct radiography was performed according to the experimental conditions already described in detail by Webster (1957) using immersion liquids. These experimental conditions (Webster, 1957) are principally different from the method of Brown (1983), who investigated pearls and pearl necklaces by direct radiography without using immersion liquids. Mainly carbon tetrachloride and tetrachloroethylene were used. Direct radiography with immersion liquids, in general, gave better results in pearl testing than without.

The luminescence of pearls under X-ray excitation was investigated before the pearls were placed in the immersion liquid for direct radiography. The reaction of the pearl under the primary X-ray beam was observed in an absolutely darkened room through a window of lead-bearing glass in the camera used for direct radiography. In this time-saving procedure both methods were performed in one single working step.

Experimental conditions: copper target, 35 kV, 24 mA; pearl to target distance variable 20–80 cm (mainly a distance of 20 cm was used); exposure time 30 seconds.

The X-ray diffraction patterns of pearls were photographed in a specially developed diffraction camera (Fig. 1). The camera works according to the principle of a two-circle goniometer. The pearl is placed at various exactly defined angles with reference to the primary X-ray beam using both a horizontal and a vertical rotation axis. For the investigation of single pearls in necklaces an additional sample holder is used (Fig. 2), which enables the attachment of the necklace in front of
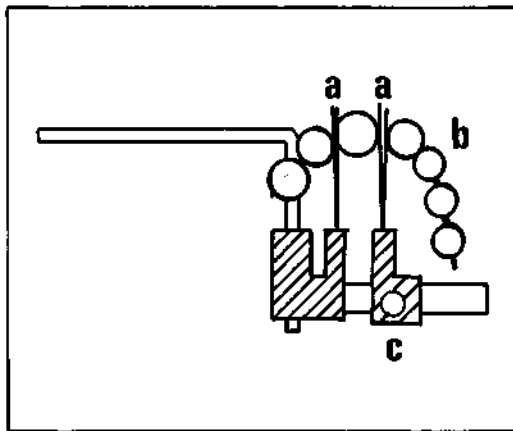


Fig. 2. Additional sample holder for X-ray diffraction photographs of single pearls from necklaces; (a) forks to support the necklace, (b) necklace, (c) movable fork with screw set adjustable according to the diameter of the pearl; length approximately 8 cm.

the collimator of the X-ray beam. By using this sample holder X-ray diffraction photographs of single pearls in necklaces are possible in all directions which are adjustable by a rotation of the pearl with the string of the necklace as a rotation axis.

Experimental conditions: two different tubes were used for diffraction experiments, copper target, 40 kV, 20 mA or iron target, 36 kV, 26 mA; pearl to target distance 12 cm, pearl to collimator and distances 0.5, 1.5 or 2.5 cm) three different collimators), pearl to film distances 8, 12 or 16 cm; exposure times 2–16 h; film type Agfa OSRAY M3.

**Results**

Generally, the results of our experimental investigations confirm the data widely scattered in the literature as well as the results of the most recent systematic examinations by Hänni (1982, 1983) and Brown (1979, 1983). Some results complete the data available in the literature, especially the data of certain types of pearls which were not previously investigated by a combination of all three experimental methods used in our study.

Imitation pearls and cultured blister pearls are often recognizable without the application of radiographic techniques (Webster, 1973). Imitation pearls are distinguishable from natural and cultured pearls by examination of the surface structure and/or by their different density. Cultured blister pearls (e.g. Mabe composite cultured pearls) are identifiable due to their characteristic external form and due to their artificial supplement on the backside of the sample. Therefore these two types of material are not discussed in further detail.

The characteristic properties of natural pearls and cultured pearls which are determinable by radiographic techniques are summarized in Table 1.

*Direct radiography*

The diagnostic features in direct radiographs of pearls are due to the different X-ray transparency of calcium carbonate (mainly aragonite with low X-ray transparency) and organic matter (conchiolin with high X-ray transparency). The not absorbed fractions of the primary beam cause the blackening of the X-ray film. In order to recognize unambiguously characteristic structures of pearls, several X-ray pictures in various orientations generally have to be taken. The best method to hold pearls steady is to use small patches of paper tissue.

The direct radiographs of a fraction of natural pearls (seawater and freshwater pearls) and of some Keshi cultured pearls reveal circles, arcs or regular cavities close to the centre of the pearls. These diagnostic structures in the X-ray film are caused by conchiolin in the centre or between the concentric layers of aragonite crystals.

**Table 1. The different types of pearl and their radiographic properties of diagnostic value**

| Type of pearl | Direct radiographs* | Luminescence under X-ray excitation | X-ray diffraction patterns** | Radiation defects |
|---|---|---|---|---|
| natural freshwater pearls | fine circles or arcs close to the centre | variable: weak to strong | identical at different angles to each other, consisting of a system of descrete spots having a six-fold symmetry or of a diffuse halo | medium to strong |
| natural seawater pearls | | not observed | | not observed |
| Keshi cultured pearls | | not observed | | not observed |
| non-bead-nucleated cultured freshwater pearls | large irregular patches of variable radiolucency | variable: medium to strong | | medium to strong |
| bead-nucleated cultured freshwater pearls | external circles or arcs, radio-opaque bead in the centre | strong | different at right angles to each other, consisting of a system of discrete spots having a two-fold symmetry (first direction) or of a system of discrete spots having a six-fold symmetry or of a diffuse halo (second direction) | medium to strong |
| bead-nucleated cultured seawater pearls | | variable: not observed to medium | | not observed |

\* diagnostic features are not observable for all pearls
\** for spherical or almost spherical pearls

Cultured pearls with mother-of-pearl nuclei (bead-nucleated cultured seawater and freshwater pearls) are recognizable on the direct X-ray picture by an almost circular structure closer to the rim of the pearl. In general, this circular structure is interrupted and sometimes only short parts are visible. The diagnostic features of bead-nucleated cultured pearls are caused by a layer of conchiolin coating the mother-of-pearl bead in a first step of growth after the seed is inserted into the oyster. Therefore an outline of the bead which may be coated by a conchiolin layer of irregular thickness becomes visible on the X-ray picture.

The direct radiographs of non-bead-nucleated tissue-implanted freshwater pearls (Biwa cultured pearls and Chinese freshwater cultured pearls) and most of Keshi cultured pearls yield irregularly formed structures of variable X-ray transparency in the centre of the pearls. In the case of freshwater cultured pearls, these structures are caused by cavities and irregularly deposited conchiolin layers. In the case of Keshi cultured pearls, the reason for similar structures is thought to be due to irregular concentrations of organic matter occasionally associated with shell fragments (cf. Brown, 1980, 1981a, 1981b).

*Luminescence under X-ray excitation*
The different reaction of pearls under X-ray excitation is explained by their different manganese contents assumed to be caused by different manganese concentrations in seawater and freshwater (Waldeck and Baier, 1970; Webster, 1975).

Under the experimental conditions used in this study, natural pearls grown in a seawater environment do not show luminescence under X-ray excitation. The luminescence behaviour of the bead-nucleated cultured seawater pearls is different. Dependent on the thickness of their skin (layer of nacre) around the mother-of-pearl nucleus (which is artificially produced from shells grown in freshwater), a weak luminescence is observed in thin-skinned pearls. In pearls with a great thickness of the layer of nacre grown in seawater, no reaction

under X-ray excitation was observed. On the contrary, pearls grown in freshwater – natural freshwater pearls and cultured freshwater pearls – reveal a distinct reaction under X-ray excitation. This greenish luminescence of freshwater pearls is of variable intensity (weak, medium or strong) and is thought to be dependent on growth conditions, i.e. the trace element content of the growth environment. A strong luminescence under X-ray excitation was observed from Biwa cultured pearls as well as from natural freshwater pearls from Scotland.

*X-ray diffraction*

The application of the Laue-method for pearls is based on the different arrangements of small calcium carbonate crystals (mainly aragonite) in the layers of natural pearls and bead-nucleated cultured pearls, respectively. The symmetry of the diffraction pattern is dependent on the symmetrical relationship in the pearl parallel to the primary X-ray beam. In almost spherical natural pearls with a concentric layered structure of aragonite platelets, identical relationships are found in different orientations of the pearl with respect to the X-ray beam. In contrast, the symmetrical relationships in bead-nucleated cultured pearls are different in directions parallel and perpendicular to the orientation of the nearly straight parallel aragonite layers of the nucleus.

A concentric layered structure is found in all natural pearls (natural seawater and freshwater pearls), in non-bead-nucleated cultured freshwater pearls and in Keshi cultured pearls. In these groups, assuming the X-ray beam passes through the centre of an almost spherical pearl, the diffraction pattern consists of a system of discrete spots having a six-fold symmetry or of a nearly concentric halo. Every transition between both basic types of pattern is observable.

The diffraction pattern of bead-nucleated cultured pearls (seawater or freshwater) is identical with the diffraction pattern of pearls with a concentric layered structure under the precondition that the direction of the primary X-ray beam is perpendicular to the aragonite layers of the nucleus. However, in other directions, especially parallel to the aragonite layers of the nucleus, the diffraction pattern of bead-nucleated cultured pearls, in general, consists of a system of discrete spots having a two-fold symmetry.

Under the precondition that the first diffraction pattern of a pearl of unknown origin shows a six-fold symmetry (as described above), a second Laue-pattern in a direction perpendicular to the first orientation of the pearl has to be conducted in order to determine the possible presence of a nucleus.

Therefore, in general, at least two or even more diffraction photographs have to be taken at exactly defined angles to each other. This procedure is easily practicable using the diffraction camera described in this paper (Fig. 1), which enables different discrete orientations of the pearl without the necessity of removing the pearl from the camera.

The diffraction patterns of non-spherical pearls are extremely complex depending on the orientation of the pearl in the X-ray beam (cf. Hänni, 1982, 1983). In such cases an identification of a pearl of unknown origin with the Laue-method only may become very difficult or even impossible.

The Laue-pattern of a thick-skinned cultured pearl with a relatively small mother-of-pearl nucleus consists of a pattern with a six-fold symmetry (caused by the skin) which is superimposed on a pattern with a two-fold symmetry (caused by the nucleus). The pattern of the nucleus, however, was clearly visible in the diffraction patterns of all samples investigated in our laboratory.

*Radiation defects*

Having investigated the diffraction pattern of freshwater pearls (natural and cultured freshwater pearls of all types) under the experimental conditions mentioned above a dark circular spot was incidentally observed on the surface of the pearl. Radiation defects were never observed during the investigation of luminescence under X-ray excitation or after direct radiography of freshwater pearls. After the investigation of seawater pearls by X-ray diffraction techniques no radiation defects were observed. Similar radiation defects were also produced on the surface of a bead-nucleus (grown in freshwater!) from which the skin of nacre had been removed. The radiation defects were found to be reversible. They disappeared after exposing the pearl to direct sunlight for several weeks, e.g. on a window seat. Nevertheless, the application of the X-ray diffraction method for the determination of freshwater pearls should be avoided if possible. The identification of freshwater pearls can be made from observations of luminescence under X-ray excitation.

*Possibilities of radiographic determination of pearls of unknown origin*

The most important result of our systematic investigations is the fact that most pearls available in the trade are adequately characterizable and sufficiently identifiable by a combination of the three radiographic techniques described in this paper (Table 1). The application of only one of the methods mentioned above allows the unambiguous determination of only a minor part of the pearls found on the market.

As already described, diagnostic internal structures of a pearl may become visible on the X-ray film by the application of direct radiographic techniques. However, structures which are suitable for an unambiguous determination of the sample were recognized in only 10–20% of natural pearls.

About 60% of direct radiographs of bead-nucleated cultured pearls (seawater and freshwater) revealed diagnostic structures on the X-ray film, i.e. the characteristic circle close to the rim of the pearl (or at least part of it) became visible. The percentage of pearls which showed diagnostic structures on their X-ray photograph, however, was extremely variable between different necklaces, e.g. the percentage of diagnostic structures was found to vary between 16 and 94%. In baroque-shaped or non-spherical bead-nucleated cultured pearls, the mother-of-pearl nucleus was recognizable on the X-ray photograph in almost 100% of all pearls investigated. These results indicate that the application of the diffraction method to non-spherical pearls is rarely required. In thin-skinned spherical pearls, however, the outline of the mother-of-pearl nucleus was seldom recognizable. The best experimental condition was a horizontal orientation of the drill hole; under this precondition, the outline of the nucleus became visible close to the drill hole. Therefore, the investigation of the diffraction pattern is of great importance for the determination of thin-skinned bead-nucleated pearls.

In our study the direct radiographs of Keshi cultured pearls yielded, in about 80% of the samples investigated, diagnostic structures which are similar to those of non-bead-nucleated tissue-implanted cultured pearls. In about 10% of the X-ray pictures diagnostic structures were recognized which are close to those only seen in the radiographs of natural pearls.

Non-bead-nucleated cultured freshwater pearls from China are, in general, recognizable due to their external shape as well as to their characteristic surface structures. A large proportion of non-bead-nucleated cultured freshwater pearls from Japan (Biwa cultured pearls) is easily recognizable by their external shape. In addition, both types of cultured pearls reveal typical radiographic features in the X-ray photograph. Spherical or nearly spherical non-bead-nucleated cultured freshwater pearls (Biwa cultured pearls), however, are easily mistaken for natural pearls or bead-nucleated cultured pearls. The direct radiographs of this type of Biwa cultured pearls revealed in only 20% of the samples the diagnostic blacking of irregular formed structures of high X-ray transparency. These results indicate that this second type of non-bead-nucleated Biwa cultured pearls without characteristic properties in the direct X-ray photograph was grown without tissue implantation (cf. Brown, 1981a, 1981b; 'first crop' and 'second crop' Biwa cultured pearls). Both types of non-bead-nucleated cultured pearls, however, are recognizable due to an intense and diagnostic luminescence under X-ray excitation.

The luminescent behaviour of pearls under X-ray excitation was examined in one single working step together with the direct radiographic exposure. The information obtainable from this test alone is not sufficient to characterize a pearl of unknown origin. However, the luminescence under X-ray excitation is suitable to give important clues which are useful to complete the information from the direct radiograph and, if necessary, the diffraction pattern. In addition, the investigation of luminescence under X-ray excitation is important for the recognition of freshwater pearls in order to avoid radiation damage caused by the Laue-method.

The investigation of the diffraction patterns can prove the presence or absence of a mother-of-pearl nucleus in pearls of unknown origin (seawater and freshwater pearls). The Laue-method is not able to distinguish between natural pearls, non-bead-nucleated cultured pearls and Keshi cultured pearls. However, it is very useful to characterize pearls without diagnostic properties in the direct radiograph, e.g. thin-skinned bead-nucleated cultured pearls as well as extremely thick-skinned bead-nucleated cultured pearls.

*Determinative procedure for the characterization of pearls of unknown origin*

In general, only those pearls which are not determinable according to their external features, e.g. surface properties or external shape, are submitted for radiographic examination. Without application of radiographic procedures the following types of pearl are often recognizable: cultured blister pearls (e.g. Mabe composite cultured pearls), most non-bead-nucleated cultured freshwater pearls from China, a fraction of non-bead-nucleated cultured freshwater pearls from Japan (Biwa cultured pearls), and imitation pearls.

It is suggested that the determination of pearls of unknown origin begins with several direct radiographs in various orientations of the pearl. In the same step the luminescence of pearls under X-ray excitation is investigated. Assuming that the direct radiographs reveal structures of diagnostic value, i.e. structures which unambiguously indicate the internal structure of the pearl, an unequivocal identification of most of those samples is possible by combining direct radiography with luminescence. A schematic diagram for determinative purposes of pearls with diagnostic structures in the direct radiograph is given in Fig. 3. For those pearls mentioned above, diffraction photographs can be

pearl of unknown origin

several X-ray radiographs in different orientations of the pearl

**fine ring structures, arcs or regular cavities in the centre**

luminescence under X-ray excitation

- weak to strong → natural freshwater pearl
- none → natural seawater pearl or non-nucleated accidental cultured seawater pearl = Keshi pearl*

**large irregular patches of variable radiolucency**

luminescence under X-ray excitation

- medium to strong → non-bead-nucleated tissue-implantated cultured freshwater pearl
- none → non-nucleated accidental cultured seawater pearl = Keshi pearl*

**external ring structures or arcs, radio-opaque bead in the centre**

luminescence under X-ray excitation

- medium to strong → bead-nucleated cultured freshwater pearl
- none or weak to medium → bead-nucleated cultured seawater pearl

Fig. 3. Schematic diagram for determining pearls of unknown origin using direct radiography and luminescence under X-ray excitation (for pearls having diagnostic structures in the direct radiograph).

* About 10% of Keshi cultured pearls investigated in this study revealed structures in the direct radiograph which are similar to the structures of natural pearls.

pearl of unknown origin

several X-ray radiographs in different orientations of the pearl

no diagnostic characteristics

luminescence under X-ray excitation

**strong**

several X-ray diffraction photographs in different orientations

with mother-of-pearl nucleus → bead-nucleated cultured freshwater pearl

non-bead-nucleated structure → non-tissue-implanted cultured freshwater pearl* or natural freshwater pearl***

**medium**

several X-ray diffraction photographs in different orientations

with mother-of-pearl nucleus → bead-nucleated cultured seawater pearl

non-bead-nucleated structure → non-bead-nucleated non-tissue-implanted cultured freshwater pearl* or natural freshwater pearl***

**weak**

several X-ray diffraction photographs in different orientations

with mother-of-pearl nucleus → bead-nucleated cultured seawater pearl

**none**

several X-ray diffraction photographs in different orientations

with mother-of-pearl nucleus → bead-nucleated cultured seawater pearl

non-bead-nucleated structure → natural seawater pearl or non-nucleated accidental cultured seawater pearl = Keshi pearl**

Fig. 4. Schematic diagram for determining pearls of unknown origin using X-ray diffraction and luminescence under X-ray excitation (for pearls without diagnostic structures in the direct radiograph).

* Pearls with the properties indicated are supposedly 'second crop' Biwa cultured pearls.

** About 80% of Keshi cultured pearls in this study were recognizable by direct radiography. The direct radiographs of about 10% revealed structures similar to natural seawater pearls, and those of about 10% were of no diagnostic value.

*** Natural freshwater pearls were often distinguishable by visual appearance from cultured freshwater pearls; natural freshwater pearls without diagnostic properties in the direct radiograph and having the strong luminescence of Biwa cultured pearls are extremely rare.

taken as a supplementary test although in those cases the application of this method is not necessary. Difficulties arise in the determination of some Keshi cultured pearls which reveal no structures in the X-ray photograph or show diagnostic structures indicating a natural pearl. The application of the Laue-method in addition does not solve these determinative problems.

In addition to the luminescence under X-ray excitation, diffraction photographs are necessary for those pearls without determinative features in direct radiographs. The investigation of freshwater pearls by the diffraction technique can cause radiation damage. Thus, the diffraction method should be avoided for those pearls which are recognized by luminescence as freshwater-grown. Without positive results of direct radiography an unequivocal identification by the combination of luminescence and diffraction radiography is possible only for a fraction of the pearls. A schematic diagram for this situation is given in Fig. 4. By the application of luminescence investigation and diffraction radiography only, natural seawater pearls are not distinguishable from Keshi cultured pearls. Also a fraction of natural freshwater pearls cannot be distinguished from non-bead-nucleated tissue or non-tissue-implanted cultured freshwater pearls by this approach. According to the results of this study, about 80% of Keshi cultured pearls are recognizable by direct radiography. For the remaining 20%, the three types of radiographic techniques are not suitable for an unambiguous distinction from natural seawater pearls. Natural freshwater pearls without diagnostic features in the direct radiograph but with a strong luminescence are easily mistaken for spherical or nearly spherical Biwa cultured pearls without diagnostic structures (non-bead-nucleated non-tissue-implantated cultured freshwater pearls). However, natural pearls having these properties are extremely rare.

*Additional remarks*

During this study it became evident that necklaces found in the trade may consist of both natural pearls and bead-nucleated cultured pearls, which are often thin-skinned cultured pearls. It is self-evident that an unequivocal characterization of necklaces composed of natural and cultured pearls is extremely difficult. If a necklace of unknown origin consists, e.g. of 100 pearls, and if furthermore by direct radiography about 10% of the pearls were recognized as natural and about 10% of the pearls were recognized as cultured pearls, the determination of the remaining 80% of the pearls without diagnostic structures in the direct radiograph will be extremely time consuming although X-ray diffraction photographs of every pearl of the

necklace can solve this problem (diffraction photographs of pearls from necklaces can be done by use of the sample holder pictured in Fig. 2). Only those pearls of the necklace having a diameter of at least 3 mm can be investigated by X-ray diffraction photography.

In conclusion it can be stated that necklaces of uniform composition, i.e. necklaces consisting of one type of pearl only, are easily determinable by a combination of all three methods discussed in this paper. On the contrary, the determination of mixed necklaces, i.e. necklaces consisting of pearls of different origins, may be extremely complicated and time consuming.

In general, single pearls of distinct size are also determinable by a combination of all three X-ray techniques, though difficulties may arise from certain types of pearls. The determination of small pearls by radiographic methods, however, may become difficult or even impossible.

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# Gemmological Abstracts

ALEXANDER, P.O. 1985. Looking for diamonds? Try geobotany. *Wahroongai News*, **19**, 7, 18–20.

The strongly mineralized ultramafic rocks of kimberlite have been found to promote vegetation so that it stands out in contrast to the sparse cover of the surrounding rock, which is also ultramafic but less rich in phosphorus and potassium.

Geobotanical studies of the Hinota kimberlite pipe have shown that the vegetation in the form of large and healthy trees is in such marked contrast as to be discernible from a distance or from the air. It is suggested that these differences in vegetation may be useful in locating buried kimberlite pipes in areas of known potential, with particular reference to the Panna diamond belt of Central India. R.K.M.

BAGUENA RUIZ, C. 1985. Estudio comparativo de tres tipos de 'hematites'. (Comparative study of three types of 'hematites'.) *Gemologia*, **22**, 65/66, 48–59, 9 figs (6 in colour).

Three types of material which have been given the name hematite are examined. X-ray diffraction is used to determine crystal structure and electrical conductivity studies establish the identity of the specimens conclusively. M.O'D.

BALFOUR, I. 1985. Famous diamonds of the world, XXIV. The 'Nassak' diamond. *Indiaqua*, **42**, 3, 133–5, illus.

The diamond known as 'Nassak' was named after the town of Nasil situated 110 miles north of Bombay. It was 'liberated' in 1818 by British forces as part of the booty in the last of the Mahratta Wars, and was handed over to the East India Company. Its shape then was triangular, and it weighed around 89 carats. After passing through many hands it was purchased by Harry Winston who had it re-cut to its present shape as an emerald-cut weighing 43.38 carats. It was finally acquired by the King of Saudi Arabia in 1977. P.G.R.

BANCROFT, P. 1985. The story behind the book. *Lapidary J.*, **39**, 9, 26–37, 8 figs (3 in colour).

The book is *Gem and Crystal Treasures** and the article gives some of the anecdotes amassed by the author while preparing the book. M.O'D.

* Reviewed in *J. Gemm.*, 1985, **XIX**, 8, 733.

BANK H. 1985. Farbloser Skolezit aus Indien. (Colourless scolecite from India.) *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 167–8, bibl.

The transparent colourless crystals were offered as natrolite, but were shown to be scolecite, SG 2.21, RI $n_x$ 1.512, $n_y$ 1.518. $n_z$ 1.523. E.S.

BANK, H., KNIEWALD, G. 1985. Farbloser Hyalophan von Busovača, Jugoslawien. (Colourless hyalophane from Busovača, Yugoslavia.) *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 169–70.

The material comes from Busovača in central Bosnia, about 50 km north-west of Sarajevo. It is colourless, transparent, density 2.89 g/cm³, RI $n_x$ 1.541–1.543, $n_y$ 1.546–1.549, $n_z$ 1.549–1.551, DR 0.007–0.008, and was found to be hyalophane. E.S.

BOUŠKA, V., FRYDRYCH, M., TURNOVEC, I. 1985. Moldavites as precious stones. *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 83–91, 8 figs (3 in colour).

Prehistoric man was already attracted by moldavites, found near Willendorf in Austria and Oslavany in Czechoslovakia. There are no medieval reports on moldavites. They were used as decorative stones from the 18th century. Examples of cut moldavites set in gold were shown at the National Exhibition in Prague in 1891. Two of the authors work in the co-operative 'Granat' in Czechoslovakia which produces modern moldavite jewellery, mainly set with uncut stones, but moldavite is also cut and two artists are mentioned as specializing in engraving moldavites. E.S.

BOWERSOX, G.W. 1985. A status report on gemstones from Afghanistan. *Gems Gemol.*, **XXI**, 4, 192–204, 14 figs in colour.

Report on production of emerald, tourmaline, kunzite and ruby, at the western end of the Himalayas in NE Afghanistan, which has increased dramatically since the Russian invasion greatly increased the need for foreign currency. Fine emerald from the Panjshir Valley (bombs sometimes reveal new localities), RI and SG are high comparable with those for South African stones. Nuristan region produces fine aquamarine, tourmaline in pink, blue, green and multi-coloured. Some of the finest kunzite comes from this region. Fine rubies occur in marble in Sorobi District at Jegdalek, but

war precludes serious mining. Considerable quantities of fine lapis lazuli are also coming across the border to Pakistan. The gems are back-packed out, the miners often walking hundreds of miles through remote and difficult country. The need for foreign exchange is great.                                    R.K.M.

CARUBA, R., BAUMER, A., GANTEAUME, M., IACCONI, P. 1985. An experimental study of hydroxyl groups and water in synthetic and natural zircons: a model of the metamict state. *American Mineralogist*, 70, 1224–31, 8 figs.

Zircon has been synthesized between 200 and 800°C at 1 kbar in a fluorinated environment. It is a solid solution in which the $(OH,F)_4$ group takes the place of a $SiO_4$ tetrahedron and is of the type $Zr(SiO_4)_{1-x}(OH,F)_{4x}$ with $0.2 < x < 0.8$. It is thought that natural zircons are formed at low temperature in a hydrous and fluorinated environment enriched by heavy rare earth and radioactive elements whose particles destroy the hydroxylated crystal lattice. F is thought to be present in the $(OH)_4$ tetrahedra.                           M.O'D.

CAVENEY, R.J. 1985. De Beers Diamond Research Laboratory Report No. 20. The strength and performance of diamond depends on many factors. *Indiaqua*, 42, 3, 123–5, illus.

It has been discovered that, when a narrow beam of laser light is passed through a diamond which is visually free from foreign inclusions, the beam experiences scattering. A direct relationship has been established between the intensity of light scattered and the performance of the diamond as a cutting tool. It is concluded that many of the previously unexplained differences in mechanical properties of diamond can now be explained by the presence of inclusions which are invisible even under a microscope.                        P.G.R.

COHEN, A.J. 1985. Amethyst colour in quartz, the result of radiation protection involving iron. *American Mineralogist*, 70, 1180–5, 3 figs.

$Fe^{3+}$ in interstitial positions in the growth loci of the major rhombohedron in quartz crystals will prevent the development of smokiness if the amount of Fe is larger than the $Al^{3+}$ impurity content. The Al impurity is responsible for the smoky colour through the operation of a trapped hole centre when ionizing radiation is used. Growth loci of the minor rhombohedra may be smoky even when there is an excess of substitutional $Fe^{3+}$ over $Al^{3+}$. When interstitial $Fe^{3+}$ is oxidized to $Fe^{4+}$ an electron becomes available for quenching the trapped hole centres on oxygens adjoining substitutional $Al^{3+}$ sites as they form. In these circumstances

the smoky colour is not developed. Amethyst colour is produced by an absorption band of the $Fe^{4+}$. In nature $Fe^{3+}$ only predominates over $Fe^{4+}$ in quartz formed under shallow-growth conditions such as cavities or geodes. Amethyst coloration is found in these conditions only.          M.O'D.

COHEN, A.J., MAKAR, L.N. 1985. Dynamic biaxial absorption spectra of $Ti^{3+}$ and $Fe^{2+}$ in a natural rose quartz crystal. *Mineralogical Magazine*, 49, 354, 709–15, 4 figs.

The absorption spectrum of $Ti^{3+}$ in quartz is characteristic for Ti in an octahedral site. However. the high oscillator strength of the band indicates intensive charge transfer, and this is most likely to take place between a substitutional $Ti^{4+}$ and an interstitial $Ti^{3+}$. The band shows biaxial anisotropy similar to that shown by that of octahedral $Fe^{2+}$ in the same crystal, which suggests that the $Ti^{3+}$ occupies the same site – an interstitial site at the intersection of the 3-fold axis with the two 2-fold axes. When the crystal is X-irradiated and then bleached by UV light or heat the dynamic nature of the Ti and Fe can be observed. $Ti^{4+}$ ions are acceptors of electrons donated by $Fe^{2+}$ during X-irradiation. This can be seen in an increase of the 2.4eV band intensity with decrease of the $Fe^{2+}$ band intensities and the appearance of $Fe^{3+}$ charge transfer bands in the UV region. The heat and UV treatment diminish the $Fe^{3+}$ charge transfer bands and increase the $Fe^{2+}$ crystal field bands, together with decrease in the 2.4eV band related to Ti.
                                          M.O'D.

COLDHAM, T. 1985. Sapphires from Australia. *Gems Gemol.*, XXI, 3, 130–46, 21 figs in colour.

A good account of the sapphire fields at Inverell, NSW, and at Anakie in Queensland, including geology, mining methods, processing, sorting and grading. Almost all the output is sold to Thai merchants skilled in heat treatment to improve colour and remove silk. Blues and yellows predominate, while pinks, purple and mauve stones are rare. Colour zoning is common, often alternating blue and yellow. These two fields are showing signs of exhaustion, but the vast area of basalts in eastern Australia probably hides other potential mining areas of considerable significance.         R.K.M.

DONTENVILLE, S., CALAS, G., CERVELLE, B. 1985. Etude spectroscopique des turquoises naturelles et traitées. (Spectroscopic study of natural and treated turquoise.) *Revue de Gemmologie*, 85, 8–10, 6 figs. First part.

Spectra for natural turquoise from the United States, plastic impregnated turquoise with added colour, plastic-impregnated turquoise with no

added colour, Gilson synthetic turquoise and 'turquoise morte' (material whose colour has been lost through exposure to sunlight) are described and illustrated.                                           M.O'D.

FRUITMAN, C. 1985. The ultima cut. *Lapidary J.*, 39, 8, 25–32, 9 figs (1 in colour).
A cut designed to increase dispersion in a variety of coloured stones is described. Loss of weight is avoided as far as possible.                   M.O'D.

FRYER, C.W. (Ed.), CROWNINGSHIELD, R., HURWITT, K.N., KANE, R.E. 1985. Gem Trade Lab notes. *Gems Gemol.*, **XXI**, 3, 171–7, 19 figs in colour.
Black star sapphire doublets and two corundums with surface-induced stars, one natural, the other a flux-grown synthetic, are described. A gambling dice cut from an industrial diamond; strontium titanate and cubic zirconia mistaken for diamonds, were totally destroyed by heat in repairs; an apparently new low grade synthetic emerald with considerable inclusions of parallel needles (RI 1.555–1.560, SG 2.67); a green and white carved bell with plagioclase and green muscovite mica as major constituents; a demantoid cat's-eye identified by its single refraction and absorption spectrum; a fine jadeite with unidentified hair-like inclusions; another with a large white single jadeite crystal as an inclusion; plastic imitations of lapis lazuli and a purplish-pink faceted sapphirine are all described and illustrated.         R.K.M.

FRYER, C.W. (Ed.), CROWINGSHIELD, R., HURWITT, K.N., KANE, R.E. 1985. Gem Trade Lab notes. *Gems Gemol.*, **XXI**, 4, 232–8, 18 figs in colour.
Reports on bi-colour aquamarine/goshenite; diamond turned yellow-brown by heat of laser sawing; diamond with internal natural radiation staining; and the composite (piggy-back) setting of two yellow diamonds. Off-colour yellow diamonds are being re-cut as modified octagonals to enhance the colour; and a cubic zirconia was similarly cut. Garnet/glass doublet, mistaken for ruby, melted under heat of repair work (low temperature soft glass). A fine jet urn is illustrated. Lapis lazuli beads had been oiled to improve colour. An interesting collection of rare pink conch 'pearls' described. A large collection of three-quarter blister pearls from Hong Kong were shown to be plastic. A pinkish-purple natural spinel had colour change to purplish-pink. Synthetic alexandritic type spinels are
rarely seen. Synthetic zincite described and illustrated. Another oddity was identified as the boiled lens of a fish's eye.                             R.K.M.

GÜBELIN, E. 1985. La identificación de los nuevos zafiros sintéticos y tratados. (Identification of the new synthetic and heat-treated sapphires.) *Gemologia*, 22, 65/66, 5–34, 49 figs (44 in colour).
Translation into Spanish of a paper first published in *J. Gemm.*, 1983, **XVIII**, 8, 677–706.       M.O'D.

HENN, U., SCHRAMM, M. 1985. Untersuchungen an braunen Turmalinen von Elahera, Sri Lanka. (Investigation of brown tourmalines from Elahera, Sri Lanka.) *Z. Dt. Gemmol. Ges.*, 34, 3/4, 98–100, 1 fig. in colour.
The brown tourmalines from Elahera were classified as uvites and dravites. Photomicrograph shows rounded zircon crystals in a brown tourmaline.                                        E.S.

HOFER, S.C. 1985. Pink diamonds from Australia. *Gems Gemol.*, **XXI**, 3, 147–55, 12 figs in colour.
Pink diamonds have been regarded as among the rarest of the colour varieties and it is considered unusual to encounter actual parcels of natural pink diamonds. But a surprisingly large number of these stones have come in to the New York Gem Trade Lab this year, all originating from material produced in the newly discovered Argyle deposits in NW Australia. Most stones are heavily included. 138 were examined in detail by this author.
Colour was an unusual smoky purplish-pink, deeper than most pink diamonds. Nuances of brown and other colours were found. The spectrum showed the Cape absorption line at 415 nm and the weak band at 520–580 nm, markedly different from the spectra of known irradiated pinks. UV fluorescence was blue but varied in strength. Colour is thought to be due to plastic deformation of crystal lattice and is unevenly distributed in the form of 'brush stroke' grain lines throughout the stone, best seen under low power magnification. 'Frosted' cleavage cracks and a pitted, sugary crystal surface seem to be characteristic of these Australian diamonds. It is thought that 'etching' is due to the crystal surfaces being dissolved by heat. [The author does not say whether the observed pitting was in reverse to the octahedral edge or parallel to it. In abstracter's experience the latter is always the case when a diamond has been burnt.] Solid inclusions had mostly assumed shapes which accorded with the morphology of the diamond. It is considered that the features described would be sufficient to identify the provenance of these Australian pinks with fair certainity.         R.K.M.

KANE, R.E., LIDDICOAT, R.T., Jun. 1985. The Biron hydrothermal synthetic emerald. *Gems Gemol.*, **XXI**, 3, 156–70, 18 figs in colour.

New hydrothermal synthetic emeralds grown in Western Australia were subjected to careful gemmological tests. Colour varied from green to slightly bluish-green with good saturation and high transparency, often apparently free from inclusions. Dichroism and absorption were as expected for synthetic emeralds and fine natural stones. Red transmission was observed under suitable lighting, but this again is seen in some of the finer Colombian stones. A strong red was seen through the Chelsea colour filter.

SG varied slightly around 2.70 so that they overlapped the values for natural emeralds, confirming these are hydrothermally produced stones. None of the stones examined exhibited any fluorescence under either type of UV light. Iron was not found in these stones and the quenching in this instance must be due to the high concentration of vanadium, which exceeded the chromium content by more than two to one. RIs of 1.569 and 1.573 were obtained giving a birefringence figure of 0.004–0.005, low values which suggest the synthetic origin, and rather more like those of a flux-grown stone than a hydrothermal synthetic.

The authors concentrate on inclusions, which are the identifying features in most synthetic emeralds. Healed fissures of the fingerprint and veil type are typical, and often consist of two-phase inclusions of bubble and liquid. Inclusions are by no means prolific, and careful illumination is often needed to bring out the tell-tale features. A variety of other inclusion forms is described and illustrated, including nail-head spicules stemming from phenakite crystals, or gold crystals which have come from the lining of the steel autoclave, both proving the synthetic origin of the stones.

Dark-field illumination shows growth irregularities and 'flows' of colour which would not otherwise be obvious. Some of these consisted of 'comet tails' of minute white particles. White specks were almost the only inclusions to be seen in the cleanest stones. A few stones showed what appeared to be seed-plates.

Chemically the presence of chlorine in these synthetics can be regarded as proof of synthesis. This element does not occur in flux-grown synthetics or in natural emeralds.

The authors suggest that the characteristic inclusions and the low refractive indices and birefringence provide principal identifying clues to these stones. Identification is not considered to be difficult provided the gemmologist is familiar with the inclusions to be expected, and uses that knowledge to the full. The presence of chlorine is

another valuable final proof for such laboratories as have facilities to test for this.

The manufacturer claims to be able to control the clarity and is concentrating on 'clean' material.

R.K.M.

KOIVULA, J.I., MISIOROWSKI, E. 1985. Gem news. *Gems Gemol.*, **XXI**, 3, 185–7, 1 fig. in colour.

News of diamond mining in Australia, Botswana, Ghana, Namibia, Sierra Leone (three diamonds over 100 carats found) and United States (kimberlites under glacial deposits in northern Michigan are being explored).

A new amethyst area in Para, Brazil, is now producing significantly. Aquamarine from the Jos region of Nigeria continues to reach Idar-Oberstein. Other supplies are coming from various African localities and Brazil. Phantom quartz with 'ghost' outlines apparently due to green chlorite inclusions is being mined at Buenopolis in Minas Gerais.

Triangular growth markings on the basal pinacoids of a very thin Yogo Gulch, Montana, sapphire were in the expected reverse orientation and so close together as to give a perfect Star of David formation when viewed along the *c* axis.

R.K.M.

KOIVULA, J.I. 1985. Gem news. *Gems Gemol.*, **XXI**, 4, 247–9, 2 figs in colour.

Reports on diamond mines in Shandong Province, China; on high potential of Indian alluvial deposits; and on UK Diamond Futures market which is mooted. Two rare 'pineapples' of opal, replacing glauberite crystals, found at White Cliffs. A new Pakistan source of emerald at Sassi in the Haramosh Mountains gives clean light-coloured stones. Alan Macnow reports that all cultured pearls are treated with mild oxidizing agent to prevent discoloration, some dyed pink or other colours. Smuggling of gems from Burma to Thailand continues. Kenyan rubies are sent to Bangkok for heat treatment to clarify them.

Pailin mines in Cambodia closed by military activity, miners cross to similar deposits in Thailand. Sapphire-bearing regions in Fujian, China, are being explored. An aquamarine crystal from Yogo Gulch, Montana, had growth pattern on basal pinacoid forming a six-pointed 'Star of David'.

R.K.M.

LIND, Th., SCHMETZER, K. 1985. Neue Untersuchungen an in Japan hergestellten synthetischen Amethysten. (New investigations of the Japanese synthetic amethysts.) *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 160–4, 6 figs in colour, bibl.

Synthetic Japanese amethysts are now available in the gem trade. Certain diagnostic properties such as inclusions, growth structures, twinning and infrared spectra are discussed. The gemstones frequently have feathers consisting of liquid-filled and two-phase inclusions, sharp growth zoning parallel to one rhombohedral face as well as twin structures, which can easily be distinguished from the polysynthetic lamellar twinning in natural amethysts. E.S.

MÜLLENMEISTER, H.J. 1985. Zirkon-Katzenauge aus Sir Lanka. (Zircon cat's-eye from Sri Lanka.) *Z. Dt. Gemmol. Ges.*, 34, 3/4. 165–6, 1 fig. in colour, bibl.
The stone described is a yellowish zircon cat's-eye with blue adularescence, cut as cabochon weighing 5.52 ct with strong chatoyancy. It is from Sri Lanka and was originally offered as moonstone. SG 4.62. The chatoyancy is caused by layered inclusions of needles; the nature of these inclusions was not determined. E.S.

NASSAU, K., HANSON, A.E. 1985. The pearl in the chicken: pearl recipes in Papyrus Holmiensis. *Gems Gemol.*, XXI, 4, 224–31, 7 figs. in colour.
Authors have found and tried ancient recipes for repolishing and/or cleaning pearls by feeding them to a chicken. Pearls remain in the bird's crop for an hour or so only and are then abstracted by killing the chicken. Some experiments failed, other succeeded. [From the chicken's viewpoint they all failed miserably.] R.K.M.

NUBER, B., SCHMETZER, K. 1984. Structural refinement of tsilaisite (manganese tourmaline). *N. Jb. Miner. Mh.*, 7, 301–4.
The crystal structure of the Na-(Al,Mn,Li)-tourmaline tsilaisite was refined to a R-value of 2.9%. The structure is closely related to the crystal structures of elbaite and schorl, and manganese was found to occupy exclusively Y sites in the tsilaisite structure. Author's abstract. B.N.

O'DONOGHUE, M. 1985. Crystals as ornament. *Gems and Mineral Realm*, 16, 4, 11–23.
An exhaustive outline of the progress of gemstone synthesis since the middle of the last century, with a bibliography. Author's abstract. M.O'D.

O'DONOGHUE, M. 1985. Pakistan. *Gems and Mineral Realm*, 16, 4, 35–7.
An account of the author's trip to Pakistan as adviser to the State Gem Corporation. The geology of the major gem deposits is outlined.
Author's abstract. M.O'D.

PIZANI, P.S., TERRILE, M.C., FARACH, H.A., POOLE, C.P. 1985. Color centers in sodalite. *American Mineralogist*, 70, 1186–92, 9 figs.
Natural sodalite subjected to various radiation and heat treatments is studied with ESR, NMR, optical absorption spectroscopy, ionic thermal currents and electrical conductivity. It is proposed that the colour centres which are involved in coloration and bleaching are associated with interstitial oxygen. M.O'D.

PONAHLO, J., KOROSCHETZ, T. 1985. Quantitative Kathodolumineszenz – ein neues Verfahren zur Unterscheidung echter von synthetischen Smaragden und Rubinen. (Quantitative cathodoluminescence – a new method of differentiating between natural and synthetic emerald and ruby). *Z. Dt. Gemmol. Ges.*, 34, 3/4, 132–42, 9 figs (7 in colour), bibl.
Quantitative cathodoluminescence is the method of microphotometric measuring of luminescence-intensities emitted during bombardment with fast travelling electrons (cathodorays). Natural rubies from Thailand show one tenth of CL intensities compared with synthetic rubies. E.S.

ROSENBERG, P.E., FOIT, F.F. 1985. Tourmaline solid solutions in the system $MgO-Al_2O_3-SiO_2-B_2O_3-H_2O$. *American Mineralogist*, 70, 1217–23, 3 figs.
A narrow range of tourmaline solid solutions in this system has been synthesized in the presence of excess silica, $B_2O_3$ and $H_2O$ in the temperature range 400–800°C at a pressure of 1 kbar. In nature tourmalines approaching the alkali-free composition are rare, most not coming even close to it. The synthesis shows that the narrow range can exist and the principal substitutions are identified. M.O'D.

ROTTLÄNDER, R.C.A. 1985. Der chemische Abbau des Bernsteins bei seiner Aufbewahrung an der Luft. (The chemical decomposition of amber when exposed to air.) *Z. Dt. Gemmol. Ges.*, 34, 3/4, 143–51, 7 figs, bibl.
Amber is of interest to gemmologists as well as archaeologists. It is known that when exposed to air and light amber decomposes with an uptake of oxygen. This was quantitatively tested over 14 years, during that time solubility increased up to 40% (among the soluble substances 65% terpenes). It was calculated that there were about 25% resin acids of the abietic acid type present as parent substances. The infrared spectra reflect oxidation of amber. E.S.

SCHMETZER, K. 1985. Distinction of natural and synthetic rubies by ultraviolet absorption spectroscopy – possibilities and limitations of the method. *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 101–29, 45 figs, bibl.

The article discusses possibilities and limitations of UV absorption spectroscopy for the differentiation between natural and synthetic rubies. For determination of rubies of unknown origin a direct comparison of the spectra of unknown samples with standard spectra of natural samples of known origins and of synthetic samples of known producers is necessary. For a great number of unknown samples, UV spectroscopy gives unambiguous information about locality of natural or producer of synthetic rubies. It may also reduce possible options regarding locality or producer. It does not provide definite information for determining each possible unknown ruby, but it is helpful when combined with microscopy and trace element analysis.                                          E.S.

SCHMETZER, K., BANK, H. 1985. Gahnospinelle aus Sri Lanka. (Gahnospinel from Sri Lanka.) *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 92-7, 8 figs (1 in colour), bibl.

The examined samples of zincian spinels (gahnospinels) from Sri Lanka were found to represent intermediate members of the spinel-gahnite series with minor components of hercynite. The investigations confirmed results published by Anderson in 1937.                                          E.S.

SCHRADER, H.W. 1985. 'Dreiphaseneinschluss' in einem Smaragd aus Südafrika. (A three-phase inclusion in an emerald from South Africa.) *Z. Dt. Gemmol. Ges.*, **34**, 3/4, 130–1, 1 fig in colour.

An English version of this article was published in *J. Gemm.*, 1985, **XIX**, 6, 484-5.                                          E.S.

SCHRADER, H.-W., HENN, U. 1985. Über die Problematik der Galliumgehalte als Hilfsmittel zur Unterscheidung von naturlichen Edelsteinen und synthetischen Steinen. (About the problems of using the gallium content to differentiate between natural and synthetic stones.) *Z. Dt. Gemmol. Ges.*, **34**. 3/4, 152–9, bibl.

An English version of this article appears on p. 108 above.                                          E.S.

SHIGLEY, J.E., KOIVULA, J.I. 1985. Amethystine chalcedony. *Gems Gemol.*, **XXI**, 4, 219–23, 7 figs (6 in colour).

A new amethystine chalcedony from Arizona, offered as 'damsonite', has normal constants for crypotocrystalline quartz, occurs in greyish, slightly reddish-purple, opaque masses varying from dark to light in colour. Heating to 550°C changed colour to a citrine orange.                                          R.K.M.

SOLANS, J., DOMENECH, M.V. 1985. Los materiales gemológicos de Asturias. (Gemmological materials from Asturias.) *Gemologia*, **22**, 65/66, 35–43, 3 figs.

Among the ornamental minerals found in the Spanish province of Asturias are chiastolite, beryl, fluorite, jasper, amber and quartz with some jet.                                          M.O'D.

SOMAN, K., NAIR, N.G.K. 1985. Genesis of chrysoberyl in the pegmatites of southern Kerala, India. *Mineralogical Magazine*, **49**, 354, 733–8, 2 figs.

Chrysoberyl had been found in association with quartz in alkali feldspar in granitic pegmatites in southern Kerala, India. It is thought to crystallize earlier than beryl and sillimanite. A model explained in detail in the paper may serve to explain the genesis of chrysoberyl in Sri Lanka.                                          M.O'D.

STOCKTON, C.M., MANSON, D.V. 1985. A proposed new classification for gem-quality garnets. *Gems Gemol.*, **XXI**, 4, 205–18, 8 figs (4 in colour).

Published work by these authors suggests a redefining of the garnet group into categories of grossular, andradite, pyrope, pyrope-almandine, almandine, almandine-spessartine, spessartine, and pyrope-spessartine. Varietal categories (e.g. tsavorite, chrome pyrope, rhodolite and malaia) are defined. These suggestions are argued convincingly and backed by gemmological data and electron-probe chemical analyses. The result is a paper on vexed questions of definition which must give grounds for further discussion.                                          R.K.M.

ZEITNER, J.C. 1985. Facet a stone from home. *Lapidary J.*, **39**, 8, 42–51, 4 figs in colour.

Describes some classic gemstones from North American localities and gives brief information on the gemstone market.                                          M.O'D.

ZEITNER, J.C. 1985. Merry Christmas gems. *Lapidary J.*, **39**, 9, 19–24, 4 figs in colour.

Describes red and green gemstones, including alexandrite, iris agate, unakite, tourmaline, bloodstone, ruby in zoisite and others.                                          M.O'D.

# Book Reviews

BARDET, M.G. 1974. *Geologie du diamant. Deuxieme partie: gisements de diamant d'Afrique.* (Geology of diamonds. Second part: deposits of diamond in Africa.) BRGM, Paris. Pagination irregular. Illus. in black-and-white. Price on application.

Forming *Memoire No. 83* of the Bureau de Recherches Géologiques et Minères, this book discusses the diamond occurrences in Africa giving simplified geological maps of each of the major sites and covering the Kimberley area in some detail. Each of the major mines is discussed and its production and features described in tables. Each major area (South, West, East and Central Africa) is provided with its own bibliography. This is one of the few books on diamond to cover the geological and mineralogical aspects of its occurrence and is essential for the mineralogist.                          M.O'D.

BERRY, F.J., VAUGHAN, D.J., (Eds.) 1985. *Chemical bonding and spectroscopy in mineral chemistry.* Chapman & Hall, London. pp. x, 325. £35.00.

Chapters in this book are: quantum mechanical models and methods in mineralogy; X-ray spectroscopy and chemical bonding in minerals; electronic spectra of minerals; mineralogical applications of luminescence techniques; Mössbauer spectroscopy in mineral chemistry; electron spin resonance and nuclear magnetic resonance applied to minerals; spectroscopy and chemical bonding in the opaque minerals and mineral surfaces and the chemical bond. Almost all the chapters have something of interest for the gemmologist but I would particularly recommend the one dealing with the electronic spectra of minerals, since it contains a good deal of information on mineral coloration. Although this topic has long been prominent in the appropriate journals it is here updated and presented lucidly with a useful reference section (all the chapters have one). Luminescence techniques are also valuable and the section on the opaque minerals should also be consulted when needed.                      M.O'D.

CONTENT, D.J. 1985. *Glyptic arts – ancient jewelry: an annotated bibliography.* Crow Hill, Houlton, Maine 04730, USA. pp. 158. Price on application.

This is the comprehensive catalogue of a bookseller specializing in engraved gems, jewellery and

the art of the goldsmith. The seventh in a series, it contains several hundred entries giving short bibliographical details of each item but no description of the text.                                M.O'D.

FORTHUBER, W. 1978. *Diamant, die härteste Währung der Welt.* (Diamond, the hardest currency in the world.) Verlag Atelier Oehri, Vaduz. pp. 131. Illus. in black-and-white. Price on application.

A pleasantly presented text on diamond with particular reference to diamond grading. Proportions and clarity grading are illustrated as are a number of instruments.                          M.O'D.

KALDIS, E. (Ed.). 1985. *Current topics in materials science.* Vol. 11. North-Holland Physics Publishing, Amsterdam. pp. 453. Price on application.

Garnets grown as thin layers and as crystals grown from high temperature solutions are discussed in the first chapter of this valuable book. Details of growth methods and the composition of melts are given. Special attention is paid to interfacial kinetics and to the correlation between growth kinetics and growth-induced magnetic anisotropy. Considerable detail on the growth of YAG, GGG and their analogues is given. The second chapter deals with substrates for epitaxial garnet layers and discusses dislocations.

The growth of iron borate, $FeBO_3$, is described in the third chapter and the growth and properties of lanthanum hexaboride in the fourth and last chapter. Readers are advised to consult this series where it can be found (for example in the Science Reference Library). Details of crystal formation and growth appear here long before reaching mineralogical or gemmological texts.    M.O'D.

KALDIS, E. (Ed.). 1985. *Current topics in materials science.* Vol. 12. North-Holland Physics Publishing, Amsterdam. pp. 483. Price on application.

Four topics are covered by the latest volume in this useful series. The first is metallic, ionic and Van der Waals clusters, the second covers metastable phases in the bulk and on substrates, the third describes vapour pressure investigation of P-T-X phase equilibria and non-stoichiometry in binary systems. The final paper covers the mechanical

properties of brittle materials, with modern theories and experimental evidence.

Readers who wish to find out more about the metastable phases of such materials as diamond will find the second paper of particular interest. R. Kern of CNRS (France) makes the point that a metastable phase of a substance means that it is quenched and transforms at so slow a rate that nobody sees any tendency to transform during a lifetime. Diamond, silica glass and amorphous semiconductors are strongly metastable rather than unstable. The thesis is developed in the paper.                                      M.O'D.

KOSKOFF, D.E. 1981. *The diamond world.* Harper & Row, New York. pp. viii, 356. Illus. in black-and-white. Price on application.

This covers very similar ground to Timothy Green's *The world of diamonds* (Weidenfeld & Nicolson, 1981) but is longer and more anecdotal. The history of the stone from mine to piece of jewellery is well outlined with useful and interesting side-lights on aspects of the diamond trade, particularly that of New York. There are some very welcome bibliographical notes and the whole book is conceived in a scholarly fashion.        M.O'D.

METZ, R. 1985. *Antlitz edler Steine.* (The faith of precious stones.) Prisma Verlag, Güterslch. pp. 188. Illus. in colour. DM 39.00.

This most beautifully illustrated book first came out in 1964, but this is a new printing with greatly enhanced colour reproduction. It is very competitively priced and can be highly recommended. It gives a simple introduction to the science of minerals with notes on the crystal systems with form and habit and valuable notes on how mineral crystals are formed. Various types of formation are described, including Alpine clefts, pegmatites and hydrothermal deposits. All through the book appropriate full-page-sized colour photographs by Arnold E. Fanck accompany the text; particularly noteworthy for me are those of blue salt crystals from the classic locality of Stassfurt and chalcanthite from Coquimbo.

The book ends with an exciting reproduction of the yellow Tiffany diamond and with a bibliography. Diagrams illustrating the basic symmetry of the crystal systems are provided. Although in German the text should present little difficulty and in any case the pictures are the main reason for buying the book.                                      M.O'D.

SANCHEZ CABELLO, A. 1978. *El interes por las piedras preciosas.* (Interest in precious stones.) Artes Graficas Vicent, Paterna, Valencia. pp. 167. Illus. in black-and-white and in colour. Price on application.

A well illustrated book on diamond with some of the major gemstones, probably written (from the style and the date) for the prospective investor. The illustrations are of very variable quality, some being excellent, others less so. There is a short bibliography.                                      M.O'D.

TABURIAUX, J. 1985. *Pearls, their origin, treatment and identification.* NAG Press, Ipswich. pp. 247. Illus. in black-and-white and in colour. £14.95.

Translated from the French *La perle-et ses secrets* this is one of the very few books to appear on pearl in the past few years. The author is professionally concerned with pearls and has visited a number of the more important areas of pearl recovery.

Much of the book is taken up by anecdotes, charming and instructive in themselves but still without the cited basis in fact that this type of book should provide. Since no references are given and there is no bibliography, the reader has to take much on trust and with the lack of serious literature on pearl for so long, it is a pity that the publishers did not try to get a more solid book. The details on the different pearl fisheries are interesting but we have no way in which to establish their accuracy or topicality without citations. The author is scarcely happier when describing the structure of pearls and is clearly not at home with the scientific basis of pearl testing. Proof-reading by the publishers, if there was any, should have picked up the description of aragonite crystals as triclinic. In this section the choice and size of chapters is capricious to say the least (if this were a stronger book and citations appropriate, such lack of arrangement would be a major drawback to the abstracter. A set of questions, useful in conception, suffers because the answers are so terse that students (who have no other book on which to draw) will take them as gospel; readers looking at the description of orient, in which light is said to be 'distorted' will be excused for feeling apprehensive about the rest of the book.

All this is a pity as the idea behind the book was good and the illustrations adequate (though some appear to have been reproduced from xerox). The lack of bibliography completely vitiates the use of the book as a serious text though the general reader will find it interesting.                        M.O'D.

# Proceedings of the Gemmological Association of Great Britain and Association Notices

## OBITUARY

Mr J.G. Shenton, F.G.A. (D.1934), Cheltenham, died on 30th September, 1985.

Mr F.S.H. Tisdall, F.G.A. (D.1936 with Distinction), Birmingham, died on 23rd January, 1986.

## GIFTS TO THE ASSOCIATION

The Council of the Association is indebted to the following for their gifts:

Mr John S. Burda, Unionville, Conn., USA, for a piece of peridot and green Transvaal garnet.

Mr R. Holt, London, for an oval emerald.

## MEMBERS' MEETINGS

### London

On 4th March, 1986, at the Flett Theatre, Geological Museum, Exhibition Road, South Kensington, London S.W.7, Prof. Pieter C. Zwaan, F.G.A., gave an illustrated talk entitled 'Gemstones from the Kataragama area in Sri Lanka'.

### Midlands Branch

On 31st January, 1986, at Dr Johnson House, Bull Street, Birmingham, Mrs H. Muller, M.Sc., F.G.A., gave a talk entitled 'Jet and its simulants'.

On 28th February, 1986, at Dr Johnson House, Mr Christopher Cavey, F.G.A., gave a talk entitled 'Some historical aspects of gemstones'.

### North West Branch

On 16th January, 1986, at Church House, Hanover Street, Liverpool 1, Dr G. Durant gave a talked entitled 'Lapidaries, leechcraft and lore'.

On 20th February, 1986, at Church House, Mr Rex Bingham gave a talk entitled 'Gold prospecting'.

### South Yorkshire and District Branch

On 24th January, 1986, at the Montgomery Hotel, Sheffield, the Annual General Meeting was held, at which Mr J.I. Reynolds, F.G.A., and Miss J.I. Platts, F.G.A., were re-elected Chairman and Secretary respectively.

On 13th February, 1986, at Sheffield City Polytechnic, Mr David Wilkins, F.G.A., gave an illustrated talk entitled 'Rescued from the scrap box'.

On 18th March, 1986, at Sheffield City Polytechnic, Mrs M.S. Carson, Deputy Assay Master at the Sheffield Assay Office, gave an illustrated talk entitled 'The history and work of the Sheffield Assay Office'. The talk was followed by a demonstration of the testing of gold, silver and platinum.

## COUNCIL MEETING

At the meeting of the Council held on 22nd January, 1986, at the Royal Automobile Club, 89 Pall Mall, London S.W.1, the business transacted included the election of the following:

### Fellowship

Allen, Vivien, Toronto, Ont., Canada. 1985
Bloodworth, Roy N., Wakefield. 1985
Georgopoulou Kyriaki, Marianna, Athens, Greece. 1985
Halton, Elizabeth M., Huddersfield. 1985.
Higham, Joyce R., Southport. 1973
Kittel, Gerhilde A., Toronto, Ont., Canada. 1985
Kothari, Rekha Y., Bombay, India. 1985
Kotila, Brian W., Don Mills, Ont., Canada. 1984
Major, Christine B., St. Ives, NSW, Australia. 1985
Pickrell, Rupert J., Turramurra, NSW, Australia. 1985
Roser, Emilio Ruiz, Valencia, Spain. 1985
Tam, Man Wai, Kowloon, Hong Kong. 1985

### Ordinary Membership

Averbrook, Jeffrey I., Everett, Mass., USA.
Chase, Moya, Hong Kong.
Clark, Berenice, Hobart, Tas., Australia.
Grange, Margaret D.J., Hong Kong.

Hulm, Valerie A., Hong Kong.
McArthur, Niven R., Gore, New Zealand.
McCulloch, Georgina K., London.
McSporran-Wirepa, Margaret, Gisborne,
                                    New Zealand.
Manning, Gerald E., Middletown, Ohio, USA.
Meister, Adrian, Zollikon, Switzerland.
Moreau, Jean M., Toulon, France.
Rich, Elizabeth, London.
Streit-Stalder, Martha V., São Paulo, Brazil.
Sullivan, Maeve D., Kowloon, Hong Kong.
Trobec, Martin B., Calgary, Alta., Canada.

## EDUCATION ADMINISTRATOR DESIGNATE

On 10th February, 1986, Mr David Eagle joined the Gemmological Association of Great Britain and the National Association of Goldsmiths to take up the position of Education Administrator Designate to take over responsibilities for education and training on the retirement of Mr Leslie Fitzgerald, F.G.A.

For twenty years Mr Eagle held senior positions with the Chartered Association of Certified Accountants, mainly in relation to their examinations, and was responsible for the establishment, development and maintenance of an accountancy diploma scheme for non-accountants.

## POOL OF SPEAKERS

The Association has formed a 'pool of speakers' from gemmologists around the world who have indicated their willingness to travel to London to give an evening presentation to members of the Association.

This pool contains a large variety of speakers but the Programme Secretary, Tony French, F.G.A., is keen to expand it. Would any gemmologists who have had experience of speaking before large groups of people, and would like their names included in the pool, please contact the Secretary at Saint Dunstan's House giving full details of their topic(s) and the times of the year when they would be available to speak.

## THE JOURNAL OF GEMMOLOGY BACK NUMBERS

The Association has a number of back-dated issues of the *Journal* for sale. For a complete list of those available please write to the Gemmological Association, Saint Dunstan's House, Carey Lane, London EC2V 8AB.

# Letters to the Editor

*From J.R.H. Chisholm, M.A., F.G.A.*

Dear Sir,

In his Letter to the Editor (*J. Gemm.*, 1986, 20(1), 70-1) Dr Crowcroft had evidently misunderstood what I wrote in reviewing the 4th edition of Webster's *Gems* as indicating that I believe that de Boismenu (and presumably Hannay too) had succeeded in making synthetic diamonds, which, of course, I don't. What I found (and still find) surprising was that, at a time when Hannay's (*then* apparently successful) attempts to make diamonds made a considerable stir, de Boismenu's attempts (*then* apparently equally successful) appeared to have passed practically unnoticed. In the light of subsequent developments we all now know that neither Hannay's nor de Boismenu's attempts to make diamonds were (or could have been) successful.

I think that in considering such a work as Webster's *Gems* Dr Crowcroft should bear in mind the readers for whom it was written – mainly members of the trade, to far too many of whom 'scientific' and 'academic' are dirty words. There must be a lot more educational work carried out before some members of the trade are ready to accept the rigours of scientific method.

Turning to something quite different, I feel that apologies are due both to the authors and to their readers for two particularly unfortunate pieces of printing in the *Journal* of October last. (1) The arrows indicating the position of the 'hillock' in Figures 2 and 3 on page 665 are misplaced (they had been correctly shown on the originals and were again correctly placed by the author on the final colour proof): to place them correctly, the arrow at the top of Figure 2 should be moved 3.5mm to the left, with the arrow at the side moved up 7mm, and the arrow at the top of Figure 3 should be moved 5.5mm to the right, with the arrow at the side moved up 6mm. (2) The very poor quality of the Map on page 677, in which the coastline together with much other detail has disappeared, is most regrettable, the author having supplied an excellently clear coloured original as well as an equally clear black-and-white copy.

Yours etc.,
J.R.H. Chisholm

10th March, 1986
The Athenaeum, London, S.W.1.

*From Peter G. Read, C.Eng, M.I.E.E.,*
*M.I.E.R.E., F.G.A.*

Dear Sir,

I refer to Peter Crowcroft's recent letter in the Journal[1] in which he claims there is 'a reluctance by traditional gemmologists to accept scientific results when it does not suit them'.

I am neither one of the older generation of traditional gemmologists that Crowcroft implies in his letter, nor do I have an 'emotional' attachment to the Beilby theory of polishing. However, as with my own discipline, I am reluctant to abandon one theory before an alternative has been formulated. The statement in the Crowcroft article[2] that 'There is no reason to believe that these mechanisms (relevant to the polishing of glass and metal surfaces) do not also apply to the polishing of all gemmological material', and the following comment that 'it still remains for a comprehensive theory to be put forward' do not seem to me to be good enough reasons to disregard the Beilby theory. The crux of the argument seems to lie with the conflict of views on the confirmatory work done by Bowden in 1954 and 1958. Indeed, Crowcroft himself seems guilty of ignoring facts which do not suit his argument (NB, the absence under Nomarski interference contrast microscopy of crystallographic features on the polished surfaces of non-diamond gem materials).

I also think it is expecting rather too much for the average gemmologist (who is usually a busy practising jeweller) to 'search out the reference at their nearest University library' in order to convince themselves of the arguments in Crowcroft's article. Very few gemmologists are physicists, and in the relatively new science of gemmology they have to rely on well-reasoned articles printed in the journals of the various gemmological associations to keep themselves informed of new techniques and theories.

My call for experimental evidence of the polishing process in *gemstones* is therefore not unreasonable in this context. When a comprehensive theory of gemmological polishing is eventually proposed, I am sure that despite Crowcroft's pessimism it will be accepted by even the older generation of traditional gemmologists.

Yours etc.,
Peter G. Read

4th March, 1986
68 Forest House, Russell-Cotes Road, Bournemouth, Dorset.

(1) *J. Gemm.*, 1986, 20, 1, 70.
(2) *J. Gemm.*, 1981, XVII, 7, 459.

*From Dr Erik G. Lundblad*

Dear Sir,

In his article 'A note on the history of diamond synthesis'[1], Dr Nassau describes why he and some other authors do not attribute the priority of diamond synthesis to ASEA in 1953 and why they do not consider the ASEA work to be a significant step in the progress towards a successful synthetic diamond industry. The main reason is that ASEA did not publish at the time claimed any descriptions of the technology to permit independent experimenters to duplicate the process. This is true.

We at ASEA made no public announcement in 1953, mainly because we wanted to improve on the size and quality of the diamonds and also to gain more detailed knowledge of the conditions of diamond formation. We also had evidence to believe that no other teams were engaged in synthesis attempts and that we therefore had time to wait. There we were apparently misled.

Although we recognized the scientific value of the first diamond synthesis we basically considered the commercial prospects to be of greater importance.

How could we now best protect our know-how? We arrived at the conclusion that only the equipment could be patented but not the process due to a number of prior publications. To keep our know-how in house, very tight security measures were applied while work continued on the development of suitable production facilities.

It was too late to change this policy, when some seven years later we realized that GE contrary to our expectations, had filed a patent application of the process, which also was granted, despite heavy opposition, in some important countries.

The 1953 synthesis was made in a complex spherical high-pressure apparatus using a thermite mixture for heating the carbon-iron matrix. Dr Nassau is quite right in describing this process as being so destructive to the high-pressure equipment that it was not worth pursuing. Thermite was used not only for heating but also basically to provide a good isostatic pressure in the very large high-pressure reaction chamber (800 cm$^3$). In later runs the matrix was also heated by electrical means.

The 'sphere' was patented but never used in production. As early as 1955 a piston-and-cylinder apparatus had been developed. Although the reaction chamber was now much smaller (5 cm$^3$) the apparatus was more practical for development work. A version of this apparatus developed in steps was subsequently used in the diamond production.

The confirmation of the 1953 synthesis and some of the following ones were made at the Institute of Inorganic Chemistry, University of Stockholm, under the supervision of the late Professor Arne

Ölander, Dean of the Chemical Faculty and also a member of the Royal Swedish Academy of Sciences. Professor Ölander was the only independent consultant that had had a full insight of the work since the 1940s. The X-ray analyses were made and confirmed by two of his assistants. However, only Professor Ölander was informed about the origin of the diamonds.

It is not for me to judge what influence our early work had on the subsequent development of diamond synthesis. Commercial production started in the early 1960s and since then the plant has been one of the world's leading producers of high-grade industrial diamonds and other sophisticated super-high-pressure products.

In 1965 a separate company was founded, Scandiamant AB, jointly owned by ASEA and De Beers, and in 1975 the operations were completely taken over by De Beers. ASEA has not been engaged in diamond synthesis since then, but whatever historians may say we were certainly involved in 1953.

Yours etc.,
Erik G. Lundbald
Vice President, ASEA AB
(former member of the diamond development team in 1953).

20th February, 1986.
ASEA AB, S-721 83 Västerås, Sweden.

(1) *J. Gemm.*, 1985, XIX, 8, 660.

### From Mrs E. Stern, F.G.A.

Dear Sir,
I read with amazement the article 'An unusual star diamond' (*J. Gemm.*, 1986, 20, 1, 52) in which S.J.A. Currie states that the star diamond described is thought to be one of only four known specimens.

It is quite true that the phenomenon is rare, but I know of a collection in Germany belonging to Dr U. Kurz-Tesch comprising 56 stones, total weight 46.55ct; the smallest weighing 0.19ct, the largest 2.14ct. They are all transparent with a slight olive-beige hue (raincoat colour), some lighter, some a little darker. The quality of the stars also varies somewhat, but all show distinct asterism. All the stones are octahedra, some without 'points'. It is presumed that the origin is Venezuela.

Yours etc.,
Evelyne Stern

3rd March, 1986.
90 Carlton Avenue East, Wembley Park, Middlesex, HA9 8LY.

### From Tony French, F.G.A.

Dear Sir,
I am pleased to be able to clarify a small doubt expressed by Mr S.J.A. Currie in the first edition of your superb new journal, regarding the star diamond[1].

Alan Fleming willed his personal collection of gems, minerals and carvings to the Auckland Museum in New Zealand. The star diamond was not, however, part of his collection.

As the person responsible to his executors in New Zealand for the disposal of his estate in this country, I knew Alan wanted this crystal to go to a museum. Having checked that the crystal was still in his New Zealand stock, I asked his executors whether they would agree to it being added to his collection in the Museum. They have since written to me confirming that this has been done.

I am sure Alan would have been delighted to know that Mr Currie's photograph of this crystal adorned the cover of the first edition of the new journal.

Yours etc.,
Tony French

10th February, 1986.
82 Brookley Road, Brockenhurst, Hants. SO4 7RA.

(1) *J. Gemm.*, 20, 1, 52.

### From Dr A. Banerjee and Dip. Min., H.-W. Schrader, F.G.A.

Dear Sir,
We are concerned at the less than objective style of the letter from G. Bosshart and K. Schmetzer, published in the January 1986 number of this *Journal*[1]. As a response to our paper 'Spectrophotometric measurements of faceted rubies'[2] we should have expected and hoped for a more critical discussion.

In the articles quoted by us (Schmetzer and Bank, 1980[3] and Bosshart, 1982[4]) the authors only describe that they have investigated '154 natural sapphire crystals' and 'ninety-four rubies' respectively. No specific information was given that they used faceted gemstones. Therefore we wrote: 'as most of the spectral measurements are carried out on thin polished platelets, the results achieved cannot be easily reproduced in the case of faceted gemstones'. We tried to introduce a general additional technique. It was neither our intention to describe how to solve minor problems on orientation

or polarization of the samples, nor to find a method of disctinction between natural and synthetic rubies.

We recognize the 'disadvantages' of methylene iodide and would refer Mr Bosshart and Dr Schmetzer to the Gems and Gemology abstract[5] where C.M. Stockton comments 'As the authors point out, methylene iodide absorbs virtually all light below about 440nm, but very clean spectral diagrams are obtained and illustrated for the rest of the visible range. Thus, the immersion method is shown to have distinct advantages'.

We wish to express thanks to the Editor of the *Journal of Gemmology* for allowing us space to publish our ideas.

Yours etc.,
Arun Banerjee
Hans-Werner Schrader

20th February, 1986.
Institut für Edelsteinforschung, Institut für Geowissenschaften, Johannes Gutenburg-Universität, Mainz, West Germany.

(1) *J. Gemm.*, 1986, 20, 7, 71.
(2) *J. Gemm.*, 1985, XIX, 6, 489–93.
(3) *Neues Jahrbuch für Mineralogie*, 139, 2, 216–25.
(4) *J. Gemm.*, XVIII, 2, 145–60.
(5) *Gems Gemol.*, 1985, XXI, 3, 182.

*From Mr D.J. Callaghan, F.G.A.*
*Gemmological Association of Great Britain*

Dear Sir,
THE BASIL ANDERSON SPECTROPHOTOMETER APPEAL.

I am happy to advise you that the target figure of £25,000 for the Spectrophotometer Appeal launched in the name of the late Basil Anderson in November 1984, has now been achieved. I shall be grateful if you will allow me to express my thanks on behalf of the Council of the Gemmological Association of Great Britain to all those people throughout the world who have contributed to the Appeal.

A supplementary list to that issued in *J. Gemm.*, XIX(8), 739–42, is being compiled, and I would be pleased if it could be published in a future issue of the *Journal*.

Yours etc.,
D.J. Callaghan
Chairman.

19th March, 1986.
London.

## CORRIGENDUM

In *J. Gemm.*, 20, 1, p.35, the radiographs for Figures 1 and 2 were transposed.

# GEMMOLOGICAL ASSOCIATION OF GREAT BRITAIN

The Arms and Crest of the Association, conferred by a grant of Arms made by the Kings of Arms under royal authority. The cross is a variation of that in the Arms of the National Association of Goldsmiths of Great Britain and Ireland. In the middle is a gold jewelled book representing the study of gemmology and the examination work of the Association. Above it is a top plan of a rose-cut diamond inside a ring, suggesting the scrutiny of gems by magnification under a lens. The lozenges represent uncut octahedra and the gem-set ring indicates the use of gems in ornamentation. The lynx of the crest at the top was credited, in ancient times, with being able to see through opaque substances. He represents the lapidary and the student scrutinizing every aspect of gemmology. In the paws is one of the oldest heraldic emblems, an escarbuncle, to represent a very brilliant jewel, usually a ruby. The radiating arms suggest light diffused by the escarbuncle and their tips are shown as jewels representing the colours of the spectrum.

## Historical Note

The Gemmological Association of Great Britain was originally founded in 1908 as the Education Committee of the National Association of Goldsmiths and reconstituted in 1931 as the Gemmological Association. Its name was extended to Gemmological Association of Great Britain in 1938, and finally in 1944 it was incorporated in that name under the Companies Acts as a company limited by guarantee (registered in England, no. 433063).

Affiliated Associations are the Gemmological Association of Australia, the Canadian Gemmological Association, the Gem and Mineral Society of Zimbabwe, the Gemmological Association of Hong Kong, the Gemmological Association of South Africa and the Singapore Gemologist Society.

The *Journal of Gemmology* was first published by the Association in 1947. It is a quarterly, published in January, April, July, and October each year, and is issued free to Fellows and Members of the Association. Opinions expressed by authors are not necessarily endorsed by the Association.

## Notes for Contributors

The Editors are 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 Editors.

Papers should be submitted in duplicate on A4 paper. They should be typed with double line spacing with ample margins of at least 25mm all round. The title should be as brief as is consistent with clear indication of the content of the paper. It should be followed by the names (with initials) of the authors and by their addresses. A short abstract of 50–100 words should be provided. 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.

Twenty five copies of individual papers are provided on request free of charge; additional copies may be supplied, but they must be ordered at first proof stage or earlier.

The Journal of
Gemmology

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