Gems & Gemology

VOLUME XXI FALL 1985

The quarterly journal of the Gemological Institute of America

FALL 1985
Volume 21 Number 3

Gems & Gemology

TABLE OF CONTENTS

ABOUT THE COVER: Of the gemstones currently coming from Australia, one of the newest and most exciting is the pink diamond. Stephen Hofer thoroughly examined more than 100 of these stones when they were submitted to the GIA Gem Trade Laboratory in New York earlier this year. He reports on their distinctive color and other gemological characteristics in this special "Australia" issue. The 3.53-ct (VS1) blue diamond on the cover, set in a ring, is surrounded by 36 Australian pink diamonds (2.64 ct total weight). The intense purple-pink heart-shaped diamond in the necklace is also from Australia. It weighs 0.72 ct and is complemented by a 3.24-ct briolette and 9.07 ct (total weight) of other diamonds. The jewelry is courtesy of R. Esmerian, Inc., New York. Photograph © 1985 Harold & Erica Van Pelt—Photographers, Los Angeles.

Typesetting for Gems & Gemology *is by Scientific Composition, Los Angeles, CA. Color separations are by Effective Graphics, Compton, CA. Printing is by Waverly Press, Easton, MD.*

 ISSN 0016-626X

FALL 1985
Volume 21 Number 3

Gems & Gemology

SUBSCRIPTIONS

Subscriptions in the U.S.A. are priced as follows: $29.50 for one year (4 issues), $82.50 for three years (12 issues). Subscriptions sent elsewhere are $40.00 for one year, $115.00 for three years.

Special annual subscription rates are available for all students actively involved in a GIA program: $24.50 U.S.A., $35.00 elsewhere. Your student number *must* be listed at the time your subscription is entered.

Single issues may be purchased for $8.00 in the U.S.A., $11.00 elsewhere. Discounts are given for bulk orders of 10 or more of any one issue. A limited number of back issues of G&G are also available for purchase.

Please address all inquiries regarding subscriptions and the purchase of single copies or back issues to the Subscriptions Manager.

MANUSCRIPT SUBMISSIONS

Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in the Spring 1985 issue of the journal, or contact the editor for a copy. Letters on articles published in *Gems & Gemology* and other relevant matters are also welcome.

Gems & Gemology is published quarterly by the Gemological Institute of America, a nonprofit educational organization for the jewelry industry, 1660 Stewart St., Santa Monica, CA 90404.

Application to mail at second class postage rates is pending in Santa Monica, CA 90404 and at additional mailing offices.

Postmaster: Return undeliverable copies of *Gems & Gemology* to 1660 Stewart St., Santa Monica, CA 90404.

Any opinions expressed in signed articles are understood to be the views of the authors and not of the publishers.

The New Australia

For generations, Australia has been the prime producer of fine opal, including the only notable black opal. Recently, it has become a major supplier of gem-quality diamonds. And Australian chrysoprase is unmatched in quality by that from any other source. Australia is also rich in technological resources: Scientists on the staff of the government's Commonwealth Scientific and Industrial Research Organization (CSIRO) were the first to synthesize opal with play of color.

Today, the international gemological community is beginning to experience the full impact of Australian activities. In recognition of the major role that Australia now plays in all aspects of gemology, this issue is devoted to some of the most recent contributions of Australia to gemology. We are pleased to present comprehensive articles on the many fine sapphires of Australia, on the beautiful new pink diamonds from Argyle, and on the new Biron hydrothermal synthetic emerald manufactured in Western Australia.

Now that the desert interior and Western Australia are beginning to be opened up, much more in the way of new gem discoveries may be expected. Already, we have heard of two new emerald finds in Western Australia, and a significant deposit of amethyst. The fine translucent ruby recovered near Ayers Rock in central Australia a few years ago has also attracted considerable attention. In my opinion, Australia is an exciting new frontier that has the potential over the next few generations to become as prolific a supplier of gem materials as Brazil or East Africa.

Richard T. Liddicoat, Jr.

SAPPHIRES FROM AUSTRALIA

By Terrence Coldham

During the last 20 years, Australia has assumed a major role in the production of blue sapphire. Most of the gem material comes from alluvial deposits in the Anakie (central Queensland) and New England (northern New South Wales) fields. Mining techniques range from hand sieving to highly mechanized operations. The rough is usually sorted at the mine offices and sold directly to Thai buyers in the fields. The iron-rich Australian sapphires are predominantly blue (90%), with some yellow, some green, and a very few parti-colored stones. The rough stones are commonly heat treated in Thailand to remove the silk. While production has been down during the last two years because of depressed prices combined with higher costs, prospects for the future are good.

ABOUT THE AUTHOR

Mr. Coldham is the owner of Sapphex P.L., a Sydney-based gemstone merchant and lapidary specializing in Australian rough and cut sapphire.

Acknowledgments: The author gratefully acknowledges the considerable help provided by Tom Nunan (Inverell) and the Jarugosol family (Bangkok) for technical information; Gordon Streight, Dr. Brenda Franklin, and members of the Mineralogy Section of the Australian Museum for proofreading and advice; Bill Scheos, Rod Brightman, Noni Primrose, and the Department of Mineral Resources (NSW) for assistance in presentation; and Sandra Pike for typing without complaint.

Unless otherwise noted, photos are by the author.

Few people realize that Australia is one of the major producers of sapphire on the world market today. Yet a fine blue Australian sapphire (figure 1) competes favorably with blue sapphire from noted localities such as Sri Lanka, and virtually all other hues associated with sapphire can be found in the Australian fields (figure 2). In fact, in the author's experience it is probable that 50% by weight of the sapphire sold through Thailand, usually represented as originating in Southeast Asia, were actually mined in Australia.

In spite of the role that Australian sapphire plays in the world gem market, surprisingly little has been written about this indigenous gem. This article seeks both to describe the Australian material and its geologic origins and to introduce the reader to the techniques used to mine the material, to heat treat it prior to distribution, and to market it worldwide.

HISTORY

The two main sources for sapphire in Australia are the New England fields, in northern New South Wales, and the Anakie fields, in central Queensland. Large-scale commercial mining has been successful at these two fields only. Geographically, the two areas are quite different. The Anakie fields are in a semi-arid area of gently undulating low hills, while the New England fields cover an area of tablelands consisting of rich grazing land and fertile river flats that comprise some of the best agricultural country in Australia.

While sapphire was first reported from Inverell (NSW) in 1854, the first sapphire mining started at the Anakie fields almost 40 years later. In 1873, Archibald John Richardson found sapphire near the town of Anakie (Monteagle, 1979), about 50 km to the west of the township of Emerald in central Queensland. Local lore has it that Emerald was so named because green sapphires found in the

Figure 1. Two fine blue sapphires, 1.11 ct and 1.61 ct, respectively, from the New England fields, New South Wales, Australia. Photo © Tino Hammid.

area were originally thought to be emeralds. Sporadic mining operations started in the Anakie fields in the 1890s, and most of the early production went to tsarist Russia via German buyers.

The Anakie area was officially proclaimed a mining field in 1902. Mining consisted of sinking shafts or digging shallow alluvials and then washing the material with sieves. By 1913, two tons of sapphire and other corundum had been removed. Single pieces of gem-quality material as large as 500 ct were reported (Anderson, 1971). Two small villages, Rubyvale and Sapphire, appeared on the fields to service the miners.

The advent of World War I, the collapse of imperial Russia, and the elimination of German buyers brought mining to a virtual standstill. Not until the early 1960s—with the onset of a burgeoning demand for rough sapphire throughout Asia—was systematic mining resumed at Anakie. By 1969, the Anakie fields were being fully exploited through a number of large-scale, fully mechanized operations. Since the beginning of the current decade, however, as the viable areas are exhausted and operating costs continue to mount, there has been a steady decline in production. Many small, semi-mechanized underground operations now run alongside the large, heavily mechanized workings.

The second major mining field is centered around the towns of Inverell and Glen Innes, in northern New South Wales, and is generally referred to as the New England fields. Although sapphire was first found here in 1854, mining did not start until many years later, and even then was only sporadic until 1959. As with the Anakie fields, the Asian buying power in the early 1960s

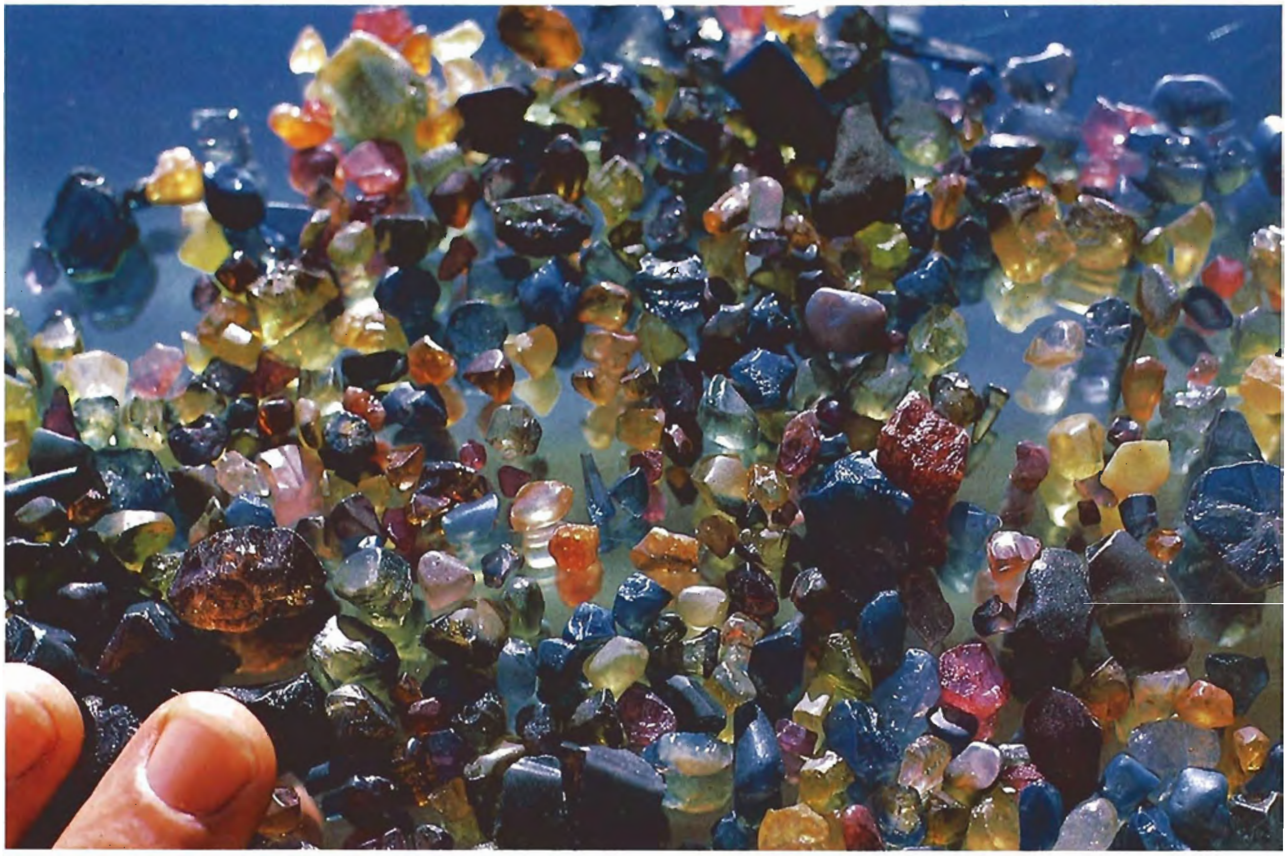


Figure 2. A miner's collection of the different-colored sapphires found at Inverell, in the New England fields, New South Wales.

created favorable conditions for large-scale mechanized mining that has continued to the present time.

Various attempts to mine at other localities in Queensland, New South Wales, and Tasmania have been made, but thus far none has proved viable. It is quite possible that future prospecting will produce new fields.

GEOLOGY

All along the eastern seaboard of the Australian continent are scattered remnant dissected flows and pipes of Cenozoic volcanics (see figure 3). The most common volcanic rock type is alkali basalt, which in many localities contains xenocrysts of such minerals as ilmenite, pleonaste, amphiboles, feldspar, zircon, corundum, and pyrope garnet. In 1902, a geologist with the Queensland Mines Department reported on the new Anakie sapphire fields, and stated that the sapphire found in the surrounding alluvials appeared to have been weathered out of the nearby basalts (Dunstan, 1902). Since then, numerous occurrences of sapphire have been discovered as far north as Cooktown in Queensland and as far south as Tasmania (again, see figure 3). In nearly every case, the sapphires have been found in close proximity to Cenozoic basalts. As mentioned above, however, in only two areas have the deposits proved to be rich enough to allow commercial mining.

In most cases, the sapphire occurs in alluvial gravels, termed "wash" by the miners. The gravels are associated with present-day rivers and creeks in the New England region (Department of Mineral Resources, 1983), and occur as large sheets that cover extensive areas dissected by the present drainage pattern in the Anakie fields.

The sapphire occurs as individual crystals and crystal fragments that in most cases have been locally concentrated, presumably by normal alluvial processes. Other minerals associated with sapphire are found in varying proportions and include (in order of abundance) pleonaste (spinel), zircon, ilmenite, magnetite, olivine, pyroxenes, and amphiboles. Zircon is the only other mineral that commonly occurs in gem quality. These zircons are of "high type" and are either pale yellow or reddish brown, ranging from sand-grain-sized

particles to the occasional clear pieces of several hundred carats. Gemologically they appear to be similar to those found at the Pailin field in Cambodia, as described by Jobbins and Berrangé (1981). The pleonaste is usually much more abundant than the sapphire and zircon; since it has a specific gravity similar to that of sapphire, it is often used as an indicator mineral by the miner. All these minerals have been found at various localities in situ in solid basalt, pleonaste quite commonly and sapphire and zircon very rarely (McNevin, 1972).

At certain localities, such as Lava Plains in northern Queensland (see figure 3), large amounts of sapphire, along with pleonaste, have been found in soil directly overlying the basalts. The surfaces of material from this locality show no evidence of having traveled any distance from their source. However, while pleonaste xenocrysts are plentiful at Lava Plains, no xenocrysts of sapphire have been found in the basalt itself from which the soil apparently derives. Personal observations by the author show that these deposits are very similar in rock type, mode of occurrence, type of stone, and associated minerals to those found at Prae in central Thailand.

Recently, quite rich deposits of sapphire were found seven miles (11 km) east of Inverell in what appears to be pyroclastic (volcanic ash) rocks interbedded with basalt flows. Accessory minerals are zircon and ilmenite (Lishmund and Oakes, 1983).

In all localities, the sapphire occurs as discrete crystals and crystal fragments, often elongated hexagonal pyramids, and occasionally bipyramids. Almost invariably, crystal faces and fracture surfaces alike show evidence of corrosion and etching. Some crystals are so corroded that they appear as long cone shapes without any suggestion of their original hexagonal cross section. For quite a long time it was thought that the material was "water worn," but it is now believed that these surfaces are a result of chemical corrosion (figure 4). These

Figure 3. The distribution of basalts in eastern Australia. Major deposits of sapphire have been found in the Anakie fields (Queensland) and the New England fields (New South Wales). But some sapphire has been recovered from as far north as Cooktown (Queensland) and as far south as Tasmania. Map adapted from an original by the Mineralogy Section of the Australian Museum. Artwork by Lisa Joko.

Figure 4. Two corundum crystals (approximately 5 ct each) from Inverell, in the New England fields. Note that the left side of the piece on the right has been protected and shows the original crystal faces.

features are the same as those reported at Pailin in Cambodia (Jobbins and Berrangé, 1981) and observed by the author in sapphire from Bo-Bloi, Chanthaburi, and Prae in Thailand. They also look very similar to the surface features reported on corundum from Colombia (Keller et al., 1985). Some minor water wearing is observed on the gem material recovered from alluvials, particularly from the Anakie fields.

Although it has been generally considered that the alkali basalt is the source rock for the alluvial sapphire in the area, it is distinctly possible that the pyroclastic rocks associated with the basalts may, in fact, be the source. According to this second hypothesis, the sapphires themselves crystallized originally in an unknown rock in the lower crustal/upper mantle regions and were eventually released into a fluid phase that rose to the surface during a period of volcanism. These fluids eventually consolidated to form the host basalt and pyroclastic rocks. Evidence for either hypothesis is somewhat conflicting and more detailed field work is necessary.

Also of interest is the similarity in rock types between the Australian and Southeast Asian (Jobbins and Berrangé, 1981) sapphire fields. For example, some of the basaltic rocks in Australia near Inverell are very similar to those at Pailin and appear to be closely associated with sapphires. In contrast, the larger tholeiitic basalts of Australia and Pailin are considered to be barren of sapphire.

MINING

The last 20 years (and, more specifically, the last 10 years) have seen the development of sophisticated commercial mining of the alluvial deposits through the use of heavy earth-moving equipment and large throughput processing plants (figure 5). Presently, mining techniques on both fields range from hand sieving, through small one-man operations that use processing plants capable of handling only a few cubic meters of material per hour, to large syndicates and companies that employ up to 30 men on a site and process hundreds of cubic meters per day.

On the New England fields, the mechanized mines dot an area of some 4,000 km^2. Each miner usually works a section of creek or river that is often hundreds of acres in area. First, samples of wash are taken to delineate the richer runs, and then mining proceeds in a systematic manner.

In contrast, on the Anakie fields, most of the mining activity is contained in an area of only a few square kilometers. Because the size of a claim is restricted by the State Mining Law, the miners tend to work almost on top of one another (figure 6), and each miner must accumulate the rights to a number of adjoining claims if he is to have sufficient room to operate. However, Anakie miners are to some extent compensated by the fact that the wash here is usually thicker and richer in sapphire than that in the New England area.

In both areas, the gravel is normally covered by 2–80 ft. (0.5–25 m) of barren overburden consisting of fine grits and brown or black soils. This overburden is removed by either a backhoe or a bulldozer. The sapphire-bearing wash is then excavated and loaded into trucks for transport to the processing plant. Some areas of the Anakie fields are reserved for hand miners who sink shafts up to 100 ft. to reach the gem-bearing alluvials (in much the same manner as their predecessors operated at the turn of the century).

Processing. On arrival at the processing plant, the gravel is tipped into dump boxes where it is washed into a trommel with a high-pressure water jet. Any large pieces of rock are, if necessary, broken up and removed by hand from the dump box. The trommel consists of a revolving screen that usually has two different-sized meshes. The first section has a fine mesh through which sand-sized particles are sieved out. The mesh in the second section is usually about three-quarters to one inch (2–2.5 cm) in size, and anything larger passes out of the trommel into rock bins to be returned to the excavation. The middle-sized fraction—i.e., of

Figure 5. A mechanized processing and recovery plant at Kings Plan, Inverell, in the New England fields.

Figure 6. Note how miners have torn up this area between Rubyvale and Sapphire in the Anakie fields.

Figure 7. Picking out the sapphire from the coarse concentrate at an Inverell (New England fields) mine site.

plus one-sixteenth inch to minus one inch from the second mesh—passes through the trommel down to a pulsator or jig. The trommels may have revolving tynes and high-pressure water jets inside to break up the gravel. In areas with concentrates of clay, the material is often passed through a second trommel or over a vibrating screen to make sure all the sapphire is released.

Because of the scarcity of water on the Anakie fields, many mines there use dry sieving methods. After excavation, the material is laid out to dry and then passed through large, semi-mobile vibrating screens to remove sand and oversized material near the excavation site. The middle-sized product is trucked to the pulsator or jig which is located adjacent to water, usually one of the series of ponds or setting dams through which this very scarce commodity is recirculated.

The pulsator is the main recovery section; the various models range from 18 inches to several feet across. The pulsator is a simple heavy-media unit that pulsates water through a screen divided by a series of riffles. The gravel is fed over the screen, and the "heavier" sapphire and other minerals collect in front of the riffles. The lighter material washes out over the end of the pulsator and is returned to the excavation. Large mines may have banks of several pulsators to process the different sizes. The recovery rate is usually 90% –95%, but it may be less in alluvials with a high clay content.

The mining operations in the New England district are much more rigidly controlled in terms of conservation and restoration than those in Anakie. The waste gravels, sands, and silts are collected in bins and then used to backfill the original excavation. After all the processed gravel has been returned, it is covered by the original overburden and topsoils. All water used in the mining operations is stored in dams and recirculated; only clean water can be returned to the rivers.

At the end of each day, the concentrate in the pulsator is removed. This gravel is composed mainly of highly iron-rich material in addition to the sapphire, pleonaste, zircon, and the like. The sapphires from the coarser fractions are often picked out of the concentrate at the mine site (figure 7). The larger volumes of medium- and fine-sized concentrates are sent to an office to be picked out and sorted.

Sorting and Grading. The first step in recovering

Figure 8. Fine concentrate after removal from the pulsator. Note the abundant black pleonaste.

the sapphire from the medium- to fine-sized concentrate (figure 8) is to dry it and pass it through a magnetic separator. This removes all the iron-rich material, black spinel, and anything else with a reasonably high magnetic attraction; it leaves a concentrate of corundum, zircon, quartz, and other minerals that usually represents 10% of the original concentrate. This material is then washed, dried, and given to the grading staff who select out all the corundum that shows any indication of being cuttable. Usually women are employed to handpick this material as it is passed over mirrors (figure 9). The mirrors reflect light through the rough material so that color and flaws can be observed without the sorter having to hold each stone up to a light.

All blue material found is sorted at the mine's sorting office into what is termed "mine run" parcels; blue sapphire represents approximately 95% by weight and value of the total salable production. A mine run is the total production of all salable blue material produced in a given (arbitrary) time from the one mine.

Often these parcels are quality graded by the miner into firsts, seconds, and thirds and then sieved into various groups. A mine-run parcel varies considerably in quality from one miner to the next, and a standard price per ounce cannot be applied. Variations in a mine-run parcel depend on the type of stone produced in the area mined as well as on the type of grading adopted by the miner. The grading process at this stage is very subjective. Other colors such as greens, yellows, and particolored sapphires are sold separately either in small lots of a few ounces or as individual stones.

A typical Inverell mine-run parcel may have about 10%–20% of the stone over 2 ct in weight, 40%–60% of medium size (0.50 to 2 ct) and 30%–40% of small material (0.20 to 0.50 ct). Material in mine runs from Anakie would be, overall, of a larger particle size (20%–40% are over 2 ct).

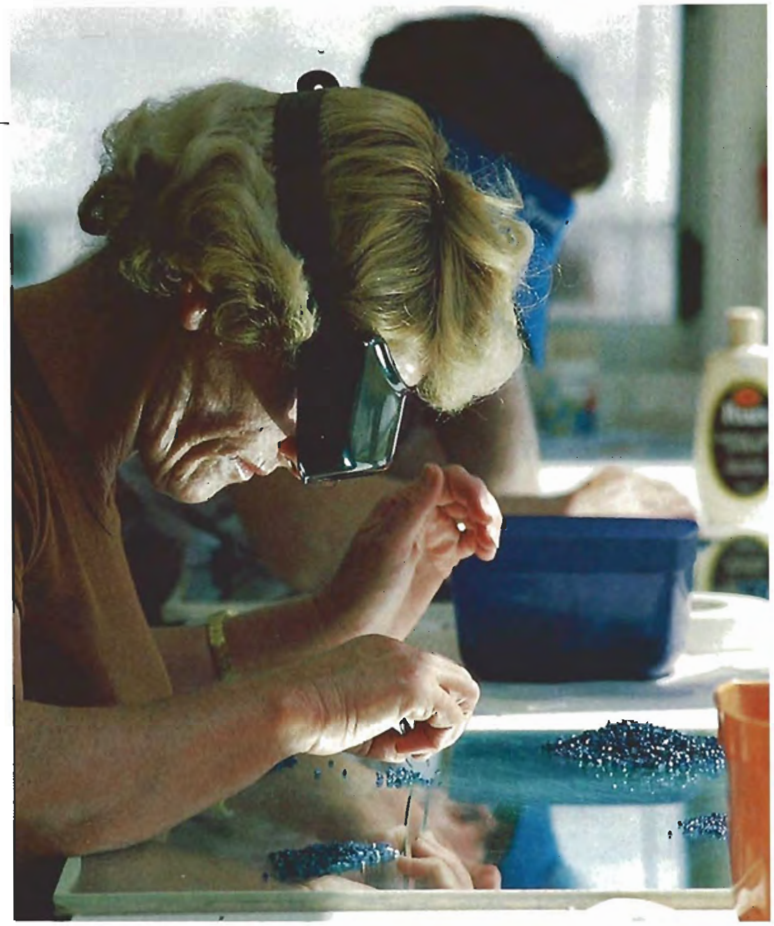


Figure 9. Sorting sapphire on mirrors at an Inverell mine office.

DESCRIPTION

The gemological properties of Australian sapphire, as determined by the author, are given in table 1. As is the case with corundum from Thailand and

TABLE 1. Gemological properties of Australian sapphire.[a]

Color	Refractive index	Birefringence	Specific gravity[b]	Spectra	Reaction to LW/SW ultraviolet radiation
Light blue	1.761–1.769	0.008	4.02	Single band 455–458 nm	Inert
Dark blue	1.763–1.772	0.009	3.99	Strong band 455–460 nm Narrow band 464–466.6 nm Single line 478 nm	Inert
Green	1.763–1.772	0.009	4.00		
Yellow	1.765–1.774	0.009	3.97	Broad band 455–465 nm Single line 478 nm	Inert
Gold	1.763–1.772	0.008	4.01	Same as for yellow, but less distinct	Inert[c]

[a]*These properties were taken from a small range of Inverell and Glen Innes stones.*
[b]*Specific gravity was determined by the hydrostatic method (±0.02).*
[c]*While almost all Australian sapphire is inert, those showing an orange or pink to mauve color will show some red fluorescence when exposed to long-wave ultraviolet radiation.*

Figure 10. A variety of faceted Australian sapphire. Note that the proportion of yellow stones is much greater than is found in overall production. In fact, 90% or more of all Australian sapphire occurs in various shades of blue. Photo by D. Barnes, courtesy of the Department of Mineral Resources, New South Wales.

Cambodia, Australian stones generally have a higher iron content than corundums associated with metamorphic environments (Webster, 1983). This results in a range of colors (figure 10) quite different from those found in Burma, Sri Lanka, and Tanzania. Analyses of sapphire from Frazers Creek, Inverell, show total Fe as over 1% (MacNevin, 1972).

The size of individual pieces ranges from less than 0.05 ct to over 1,000 ct. Stones over one inch in diameter are rarely found these days, as they are removed with other coarse gravel by the trommel. On average most of the cuttable material is under 2 ct in the rough state; clean stones over 10 ct are quite rare.

The vast majority of gem-quality Australian sapphires, perhaps 90% by weight, occurs in various shades of blue (again, see figure 10). These shades range from almost colorless through rich royal blue to some that are so dark as to appear black when cut. The greater proportion occurs as medium to dark material.

The second most common color range covers various tones of greenish blue, and most frequently occurs in a light to medium, very slightly greenish blue.

The two other colors that often occur are yellow and green. The yellows range from light through intense yellow to strong gold (figure 11). Bright orange stones are also encountered, though

Figure 11. A range of fine, natural-color yellow and gold sapphires from the Anakie fields. The large stone in the center weighs 30 ct.

rarely. The greens occur in a great variety of shades, including yellow-green, yellowish green, and brownish green, with tones that range from very pale through almost black. Evenly colored green, yellow, or gold gemstones of over one carat are quite rare, but the author has seen gem-quality rough that weighs over 300 ct.

Occasionally pink, purple, and mauve stones are found, but they are extremely rare. Also seen, but only rarely, are color-change sapphires, some of which show effects similar to those seen in alexandrite, while others change from greenish yellow to orangy pink. The coarser banding of colors such as green, blue, and yellow results in parti-colored stones, some of which are extremely attractive. This coarse banding seems to be much better developed in the Australian material than in that from other localities. One large (2,019.5 ct) piece of gold, green, and blue particolored rough was recently found.

The term *wattle* sapphires has recently come into vogue to describe parti-colored stones that range from yellow with a touch of green to green with a touch of yellow. (*Wattle*, called mimosa in many countries, is Australia's national flower; it has a yellow to gold blossom with green to olive-green foliage.) When this material is cut correctly, the resultant gem can rank as one of the most beautiful of the corundum family (figure 12). Miners often collect them, and both Thai and Australian dealers give them to their wives or sell

Figure 12. An approximately 6-ct parti-colored ("wattle") sapphire from the New England fields. Photo by D. Barnes, courtesy of the Department of Mineral Resources, New South Wales.

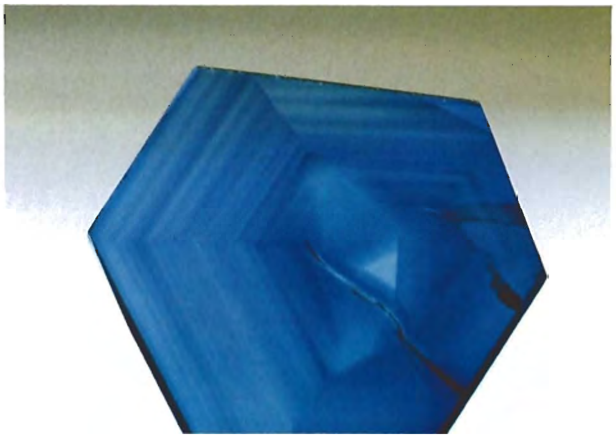


Figure 13. This 1.5-cm thin section of an Australian sapphire crystal, cut at right angles to the c-axis, shows color banding parallel to the crystal faces.

them to friends, so the general retail customer rarely gets a chance to see fine wattle sapphires.

Color banding is a very common feature of Australian sapphire, and even very uniformly colored stones will show fine banding under the microscope; however, patches of color without clear planar boundaries are rare. The banding occurs in two directions (MacNevin, 1972), the first being parallel to the c-axis, which often results in a hexagonally or trigonally banded cross section in which the colors generally are lighter toward the center of the crystal (figure 13). The second type occurs at right angles to the c-axis and generally grades from darker at the base of the crystal to lighter at the top.

In the blue material, darker and lighter shades of blue may alternate randomly with colorless or very pale yellow bands. As mentioned above, coarse to very coarse banding gives rise to particolored sapphire. When the bands are wide enough to give a clear separation between colors such as green and gold or blue and yellow, the effect is quite beautiful; however, alternating fine bands of green and blue cause a rather unpleasant green-blue parti that along with black or heavily included blue material makes up the lower quality end of Australian commercial production.

Star sapphire is also found, the most common of which is black or bronze material very similar to that from Bang Kha Cha in Thailand. Asteriated stones also occur in blue, blue-gray, and occasionally green and gold. Stars may occur in particularly large pieces—one was recorded to weigh approximately 1,900 ct.

Overall differences in color can be noted in the sapphires from the Anakie and the New England fields. The Anakie fields produce darker blue sapphires and more pure green and pure yellow stones than the New England fields, which may be related to the fact that the Anakie material crystallized in a more iron-rich environment. Glen Innes, and particularly Reddistone Creek, in the New England fields is reputed to produce the finest blue stones. Many stones from this area show colorless to pale blue side color* without any hint of green.

HEAT TREATMENT

The color of Australian sapphire is often greatly affected by silk. The blue shades are particularly prone to be silky to varying degrees. Evenly silked stones may be cut as star sapphire, but more commonly the silk mars the beauty of the cut stone by making it appear dull and/or oily green (figure 14). The silk usually appears as very fine, needle-like inclusions oriented parallel to the crystal structure of the host corundum. Sometimes the individual needles cannot be resolved even under very high magnification. The most common type of silk has a whitish appearance and only sometimes produces chatoyancy; it is most likely rutile (Nassau, 1984).

The presence of silk in the blue material results in a gridwork of reflective surfaces throughout all or part of the stone that interferes with the body color and is probably one of the most commercially important features of Australian sapphires. When light enters sapphire, which is doubly refractive, it is split into two waves; in Australian blue sapphire, one ray is pure blue and the other is blue-green. The effect of the silk is to reflect and scatter the two rays as they pass through the stone, such that the blue and blue-green dichroic colors merge into one unattractive oily greenish blue color. This effect can be so complete in very evenly silked stones that the color is the same regardless of the orientation of the stone.

Basically, heat treatment "removes" the silk by forcing it back into solid solution within its

Usually sapphire is cut with the table at right angles to the c-axis to get the best blue. When the stone is viewed through the side (e.g., through the girdle rather than through the table), a greener color is normally seen, thus the term side color.

host; a subsequent quick cooling (i.e., in a few hours) traps the silk there. Without heat treatment to clear the stone, the mining of Australian sapphire would not be commercially viable.

The treatment of silk in sapphire appears to have started about 25–30 years ago in Europe, where it was quietly practiced by a few people. At that stage, the demand for Australian sapphire was small, and mechanized mining had just begun.

Twenty years ago it was found that such processes worked very well on Australian sapphire, and Thai dealers—who had become very adept at heat treatment—started visiting Australia to buy. This increase in demand prompted increased production that resulted in the large-scale mechanized mining that continues to the present day.

Most of the Australian blue sapphire is treated in Thailand. The method for treatment of blue Australian sapphire is quite simple, although it differs significantly from the treatment of the Sri Lankan material (which is done for the purpose of darkening color rather than removing silk). The rough Australian stones are first thoroughly washed and any iron stains are removed by acid. The rough stones are then packed in a white glazed porcelain crucible and the lid is sealed with a high-temperature cement.

Some years back, a great variety of chemicals were placed in the crucible with the sapphire, including cobalt salts, fluxes, chloride salts, and the like. While such treatment resulted in stones that appeared to be a bright cobalt blue, it was soon realized that the effect was only superficial, a coating that was removed in faceting. These days, if any chemicals are used at all, they are fluxes such as borax, and the rough stones are simply wet with a mild solution before treatment. The effect of the flux after cooking is to slightly glaze the surface of the stone, which results in brighter-looking rough. It is hard to ascertain if the flux has any internal effect.

After the porcelain crucible has been prepared, it is sealed (with clay) into a slightly larger black assay crucible. Sometimes fine charcoal dust may be placed between the two crucibles, depending on the type of stone (i.e., its origin and general hue), to keep any oxygen from reaching the stone during the burning. While this practice used to be common, most treaters no longer feel it is necessary.

Traditionally, the furnace is a simple coke-fired one (figure 15), around four and a half feet (1.5 m) tall. First a wood fire is built inside the inner

Figure 14. This single piece of Australian sapphire was cut in half and the piece on the right heat treated. Note that while there is improvement in clarity and color, the change caused by heat treatment is not as dramatic as that commonly seen in white or light-colored Sri Lankan sapphires that are turned blue by heat treatment. Photo © Tino Hammid.

chamber of the furnace and then a small amount of coke is added until a glowing base is obtained (figure 16). The whole chamber is then filled with coke and the crucible nestled into a hollow at the top of the pile. A high-temperature brick cap is added to narrow the gas exit to about one-third the diameter of the air inlet. An air blower is used to force air up through the coke.

Generally, a burn takes from 45 minutes to one hour before the flame starts to die. As the coke burns from below, the crucible moves down into the hottest part of the furnace. It is very difficult to measure the actual temperature reached, as a pyrometric probe placed in the center of the chamber would be damaged by the movement of the coke and the fluxing action of the slag that results from the burning coke. The author's attempts at such measurements indicate that the hottest temperature is in the area of 1600°–1700°C.

As soon as the blower is turned off, the furnace is sealed at both inlet and outlet and is left to cool for from two to 12 hours or more. Tongs are then used to remove the crucible (figure 17). The operation results in the stones being both heated and cooled in a reducing environment.

Although the body color of the material may be affected, such changes are usually slight and, in most cases, detrimental. The most common prob-

Figure 15. A Thai furnace typical of those used to treat rough Australian sapphire.

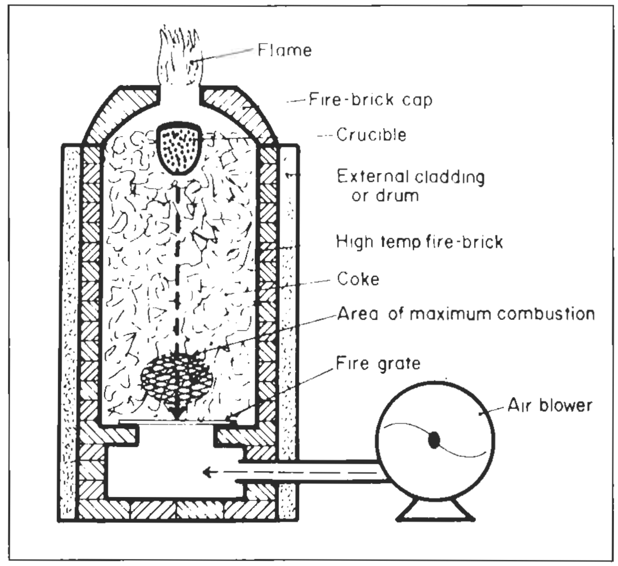


Figure 16. This diagram of the furnace depicted in figure 15 illustrates the process used to heat treat Australian blue sapphire. Artwork by R. Brightman.

Figure 17. The inner crucible has been broken open after treatment of these Australian blue sapphires was completed.

lem is that unsuitable time/temperature parameters may result in a slight to fairly obvious darkening of the stone. Any leakage of air into the crucible in the final stages of the burn or on cooling generally strengthens slightly any green hue that was originally in the stone.

Up until about 10 years ago, a lot of innovations were tried with length of treatment and the like, but over the last decade, the procedure for removal of silk has become more or less standard. The only recent innovation is the use of gas-fired furnaces. Once the process has been mastered and minor adjustments are made for the particular type of stone (e.g., color, density of color, silkiness, and locality of origin—Anakie or New England fields) being treated, the results are quite predictable. Experts at using this type of furnace have many subtle variations in their methods, which results in different people specializing in particular types of stone.

Sapphire other than blue is only occasionally treated, usually to remove silk. The effect on color is usually not great, although occasional strengthening of yellow and gold hues is encountered. Usually the green, yellow-gold, and particolored stones are heated in an electric furnace in crucibles open to the air (an oxidizing environment) inside the chamber.

INCLUSIONS

Very little detailed study has been done on inclusions in Australian sapphire. As most of the rough stone is processed in Thailand, it has been difficult for researchers outside of Australia to acquire material that can be clearly identified as Australian. Microscopic examination of Australian material for this study revealed inclusions similar to those reported for Thai and Cambodian sapphire and may reflect their apparently similar geologic origins.

For example, inclusion of feldspar crystals reported by Gunawardene and Chawla (1984) for blue sapphire from Kanchanaburi, and by Gübelin (1974) for sapphire from Thailand, appear identical to inclusions commonly seen in Australian sapphire (figure 18). Positive identification of feldspar as an inclusion in Australian sapphire was reported by Schubnel (1972). He described colorless transparent crystals between 20–400 microns, sometimes euhedral and sometimes surrounded by circular fractures. These inclusions also sound similar to those shown in figure 18.

Also very common in Australian sapphires are euhedral to subeuhedral bright red to brownish red crystals, sometimes associated with wing-shaped liquid "feathers". They may sometimes have trails of bubbles streaming from them like comet tails (figure 19). The red crystals look similar to those identified as uranium pyrochlore in Pailin sapphire by Gübelin (1974). Such "comet tails" have also been observed coming from other inclusions, particularly from colorless crystals of high relief that may well be zircon.

Unlike the silk in blue star sapphire, asterism in black star material does not appear to be due to rutile but rather to a needle-like precipitate of iron titanium oxide ($FeTiO_2$) with or without lath-like particles of a brown material, possibly hematite (Moon and Phillips, 1984).

Different types of inclusions tend to predominate in sapphire from different localities. For example, bright red crystallites (uranium pyrochlore?) commonly occur in stones from the New England fields. The sapphires found at the Anakie fields commonly contain inclusions, as yet unidentified, that are dark brown to opaque euhedral platelets and stubby rods of what appear to be types of mica and horneblende, respectively.

Other internal features commonly encountered are very well-developed polysynthetic twinning and fine "fingerprint" inclusions. The author is at present embarking on a detailed study of Australian sapphires in which electron microanalysis will be used to identify individual inclusions.

Figure 18. This colorless euhedral crystal surrounded by a tension halo and accompanied by a "comet tail" is a common inclusion in Australian blue sapphire. Photo by B. Scheos, Diamond Laboratory Services; magnified 40×.

DISTRIBUTION TO THE MARKET

The greatest proportion of Australian production is purchased by visiting buyers from Thailand. The price is reached by bargaining between the buyer and the producer, and takes into account previous selling prices, apparent quality of the stone, proportion of large stones, and the overall size of the parcel. The Thais buy anything from individual stones to mine-run parcels. Until two years ago, it was not uncommon to hear of 10 separate buying syndicates on the fields at one time. The galva-

Figure 19. A subeuhedral reddish brown crystal in blue Australian sapphire from Glen Innes. Such inclusions are very common in blue Australian sapphire, either alone or accompanied by small liquid feathers and "comet tails." Photo by B. Scheos, Diamond Laboratory Services; magnified 40×.

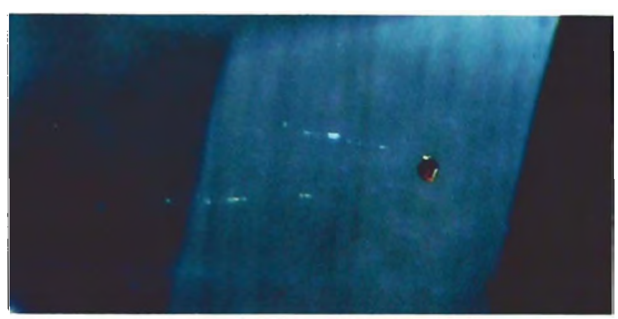


Figure 20. The office of a Thai sapphire buyer on the Anakie fields.

nized iron offices of the Asian buyers at Rubyvale are an accepted part of the scenery (figure 20). Apart from the material purchased by the Thai buyers, a small amount of rough stones are sold to European and Australian cutters.

Thailand, as a result of its own sapphire mines, has long been a center for sapphire processing and marketing. Now, with little production from Thailand's own mines and the virtual cessation of mining in Cambodia, Australian production supplies the raw material to keep a large number of lapidaries and gem merchants going. Until the Thais began processing Sri Lankan sapphire as well a few years ago, it is estimated that some 80% by weight and value of Thailand-cut sapphire exports were of Australian origin. Even with the present drop in production, Australian sapphire could well account for at least 50% of the carat weight of Thailand's total exports of sapphire (pers. comm. with major Thai merchants).

Usually, when the rough parcels arrive in Bangkok, they are split up and sold in smaller lots to the cutting factories. Often, the parcels are of selected rough stone to suit the particular talents of the individual lapidaries. Some lapidaries prefer to work only certain sizes or, because of their particular heat-treatment skills, only one type of stone, e.g., all darker or lighter material.

Since the Thais first began buying Australian sapphire in the late 1960s, the average combined annual production from the New England and the Anakie fields has risen from $1 million (Australian) per year in 1965 to more than $50 million in 1977. While the rise in production has not been steady in recent years (see figure 21), it has not dropped below $25 million since 1971.

DISCUSSION

In almost all cases, Australian miners sell their raw material without the knowledge that would enable them to assess the value of the finished goods (like a farmer selling wheat and not knowing the price of flour). The miners cannot be blamed for this, as they were not, and still are not (to varying degrees), familiar with the changes that can be made in their raw materials by heat treatment.

This situation has allowed the Thais to virtually monopolize the buying of Australian rough, purchasing approximately 95% of the total production. While various Thai buying groups compete against one another, it is interesting to note that, historically, overall prices offered are always only slightly above average production costs. The cut-stone business in Thailand is highly competitive with an ever-continuing "price war" between merchants. Business is generally conducted on a "high turnover, low profit" principle. This has kept prices very low. To reduce their overhead, lapidaries cut the rough stone for maximum weight return and the least labor time required to produce acceptable goods. Unfortunately, visiting cut-stone buyers are prepared to buy such goods, because they in turn need to be competitive in their own local markets with other mechants who buy stock from Bangkok. Therefore, the full potential of a very large amount of excellent gem material is not realized because of poor cutting.

In addition, better-quality Australian sapphire is often not sold as such in Thailand. Quite a considerable amount of the best Australian material is sold mixed into parcels of Sri Lankan, Cambodian, or Thai sapphire. While Thai merchants increasingly refer to average and better-quality goods as Australian, many of their customers still insist on selling such goods on their home market as Thai or Cambodian in origin when, in fact, they know and ask for Australian goods when buying in Bangkok.

At the lower end of the scale, all poor-quality goods in Thailand are commonly referred to as Australian, whether they are Thai or Australian in origin. This has caused Australian sapphire to gain an ill-deserved reputation as being of poorer quality than Thai sapphire.

In addition to blue sapphire, Australia produces some magnificent gold, yellow, and green sapphires. Because these goods are so rare in relation to the blue production, and because their potential is easily assessed in the rough form, they are usually cut and marketed in Australia. However, all the yellow, green, and parti-colored sapphire rough produced would not represent 1% by weight or value of blue production. As beautiful as they are, they are only of very minor economic importance to the miners.

Almost any jewelry store in the world with a reasonable range of jewelry set with sapphires is bound to have within its doors an Australian sapphire, and perhaps as much as 80% of all the smaller, medium to dark blue stones come from "Down Under."

FUTURE PROSPECTS

The aerial extent of the basalts of eastern Australia is huge (approximately 350,000 km^2) compared with Southeast Asia (90,000 km^2), so the potential

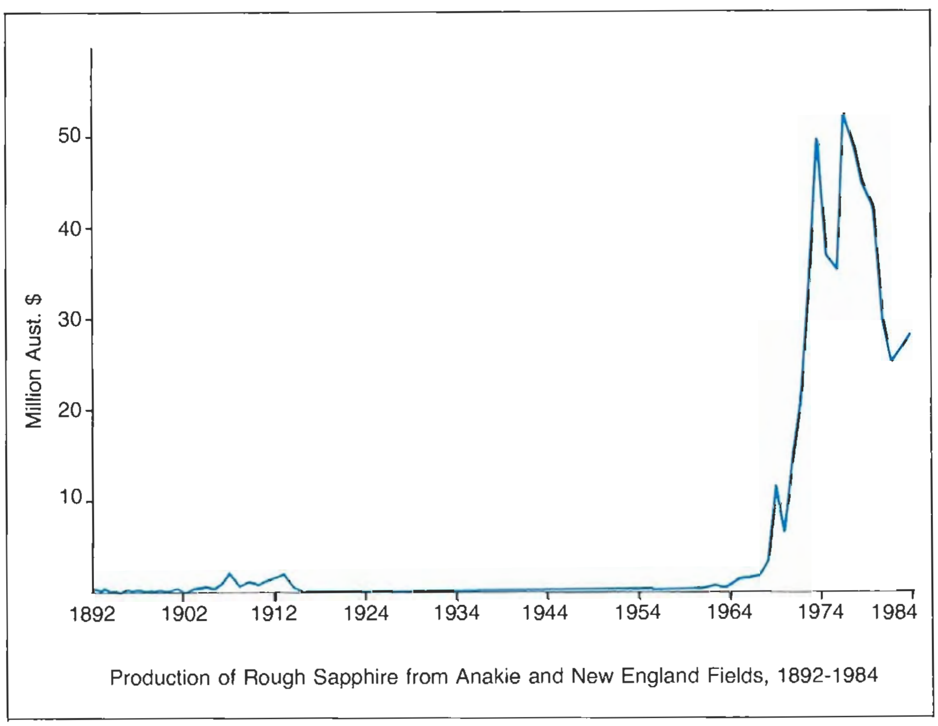


Figure 21. Production of Australian rough sapphire from the Anakie and New England fields, 1892–1984, as compiled by B. C. O'Leary (1985) from the Australian Bureau of Statistics. Note that the production returns on which these figures are based (given in Australian dollars) are only provided by the larger producers. The author suggests that actual production may be twice that indicated. Also, the values do not take into account increases in unit selling prices; today's market value of pre-1924 production would be considerably greater than the graph indicates. The current value of the Australian dollar is approximately US$0.75.

for the discovery of new, economic sapphire fields is good. Considering the similarity of the deposits and the types of gemstones produced in both Australia and Southeast Asia, it is surprising that only very few pieces of ruby have ever been found. Perhaps future prospecting will uncover deposits similar to those of Cambodia and Thailand.

During the last few years, however, there has been a reduction in sapphire mining at both the Anakie and the New England fields. This is due to several factors and, at this stage, it is difficult to determine whether or not it will continue. Specifically, a number of presently known reserves appear to have been mined out. Also, the last few years have seen a rapid rise in fuel, labor, and equipment costs. As there has been no major increase in demand or in prices due to the recent general world recession, many operators—both large and small—have stopped mining. Current production levels from New England are estimated to have dropped approximately 40%, and at Anakie approximately 60%, in the last five years (pers. comm. with miners).

It will be interesting to see what happens when the effects of this reduced production filter down to the marketplace. In order for there to be an increase in mining activity, prices will have to rise considerably, to such an extent that current marginally profitable deposits will become viable propositions.

There is also the possibility that the virtual monopoly that the Thais have over Australian rough purchases may be eroded in the future. As the number of miners is reduced, there is more chance of regulation, either self-imposed or government-enforced, of rough-sapphire marketing techniques. This, combined with an increased worldwide knowledge of heat-treatment methods and a demand for better-quality cutting, could result in larger volume markets for rough stones within Australia and internationally at centers other than Thailand.

REFERENCES

Anderson O. (1971) A century of sapphire mining. *Queensland Government Mining Journal,* February, pp. 41–51.

Department of Mineral Resources, New South Wales (1983) *Sapphires in New South Wales* (brochure).

Dunstan B. (1902) The sapphire fields of Anakie. Report, Geological Survey of Queensland.

Gübelin E. (1974) *Internal World of Gemstones.* ABC Editions, Zurich, Switzerland.

Gunawardene M., Chawla S.S. (1984) Sapphires from Kanchanaburi Province, Thailand. *Journal of Gemmology,* Vol. 19, No. 3, pp. 228–239.

Jobbins E.A., Berrangé J.P. (1981) The Pailin ruby and sapphire gemfield, Cambodia. *Journal of Gemmology,* Vol. 17, No. 8, pp. 555–567.

Keller P.C., Koivula J.I., Jara G. (1985) Sapphires from the Mercaderes-Río Mayo area, Cauca, Colombia. *Gems & Gemology,* Vol. 21, No. 1, pp. 20–25.

Lishmund S.R., Oakes G.M. (1983) Diamonds, sapphires, and Cretaceous/Tertiary diatremes in New South Wales. *Geological Survey of New South Wales, Quarterly Notes,* No. 53, pp. 23–27.

MacNevin A.A. (1972) Sapphires in the New England District of New South Wales. *Records of the Geological Survey of New South Wales,* Vol. 14, Part 1, pp. 19–36.

Monteagle D.B. (1979) *The Sapphire Fields 1879–1979.* City Printing Works, Rockhampton.

Moon A.R., Phillips M.R. (1984) An electron microscopy study of exsolved phases in natural black Australian sapphire. *Micro and Microscopica Acta,* Vol. 15, No. 3, pp. 143–146.

Nassau K. (1984) *Gemstone Enhancement.* Butterworths, London, England.

Schubnel H.J. (1972) *Pierres Precieuses.* Dans le Monde, Paris.

Webster R. (1983) *Gems: Their Sources, Descriptions and Identification,* 4th ed. Revised by B. W. Anderson, Butterworths, London, England.

PINK DIAMONDS FROM AUSTRALIA

By Stephen C. Hofer

During the first few months of 1985, the New York office of the GIA Gem Trade Laboratory examined more than 150 gem-quality fancy pink diamonds, most of which had similar color, spectra, luminescence, color zoning, surface textures, and inclusions. This dramatic increase in the number of pink diamonds offered in the trade recently, along with the fact that a great majority exhibit similar physical properties, suggested a new source of pink diamonds. This observation, together with information received from several diamond dealers to the effect that pink diamonds had been recovered from the Australian deposits, suggests that most or all of the above-mentioned stones originated in Australia. This article reports on the gemological properties of these "new" pink diamonds and describes a number of characteristics that, seen in combination in a stone, are indicative of Australian origin.

ABOUT THE AUTHOR

Mr. Hofer, formerly senior staff gemologist with the Gem Identification Department at the GIA Gem Trade Laboratory, Inc., New York, is currently an independent consultant residing in Canton, CT.

Acknowledgments: The author wishes to thank R. Crowningshield and D. Hargett of the GIA Gem Trade Laboratory, Inc., for their many helpful suggestions. Special thanks go to the following, who made the stones available for study and helped establish the origin of this material: A. Arslanian, B. Bogel, A. Bronstein, E. Elzas, R. Esmerian, S. Goldberg, W. Goldberg, Y. Mendelbaum, and L. Wolf.

Unless otherwise noted, the photomicrographs are by the author.

Diamonds with a pink body color have long been considered one of the rarest color varieties of diamond. Their rarity is due to the fact that pink diamonds are known to occur in only a few mines throughout the world, and none of these mines has ever proved to be a steady commercial source for gem-quality pinks. The famous alluvial deposits in southern India (stretching eastward from the Deccan Plateau highlands) produced a limited quantity of pinks during the active mining years in the 17th century. The many alluvial deposits throughout Brazil have historically been a notable but infrequent source of pinks, and in recent years Brazil has boasted a small production of pinks from the area around Diamantina (S. Moskal, pers. comm., 1984). Several Russian and African deposits—including the Williamson mine in Tanzania, a kimberlite deposit known as the Mwadui pipe—have also contributed to the sporadic output of pink diamonds worldwide. Usually, though, these deposits have yielded no more than a few carats of gem-quality pink stones at a time. It is therefore quite unusual to encounter parcels of natural pink diamonds. In fact, the number of natural fancy pink diamonds (152) examined in the first three months of 1985 at GIA's New York Gem Trade Laboratory represents more than the total number of pink diamonds examined in any previous year. According to diamond dealers who handled the rough material, the stones were from the recent productions of the newly discovered Argyle deposits in northwestern Australia (A. Arslanian, A. Bronstein, E. Elzas, W. Goldberg, pers. comms., 1985). Their information favored the notion that a significant number of these small stones were being fashioned by skillful cutters from larger, "lower quality" rough pink diamonds. In one example, the author examined a 0.38-ct round brilliant of fancy purplish pink color, heavily included, that was reportedly cut from the "cleanest area available from within a 2.50-ct rough Australian stone" (E. Elzas, pers. comm., 1985).

In an effort to characterize this new material, the author made a number of observations and conducted several

Figure 1. These examples of Australian pink diamonds from the study group illustrate the subtle differences among the characteristic hues. The stones range in size from 0.20 to 0.37 ct. Photo ©Tino Hammid.

gemological tests on 138 of these unusual pink diamonds. While there appears to be no one feature by which these stones can be distinguished, there are several characteristics that, when they appear in combination, indicate that a pink diamond is of Australian origin.

GEMOLOGICAL PROPERTIES

On reviewing the available literature, it became apparent that relevant gemological information on pink diamonds is sparse and often articles or notes on pink diamonds are based on observations of one stone. Therefore, we were pleased that our clients were willing to give us the opportunity to study a large selection of these pink diamonds.

Consequently, several gemological tests were conducted by the GIA Gem Trade Laboratory on 138 pink diamonds (ranging from 0.04 to 2.65 ct) that had been cut from Australian rough. The testing and initial observations of several of these pink diamonds revealed a number of distinctive characteristics, including an unusual body color that can be loosely described as "smoky purplish pink" (figure 1), characteristic spectral absorption patterns, similar fluorescent and phosphorescent reactions, distinctive color zoning, and irregular surface and internal features with a pitted texture that appears "frosted" or "sugary," in addition to well-formed colorless crystal inclusions. The refractive index and specific gravity measurements on all stones in this study were found to be within the normal range for diamonds.

Color. Of the 138 pink diamonds color graded during this study, nearly all had a body color strong enough to be in the "fancy" grade, a small percent were "fancy light," and only a very few were considered "light" pink. The fact that most of the stones—even round brilliants (figure 2)—had a color strong enough to be graded "fancy" is unusual, considering that the majority of pink diamonds examined in the laboratory previous to this study were in the "faint" through "fancy light" grades (R. Crowningshield, pers. comm., 1985).

Diamonds in the pink color family often contain secondary colors in addition to the primary pink color, referred to as modifiers. Modifying colors such as orange, purple, and brown are common in pinks; gray is also seen as a modifier, but less often. The assortment of natural pinks in figure 1 illustrates the variety of color seen in the pinks examined in this study: ranging from pink through purplish pink and including some with brownish overtones.

Most of the 138 stones when viewed separately appeared to contain some purple (again, see figure 1). However, when several stones were viewed side by side and table-down, the differences in color—including the subtle nuances of brown—were recognizable. In many of the purplish pink gems, these hints of brown were so weak and not readily observable face-up that they were not mentioned in the color grade; rather, such stones were graded as purplish pink. In the experience of the Gem Trade Laboratory, this unique combination of a very weak "smoky" brown together with varying

Figure 2. This necklace contains a total of 14.80 ct of Australian pink diamonds, including 143 brilliants. Only the 5.57-ct pear-shaped drop is from Brazil. Photo courtesy of R. Esmerian, Inc.

amounts of purple is not often seen in natural pink diamonds and thus helps the gemologist recognize and differentiate these diamonds from others in the pink color family.

The intensity of the pink color in the diamonds in this study is also unusual and is exemplified by a 0.72-ct fancy purple-pink gem that exhibited such a strong color saturation that it was outside the range of colors normally associated with natural pink diamonds (see cover). In fact, the color is comparable in strength to that seen in treated pinks, which have been referred to as "cranberry" pink. Also included in this study group were two diamonds that were graded as brown-pink that retained an attractive face-up color.

Spectral Analysis. The optical absorption spectra were observed with a Beck hand-held prism spectroscope first at room temperature and then at low temperature by resting the diamonds on an aluminum viewing block cooled with dry ice (Hofer and Manson, 1981). All the diamonds examined in this study showed the familiar 415-nm (Cape) absorption line in the violet region. In addition, a weak "smudge" was observed at about 520 to 580 nm in the green spectral region of two vivid purple-pink stones (figure 3).

Further testing with a Pye Unicam SP8-400 dual-beam spectrophotometer confirmed both absorption features (see spectra A and B in figure 4). The absorption strength of the 415-nm line at room temperature varied from weak to moderate and tended to be stronger in the purple-pinks. The broad absorption feature centered at approximately 550 nm correlates with the position and strength of the "smudge" seen in the hand spectroscope. This band at 550 nm was first noted in the spectra of pink, purple, and brown diamonds from Africa (Raal, 1958). Raal's study of pink diamonds states that "the strength of the band at 550 nm varies considerably and is correlated with the intensity of coloration of the diamond" (p. 846). Examinations and testing of natural pink diamonds at the Gem Trade Laboratory supports and confirms this previously published observation.

Further study of pink-diamond spectra was made by comparing the spectra of the two diamonds in the present study that exhibit the greatest visual color difference (again, see figure 4). The absorption curves are similar in appearance—that is, both resemble spectral absorption curves recorded for diamonds in the pink color family (Raal, 1958). However, it can be stated that the absorption spectra recorded on all pink diamonds

Figure 3. Drawing of the absorption spectrum recorded (at low temperature) from the 0.72-ct fancy purple-pink heart-shaped stone shown on the cover.

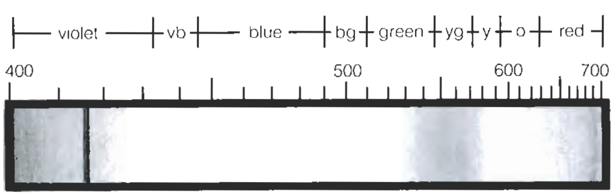
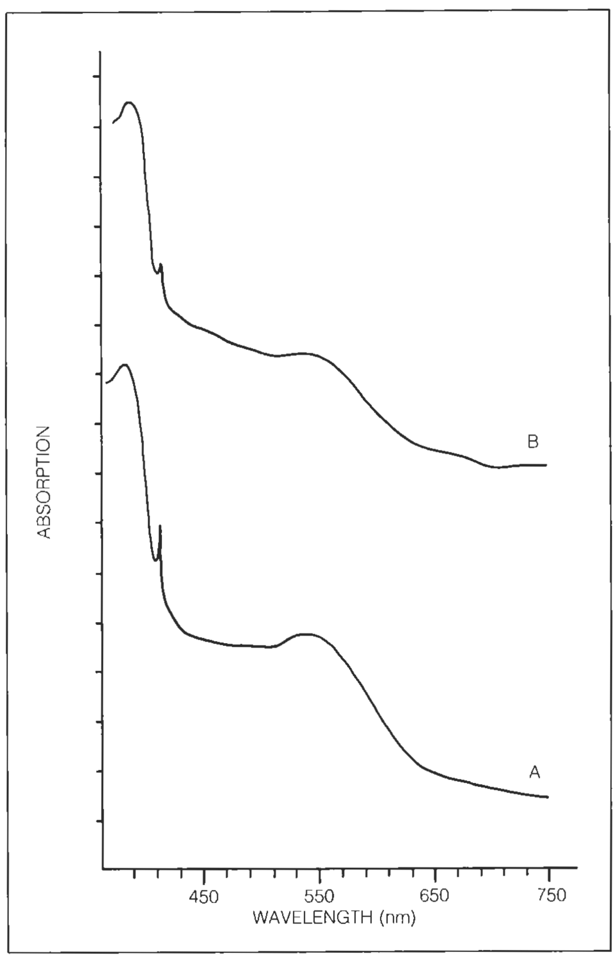


Figure 4. Optical absorption curves of two Australian pink diamonds from the study group. Spectrum A (lower) is recorded from an intense 1.64-ct purple-pink stone. Spectrum B (upper) is from a 1.93-ct brown-pink diamond.



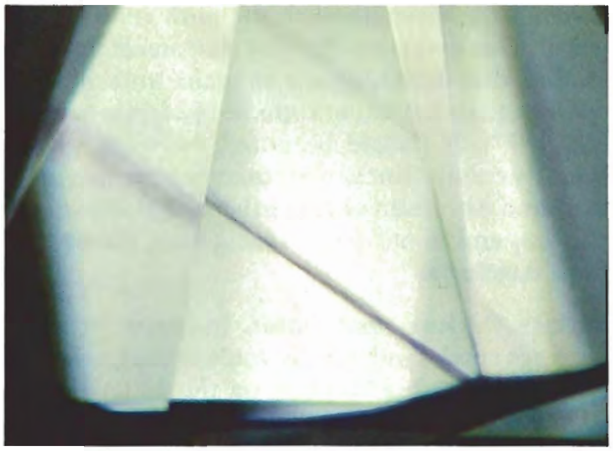


Figure 5. An obvious pink grain line as viewed through the pavilion of a colorless diamond at 10× magnification. Note the difference in appearance as the angle of observation changes. Photo by R. Kane.

Figure 6. This 5× view inside an Australian pink diamond shows the concentrated areas of minute pink grain lines. Note the pink "patches" of color.

from this study are markedly different from the spectra of treated pink diamond as observed in the hand spectroscope (Liddicoat, 1981, p. 193).

Luminescence Reactions. All of the diamonds from the study group were exposed to ultraviolet radiation in a darkened room: for each the color and the strength of the fluorescent glow were noted. The fluorescence varied from a very weak to a very strong blue when exposed to long-wave (366 nm) ultraviolet radiation and from none to a moderate blue when exposed to short-wave (254 nm) ultraviolet radiation. In addition, a yellow phosphorescence was noted in diamonds that fluoresced very strong blue, and virtually no phosphorescence was seen in diamonds that had a weaker blue fluorescence.

EXAMINATION WITH THE MICROSCOPE

A binocular microscope was used to examine all 138 stones at 5× to 75× magnification. The stones were examined for color zoning and distribution of color, birefringence patterns, surface and internal features and their textures, and inclusions.

Color Distribution and Zoning. Generally speaking, the color in pink diamonds is unevenly distributed throughout the body of the stone. The color occurs along narrow directions or zones known as grain lines. When viewed at various angles under magnification, the color in the grain lines (referred to by some diamond graders as "pink graining") appears to be concentrated along parallel, "needle-like" directions that alternate with colorless areas (figure 5; Kane, 1982). In most diamonds, these distinctive color-zoning features are usually very faint or are sparsely distributed throughout the crystal and therefore lack the potential in most cases to impart a strong pink color to the diamond when cut and viewed face-up.

By comparison, the diamonds in this study, the majority of which have a very obvious pink color face-up, have numerous minute pink grain lines that are more closely spaced than has been observed in most diamonds with pink graining examined previously. At low magnification, the pink graining appears very fine and close-knit, occurring throughout the entire stone or, more commonly, with the grain lines grouped together as patchy areas of pink (figure 6). The color in these areas looks similar to strokes of pink watercolor paint on paper and is referred to by the author as "brush stroke" graining. The minute pink grain lines that comprise these "brush stroke" areas are so slender and so closely spaced together that they are extremely difficult to resolve under high magnification. The most satisfactory results in examining these features are obtained by using low-power magnification and a shadowing technique to accentuate the details (Koivula, 1982). The concentrated patches of grain lines (figure 7) produce the overall appearance of strong pink color seen in these diamonds.

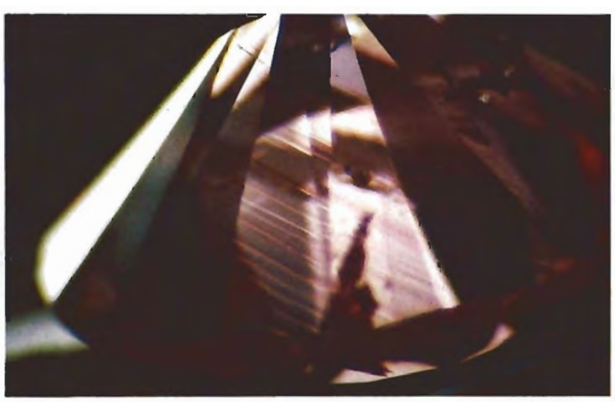
An early study (Raal, 1958) proposed that manganese causes the color in pink diamonds, but this theory has since been refuted (du Preez, 1965). Current explanations for the cause of pink color in diamonds involve defects in the atomic structure that result from gliding (the very slight movement of atoms along the octahedral direction) as a result of plastic deformation (Orlov, 1977). To confirm this and correlate these "defects" with the color in the pink grain lines, it is necessary to observe the birefringence pattern of diamonds.

Birefringence. Birefringence, or the strength of double refraction, is virtually nonexistent in strain-free, unincluded diamond (diamond is isotropic). However, most diamonds show some anomalous birefringence as a result of included crystals, various growth irregularities, or because they have been subjected to an epigenetic event such as plastic deformation (exposure to extreme temperature/pressure conditions after formation), as discussed by Lang (1967). Studying birefringence patterns in diamonds gives the gemologist a clue as to how strain is distributed within a diamond.

Birefringence can be examined with a microscope fitted with polarizing filters by holding the diamond in tweezers culet-to-table and viewing through the stone's pavilion at an oblique angle in transmitted or diffused transmitted light. With the diamond so positioned between the crossed polaroid plates, the pattern of interference colors, their strength (low-order grays up through high-order bright colors), and their coincident location around inclusions or grain lines can be observed.

All the pink diamonds in this study revealed a linear pattern of bright interference colors that coincided in strength with the pink graining (figure 8). This confirms the observations of previous studies that birefringence at grain lines is more distinct than any other form of birefringence (Orlov, 1977). It should be noted, however, that a brightly colored linear pattern only indicates that a diamond has strain characteristic of plastic deformation, and is not proof that a pink diamond is from Australia.

Figure 7. Needle-like pink grain lines can be seen cutting across an irregular pale pink color zone in an Australian diamond. Magnified 10×.



Surface Textures and Forms. Irregular "frosted" cleavage cracks and narrow voids or channels with a rough or "pitted" texture on the surface of the stone are considered to be very characteristic of the Australian material (figure 9). R. Liddicoat (pers. comm., 1985) saw large lots of rough during a recent visit to Australia and reported that nearly all the rough had an irregular "frosted" surface that resembles etching. This observation was further substantiated by R. Buonomo (pers. comm., 1985), who examined recent productions from the Argyle deposits at the Central Selling Office in London. His description of the Australian material noted the surface textures as appearing "frosted" or "sugary" to the unaided eye. The presence of similar features on the pink diamonds in the study sample is consistent with the Australian origin reported for these stones.

Researchers studying the process of etching have established that very strong heating of diamonds in situ can lead to the action of dissolution (process of dissolving) and consequently etch features (Frank and Puttick, 1958). As dissolution proceeds, the surface-etching textures develop in

Figure 8. A 10× view inside the same stone as in figure 7, using polarized light, shows the typical banded or linear birefringence pattern that signifies internal strain in the diamond, coincidental with the grain lines.

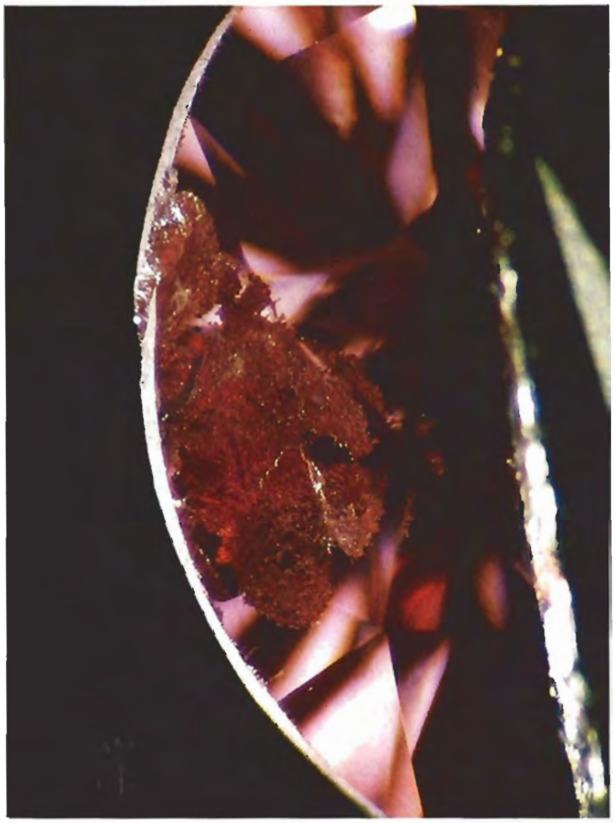


Figure 9. A cleavage crack that has been naturally etched appears "frosted," similar to worn beach glass. Note the extent of the etching inward and the open void at the girdle. Magnified 10×.

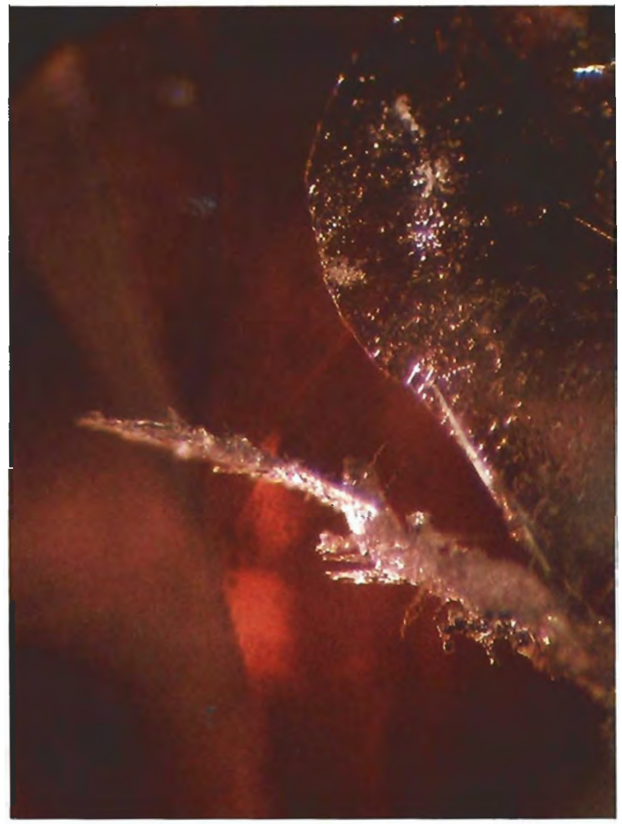


Figure 11. Etching that proceeds along a zone of weakness in a diamond can propagate in many directions inside the gem, resulting in many unusually shaped voids or hollow channels. Magnified 25×.

Figure 10. The early stages of etching are evident on a flat cleavage plane inside this pink diamond. Note the triangular markings that resemble trigons, which are actually triangular etch pits (Orlov, 1977). Magnified 45×.

various stages. Starting as small pits (weak etching), they subsequently develop into frosted planes and eventually, with prolonged heat, result in narrow voids (highly etched channels) resembling cracks (Berman, 1965; Orlov, 1977).

The various stages of etching noted by these workers is similar to that seen in the pinks examined in this study. For example, some of the diamonds had etch features seen on unpolished surfaces (naturals) resembling smooth "frosted" glass that suggest early stages of etching. Various gradual stages up to intensive etching were also seen to occur on the surface and along fractures in several cut diamonds (figure 10). Where etching has proceeded along a cleavage direction, the etching appears to widen and deepen the cleavage. These etch features were thus seen to propagate inward in the diamond, resulting in a network of unusual voids and channels (figure 11). When such channels intersect, they seriously affect the dura-

Figure 12. A part of the original surface on the girdle of this pink diamond shows evidence of "frosted" etching. Note the small amount of dirt or polishing material that has remained intact in the narrow section parallel to the girdle plane. Magnified 20×.

Figure 13. This cluster of colorless, polyhedral, solid crystal inclusions (possibly olivine) in pink diamond appears in moderate to high relief in dark-field illumination. Magnified 20×.

bility of the diamond and often result in breakage. In addition, narrow etch channels open at the surface are commonly filled with a dark material, possibly from the polishing process or simply from dirt, which can darken the appearance of the voids (figure 12).

Other Inclusions. Of the 138 pinks examined in this study, all of which had considerable pink graining and showed evidence of etching, the majority (more than 90%) also contained numerous small, solid, colorless, polyhedral crystal inclusions (figure 13). Microscopic study of these inclusions showed that they did not have a characteristic crystal habit; rather, they assumed the morphology of the host diamond. They are very similar in appearance to the colorless olivine inclusions commonly seen in diamonds found in kimberlite deposits (Mitchell and Giardini, 1953; Hall and Smith, 1984). Because such inclusions are common in diamonds found at various locations, they cannot be considered conclusive proof of Australian origin. However, colorless crystals when observed in a natural pink diamond with the previously described color, spectra, luminescence, graining and surface features can be considered indicative of Australian origin.

CONCLUSION

The author was not able to obtain information on the abundance and availability of these Australian pink diamonds. It has been reported in the literature, however, that deposits at the Argyle project in northwest Australia "produce a characteristic pink diamond, which is likely to be the signature of the mine over the next few years" (McIlwraith, 1984).

The sudden occurrence of increased numbers of natural pink diamonds in the gem market reinforces the idea that continued mining and recovery efforts may significantly augment the traditionally limited supply of natural fancy-colored diamonds annually recovered.

The gemological and microscopical findings reported in this article suggest that there are several features that are characteristic of pink diamonds from Australia: their intense purplish pink color, the concentrated patches of "pink graining," luminescence, birefringence, a "frosted" surface, and included small, colorless crystals. While no one or two of these features alone would provide proof of the stone's origin, the occurrence of several of these features in a pink diamond would strongly suggest that the stone came from the Australian mines.

Editor's Note: *In August 1985, the GIA Gem Trade Lab in New York was informed that certain brownish pink diamonds from Australia improve in color with repeated heat treatment (not identifiable by known gemological tests). Somewhat similar behavior in brownish pink diamonds has been reported previously (Gem Trade Lab Notes,* Gems & Gemology, *Vol. 19, 1983, p.44). At the same time, it was reported that the Australian material has become much scarcer during the past four to five months.*

REFERENCES

Berman R. (1965) *Physical Properties of Diamond.* Clarendon Press, Oxford, England.

du Preez L. (1965) *Electronparamagnetic Resonance and Optical Investigations of Defect Centres in Diamond.* Ph.D. thesis, University of Witwatersrand.

Frank F.C., Puttick K.E. (1958) Etch pits and trigons on diamonds. *Philosophical Magazine,* Vol. 3, No. 35, pp. 1262–1279.

Hall A.E., Smith C.B. (1984) Lamproite diamonds—are they different? In *Kimberlite Occurrence and Origin: A Basis for Conceptual Models in Exploration,* J.E. Glover and P.G. Harris, eds., University of Western Australia, pp. 167–212.

Kane R.E. (1982) Graining in gem diamond. In *Procedures of the International Gemological Symposium,* Gemological Institute of America, Santa Monica, CA.

Koivula J.I. (1982) Shadowing: a new method of image enhancement for gemological microscopy. *Gems & Gemology,* Vol. 18, No. 3, pp. 160–164.

Lang A.R. (1967) Causes of birefringence in diamond. *Nature,* Vol. 213, No. 5073, pp. 248–251.

Liddicoat R.T. Jr. (1981) *Handbook of Gem Identification.* Gemological Institute of America, Santa Monica, CA.

McIlwraith J. (1984) De Beers chairman invited to Argyle diamond mine. *Indiaqua,* No. 39, p. 43.

Mitchell R.S., Giardini A.A. (1953) Oriented olivine inclusions in diamond. *American Mineralogist,* Vol. 38, Nos. 1–2, pp. 136–138.

Orlov Y.L. (1977) *The Mineralogy of the Diamond.* J. Wiley & Sons, New York.

Raal F.A. (1958) A new absorption band in diamond and its likely cause. *Proceedings of the Physical Society,* Vol. 71, No. 461, pp. 846–847.

THE BIRON HYDROTHERMAL SYNTHETIC EMERALD

By Robert E. Kane and Richard T. Liddicoat, Jr.

A new synthetic emerald grown in Western Australia is now commercially available as faceted stones. Infrared spectra revealed the presence of water, thereby confirming that these synthetic emeralds are synthesized by a hydrothermal process. Chemical analysis showed that they contain vanadium as well as lesser amounts of chromium. This new synthetic exhibits some characteristics that are distinctly different from other synthetic emeralds and therefore must now be considered when identifying emeralds. In addition to distinctive inclusions such as gold, the Biron synthetic is inert to ultraviolet radiation, has a specific gravity of 2.68–2.71, and refractive indices of $\epsilon = 1.569$ and $\omega = 1.573$. This article examines in detail the gemological properties of the Biron hydrothermal synthetic emerald and discusses means of identifying this new synthetic.

ABOUT THE AUTHORS

Mr. Kane is research and gem identification supervisor of the GIA Gem Trade Laboratory, Inc., Los Angeles, California; and Mr. Liddicoat is chairman of the board of the Gemological Institute of America, Santa Monica, California.

Acknowledgments: The authors would like to thank Mr. W. L. Cotton and Biron Minerals Pty., Ltd., for the loan and generous donation of some of the synthetic material examined in this study; and Bill Kerr for preparing some samples for analysis and photomicrography. All photographs, unless otherwise indicated, are by Robert E. Kane.

Emerald was first synthesized by Ebelman in 1848 by adding natural emerald powder to a molten boric acid flux, which produced very small prismatic emerald crystals as the mixture cooled. In the ensuing years, the flux growth of synthetic emerald was achieved by many researchers (Nassau, 1980; Sinkankas, 1981). In 1957, the growth of minute beryl crystals by a hydrothermal process was first reported (Wyart and Šćavničăr, 1957). Although many processes for growing synthetic emerald hydrothermally have been described since then (summarized in Sinkankas, 1981), until recently only three major productions of hydrothermal synthetic emerald have been commercially available to the jewelry trade: Linde (patented process now owned by Regency), Lechleitner (full synthetic in addition to overgrowth), and, most recently, those grown in the Soviet Union (see Takubo, 1979).

The synthetic emerald reported on here represents a new hydrothermal process that can yield unusually clean faceted stones (figure 1) from remarkably large single crystals (figure 2). This material will be commercially available in the latter part of 1985. This new hydrothermal emerald is being synthesized in Western Australia and marketed as faceted stones under the trade name Biron. Note that this is not the same material as the vanadium-doped synthetic emerald that was grown several years ago in Melbourne, Australia, by Taylor (1967).

The manufacturer reports that research on the Biron synthetic emerald began in 1977 in Western Australia. Since then, a few brief notes based on the examination of a very small number of stones have appeared in the literature (Brown, 1981 and 1983; Brown and Snow, 1984; Darragh and Willing, 1982; Tombs, 1983). In the interest of providing detailed information to the gemological community on the properties and identifying characteristics of this synthetic emerald, however, the manufacturer, Biron Minerals Pty., Ltd., and the distributor made available to

Figure 1. These faceted Biron hydrothermal synthetic emeralds are representative of many examined in this study. The stones shown here have a high clarity and range in weight from 1.20 to 3.00 ct. Photo © Tino Hammid.

GIA 202 samples of the new Biron synthetic emerald. The samples included 150 faceted stones of various shapes and cuts (ranging from 0.05 ct to 3.00 ct), 50 preforms (weighing from 1.50 ct to 5.00 ct), and two rough crystals (96.08 ct and 108.05 ct). These specimens were examined carefully and subjected to several gemological tests; a few were also chemically analyzed. A detailed study of the inclusions present was also conducted. The results of these examinations and tests are reported below and summarized in table 1.

VISUAL APPEARANCE

The faceted Biron synthetic emeralds studied varied in hue from green to slightly bluish green in moderate to vivid saturation (figure 1). The well-cut stones were relatively consistent in color with vivid saturation. As would be expected, small stones and those that were cut shallow were considerably lighter in tone.

Nearly all of the faceted Biron synthetic emeralds examined were very transparent. When examined with the unaided eye and overhead illumination, they ranged from stones that appeared to be completely free of inclusions to those that had areas of visible inclusions.

PLEOCHROISM

Using a calcite dichroscope, we observed dichroism in strongly distinct colors of green-blue parallel to the c-axis and yellowish green perpendicular to the c-axis. These results are typically observed in other synthetic emeralds, as well as in many natural emeralds.

SPECTRAL EXAMINATIONS

The visible-light absorption spectra of several of the faceted Biron synthetic emeralds were examined with a GIA GEM Instruments spectroscope unit. The observed spectra appeared to be essentially the same as the well-known absorption spectra of emerald described by Liddicoat (1981, p. 194), which are the same for both natural and synthetic emerald.

When looking down the optic axis direction, we observed in all of the stones tested a vague general absorption from 400.0 nm to approximately 480.0 nm, a superimposed sharp line at

Figure 2. An exceptional example of the Biron hydrothermal synthetic emerald crystals grown in Western Australia. This crystal measures 3.50 cm long by 1.6 cm wide, and weighs 96.08 ct. Photo by Tino Hammid; © W. L. Cotton.

477.0 nm, a broad band of absorption between 580.0 and 615.0 nm, and lines in the red situated at 637.0, 646.0, 662.0, 680.5, and 683.5 nm. We observed a similar absorption when we examined the spectrum perpendicular to the optic axis; however, the sharp line at 477.0 nm was absent. The same absorption features also occur in natural emeralds.

When the Biron synthetic emeralds were placed over the opening of the iris diaphragm on the spectroscope unit, a red transmission was observed. This transmission ranged from weak to very weak, depending on the position of the stone and of the light source, as well as on the size of the stone. We have observed that this phenomenon is typical of many synthetic emeralds and is also exhibited by some natural emeralds, inasmuch as it is occasionally observed in very fine-color emeralds from Chivor, and in medium to light emeralds from Gachalá, in Colombia.

Infrared absorption spectra were obtained by Dr. George Rossman, of the California Institute of Technology, using a Nicolet series 60SX Fourier transform infrared spectrometer system. The spectra, taken from several samples of Biron synthetic emerald, revealed the presence of water, thus confirming that these synthetic emeralds are grown by a hydrothermal process. All natural emeralds and hydrothermal synthetic emeralds contain some water, whereas flux-grown synthetic emeralds contain no water (Nassau, 1980).

COLOR-FILTER REACTION

Several of the Biron synthetic emeralds were tested with a Chelsea color filter. All of the stones tested revealed a strong red appearance under the filter, as is also the case with many other hydrothermal and flux-grown synthetic emeralds. Unfortunately, many natural emeralds from various sources show the same reaction. Therefore, the color-filter reaction alone provides no indication of the synthetic origin of this material.

SPECIFIC GRAVITY, REACTION TO ULTRAVIOLET RADIATION, AND REFRACTIVE INDICES AND BIREFRINGENCE

Traditional gemological tests for the distinction of synthetic emerald from natural emerald have always considered microscopic examination of characteristic inclusions to provide definitive proof of origin. However, this test is often considered the most difficult to master because of the similarities of some of the inclusions (such as "fingerprints" and "veils") found in both synthetic and natural emeralds. Consequently, many gemologists and jewelers have relied on magnification the least, and have arrived at an identification on the basis of refractive indices, birefringence, reaction to ultraviolet radiation, and specific gravity. However, with the new Biron synthetic emerald, as well as with other newer hydrothermal synthetic emeralds, such as the Russian material (Takubo, 1979), some of these standard tests no longer provide even a vague indication of synthetic origin.

Specific Gravity. The specific-gravity values for the Biron hydrothermal synthetic emeralds were determined by the hydrostatic method with a Voland diamond balance. The sample stones showed slight variations in density from 2.68 to 2.71. All of the faceted synthetic emeralds were

TABLE 1. The gemological properties of the Biron hydrothermal synthetic emerald.

Properties that overlap with those of natural emeralds from differing geographic localities	Pleochroism	Strong: green-blue parallel to the c-axis and yellowish green perpendicular to the c-axis.
	Absorption spectrum[a] (400–700 nm)	Optic-axis direction: absorption lines at 477.0, 637.0, 646.0, 662.0, 680.5 and 683.5 nm; a vague general absorption from 400.0 to 480.0 nm and a broad band of absorption between 580.0 and 615.0 nm. Perpendicular to optic-axis direction; same as above, with the exception that the 477.0 nm line is absent.
	Color-filter reaction	Strong red
	Specific gravity	2.68–2.71
	Luminescence to long- and short-wave U.V.	Inert
Key identifying properties	Refractive indices and birefringence	$\epsilon = 1.569$, $\omega = 1.573$ (+0.001) 0.004–0.005
	Inclusions	Various forms of fingerprints, veils, and fractures; single occurrences of large two-phase inclusions; nail-head spicule inclusions with liquid and gas phases; several forms of gold; phenakite crystals; numerous types and appearances of growth features; white particles forming comet-tails and stringers or randomly scattered throughout; and, rarely observed, seed plates.

[a]*As observed through a hand-held type of spectroscope.*

also tested in a standard 2.67 (specific gravity) heavy liquid (methylene iodide diluted with benzyl benzoate). Before we present the results, a brief discussion is necessary concerning the factors that can influence the specific-gravity values of beryl.

Studies on the chemical composition of natural beryls (Bakakin and Belov, 1962; Goldman et al., 1978; Schaller et al., 1962) state that both filling of structural voids and substitution by Cr, Fe^{3+}, Fe^{2+}, Mg, Li, other ions, and water molecules can occur in the crystal structure of beryl. These ions and water molecules appear to be a major cause of variation in specific gravity and refractive index among natural beryls (Flanigen et al., 1967). Just as with natural emeralds, the specific gravity and refractive indices of hydrothermal synthetic emeralds are also dependent in part on the amount of impurity ions and molecules they contain. Because of the different synthesis techniques used, these properties frequently differ from one manufacturer to another.

From our observations, the specific-gravity values of flux-grown synthetic emeralds of various manufacture are often lower than the values of their natural counterparts; such stones usually float in the 2.67 liquid, thus providing some indication of their synthetic origin. In contrast, the values obtained for many hydrothermal synthetic emeralds are slightly higher, with the stones sinking in the 2.67 liquid, thereby overlapping with the specific-gravity range of natural emeralds. All of the Biron hydrothermal synthetic emeralds examined by the authors in this study had densities greater than 2.67. Because many natural emeralds have similar specific-gravity values, the specific gravity of the Biron hydrothermal synthetic emeralds provides the gemologist with absolutely no indication of the synthetic origin of the material.

Reaction to Ultraviolet Radiation. All of the Biron hydrothermal synthetic emeralds were exposed to long-wave (366 nm) and short-wave (254 nm) ultraviolet radiation. To insure observation of even the weakest fluorescence, we performed the test in a completely darkened room, placing the synthetic emeralds on a black pad raised to within a few inches of the ultraviolet lamp inside a standard ultraviolet viewing cabinet. The faceted Biron synthetic emeralds did not exhibit any visible fluorescence under these conditions.

It has been stated that the presence of iron in either natural or synthetic emeralds can quench chromium fluorescence, slightly increase specific gravity, and raise refractive indices and birefringence (Fryer, 1969/70; Kane, 1980/81; Gübelin, 1982). We suggest that, because of the lack of detectable iron in the Biron hydrothermal synthetic emerald (see table 2), something other than iron must be responsible for the inert reaction of the material when exposed to long-wave and short-wave ultraviolet radiation. Rather, the lack of fluorescence appears to be due to the high concentrations of vanadium (see table 2). This conclusion is supported by Linares's experiments on the flux growth of synthetic emerald (1967). Linares used

TABLE 2. Chemical analyses of two faceted Biron hydrothermal synthetic emeralds.[a]

Catalog no.	Oxide component (wt.%)[b]								
	Na_2O	MgO	FeO	Al_2O_3	V_2O_3	Cr_2O_3	SiO_2	Cl	Total[c]
GIA 120[d]	nd[f]	nd	nd	18.1	0.7	0.3	66.4	0.3	85.8
GIA 14622[e]	nd	nd	nd	18.2	0.6	0.2	65.4	0.3	84.7

[a]*These samples were analyzed with a MAC electron microprobe at an operating voltage of 15 KeV and beam current of 0.05 μA. The raw data were corrected by using the Ultimate correction program of Chodos et al. (1973). Analyst: Carol M. Stockton, GIA Research Dept.*
[b]*Values represent the average of three analyses for each sample.*
[c]*These totals are low (less than 100%) because no analysis was made for light elements (of atomic number below 11) present in beryl. Ideally, BeO should be about 14.00 wt.%.*
[d]*Sample synthesized in 1982.*
[e]*Sample synthesized in 1984.*
[f]*Not detected; below the detection limits of the instrumentation used (approximately 0.1 wt.%).*

various ratios of a lead oxide–vanadium oxide flux system ($PbO-V_2O_5$), in addition to chromium oxide (Cr_2O_3), for his synthetic-emerald experiments. When the synthetic emeralds grown from these fluxes were exposed to ultraviolet radiation, no chromium fluorescence was observed. Linares speculated that considerable vanadium was incorporated into the synthetic emerald during the growth process; the vanadium then interacted with the chromium to quench any fluorescence that might have been caused by the chromium.

Flanigen et al. (1967) also reported the absence of fluorescence in their experimental vanadium flux (V_2O_3) synthetic emerald. In contrast, they reported that their Linde hydrothermal synthetic emerald, which contained no vanadium, showed a bright red fluorescence when exposed to both long- and short-wave ultraviolet radiation. The absence of fluorescence has also been observed in vanadium-doped synthetic ruby and synthetic alexandrite (Linares, 1967).

An inert reaction to ultraviolet radiation has frequently been used as an indicator of natural origin for emeralds, since many natural emeralds are inert to either long-wave or short-wave U.V. and many hydrothermal and flux synthetic emeralds are not. However, with the introduction of the Biron synthetic emerald, which is also inert to such radiation, the absence of fluorescence can no longer be used as an identifying criterion.

Refractive Indices and Birefringence. Refractive indices were obtained using a GEM Duplex II refractometer in conjunction with a sodium light source. The Biron synthetic emeralds were determined to be uniaxial negative with a refractive index of $\epsilon = 1.569$ and $\omega = 1.573$ (+0.001), with a corresponding birefringence of 0.004–0.005. These low values provide some indication of synthetic origin. Although an identification should not be based solely on this property, these optical values are very unlikely to be observed in a natural emerald. For a comparison of refractive index and birefringence values of natural emeralds from numerous different geographic localities, see Gübelin (1982, p. 13, table 3). Interestingly, the values recorded for the Biron synthetic emerald are low for a hydrothermal synthetic emerald and are more typical of flux-grown products.

INCLUSIONS

The Biron hydrothermal synthetic emeralds were all examined thoroughly with a gemological binocular microscope in conjunction with various sources of illumination. Several types of characteristic inclusions were observed; some were reminiscent of synthetic emeralds of different manufacture, while several others identified by the authors appear to be unique to the Biron synthetic emerald.

The faceted Biron synthetic emeralds examined ranged in clarity from those with prominent inclusions, growth features, and color zoning, to those that were remarkably clean and appeared to be nearly flawless, with perhaps only minor, nondescript growth features.

Two-Phase Inclusions. Evident in some of the Biron synthetic emeralds examined were two-phase inclusions consisting of a fluid and a gas bubble. These two-phase inclusions were observed to have three distinct appearances: (1) forming "fingerprint" patterns and curved (wispy) "veils"; (2) as large, irregular voids containing one or more gas bubbles; and (3) trapped within the tapered portion of "nail-head spicules."

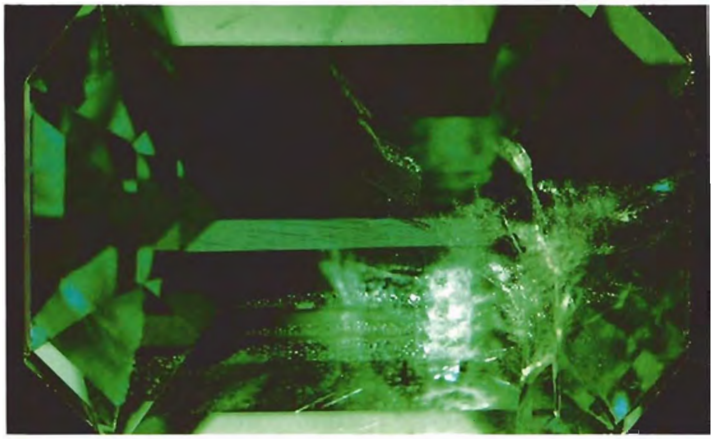


Figure 3. Overview of a 1.70-ct faceted Biron synthetic emerald showing secondary "fingerprint" and "wispy veil" inclusions and irregular growth features in the center of the stone. Dark-field illumination, magnified 13×.

Fingerprints, Veils, and Fractures. As with other hydrothermal synthetic emeralds, the Biron typically contains various types of secondary growth defects commonly referred to as fingerprints and veils. The term *wispy veil* is also often used to describe such inclusions in synthetic emeralds and other synthetic gem materials. The Biron synthetic emeralds exhibited fingerprint and veil patterns of various appearances (figures 3 through 6).

In contrast to flux-grown synthetic emeralds, in which the fingerprints and veils are healed fractures with flux fillings, the fingerprints and veils in hydrothermal synthetic emeralds generally consist of many small two-phase inclusions that are usually concentrated at curved and planar interfaces; although flux inclusions may be similar in appearance, they are completely solid. These fingerprints and veils in the Biron synthetic emerald are healing fissures that are in some cases remarkably similar in nature and appearance to those observed in some natural emeralds (figure 4). The mechanism that produces this healing process in natural minerals has been well documented (see Eppler, 1959, 1966; and Roedder, 1962, 1982, 1984); for illustrations of the formation process of these secondary inclusions, see Roedder (1982, 1984) and Koivula (1983). Although the conditions required to heal a fracture resulting in a fingerprint-like pattern in a natural or synthetic crystal are different, the mechanism should be the same.

One or two of the faceted Biron synthetic emeralds exhibited areas of somewhat dense concentrations of wispy and planar fingerprints and veils of various forms that often originated from a common central point, extending outward in a spiral arrangement. This is illustrated in figure 3; interestingly, this stone was probably the most included of all the 200 examined, yet the wispy

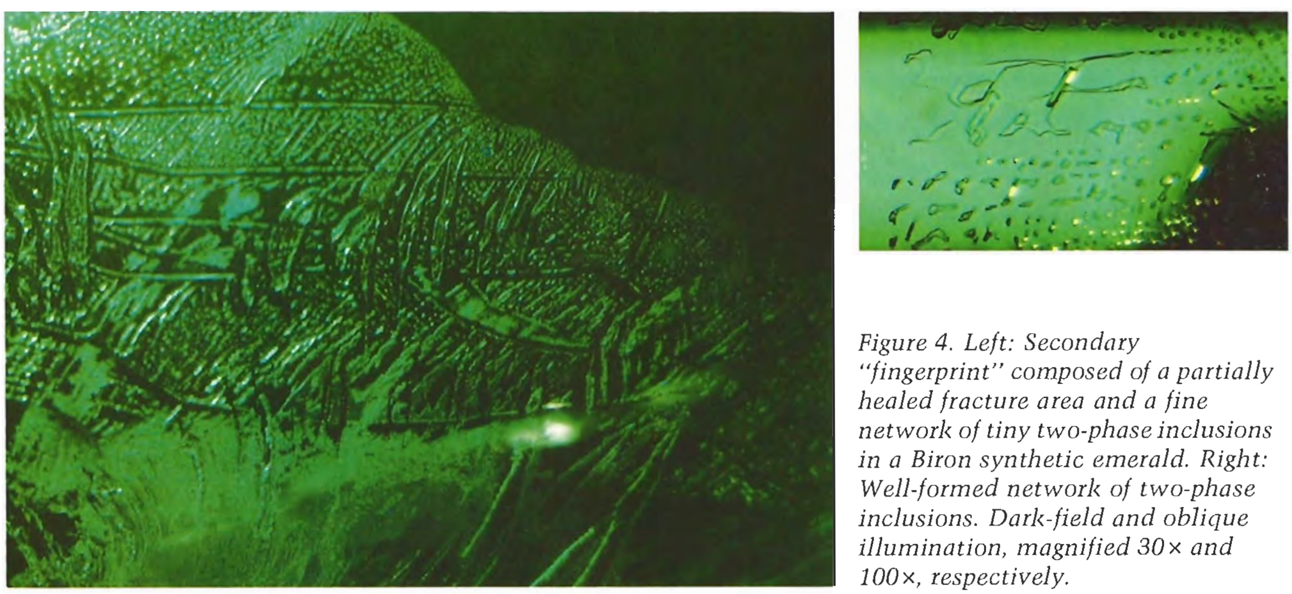


Figure 4. Left: Secondary "fingerprint" composed of a partially healed fracture area and a fine network of tiny two-phase inclusions in a Biron synthetic emerald. Right: Well-formed network of two-phase inclusions. Dark-field and oblique illumination, magnified 30× and 100×, respectively.

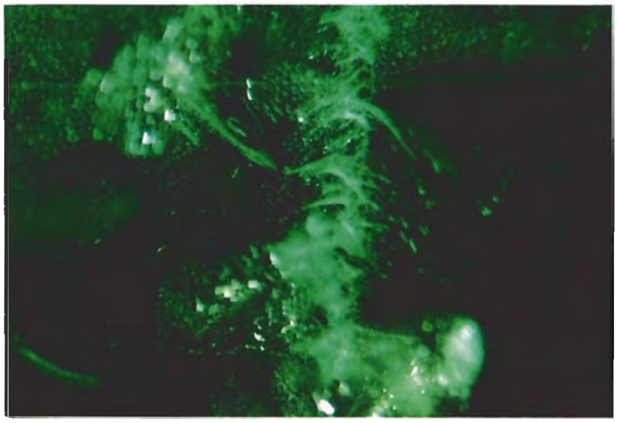


Figure 5. These spiral arrangements of small "fingerprints," frequently referred to as a helix pattern, in the Biron synthetic emeralds should not be confused with very similar-appearing inclusions in some natural emeralds. Dark-field illumination, magnified 20×.

veils occupied less than one-half of the faceted stone. This clarity is in contrast to many other synthetic emeralds, both flux and hydrothermal, which (with the exception of some Inamori flux synthetic emeralds and Russian hydrothermal and flux synthetic emeralds) are typically very heavily included.

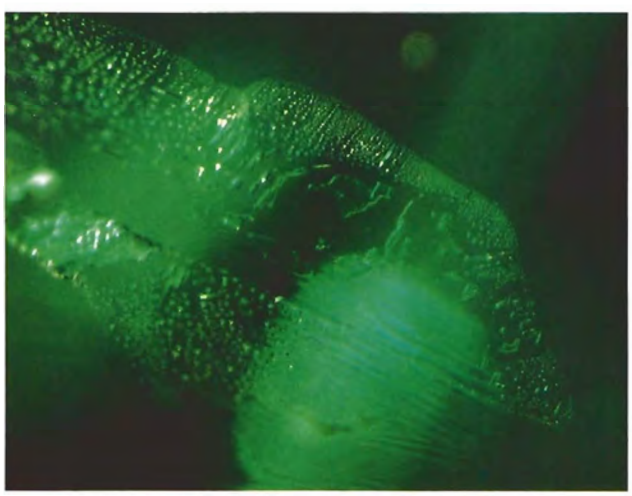
Observed in several of the Biron synthetic emeralds were spiral arrangements of a small fingerprint pattern (figure 5), sometimes referred to as a helix pattern. This type of spiral growth pattern is also occasionally observed in natural emeralds (Gübelin, 1974; Fryer et al., 1983) and therefore may be confusing to the gemologist.

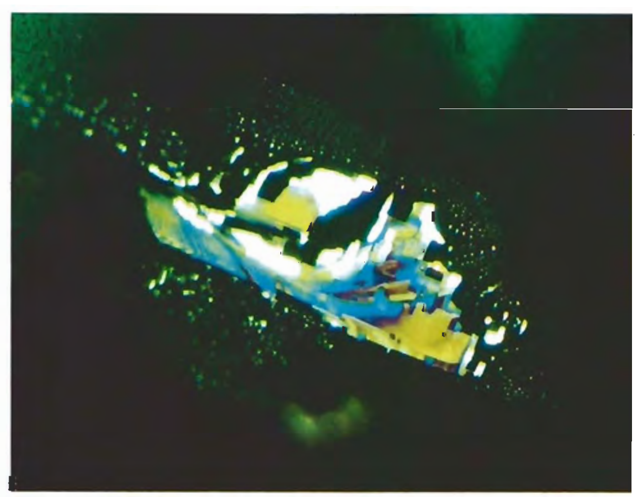
Some of the Biron synthetic emeralds contained areas of partially healed fracture-fingerprint patterns that, when tilted to specific viewing angles in dark-field or reflected light, exhibited a multicolored display of interference colors (see figure 6). The same phenomenon is occasionally observed in some natural emeralds that contain ultra-thin layers of two-phase (liquid and gas) inclusions; in the natural stones, however, the patterns are quite distinctive, ranging from minute to large in randomly oriented, rounded, irregular forms (figure 7).

Also observed were fractures and healed fractures, some of which were similar in appearance to the epigenetic staining that is observed in many natural gem materials, including emeralds. Thus, these fractures do not provide any evidence of synthetic origin.

Single Irregular Two-phase Inclusions. In a few of the faceted Biron synthetic emeralds, rather unusual, large, individual two-phase inclusions were observed (figure 8). Frequently trapped within a tapered, irregular, flattened void that exhibited sharp angular to slightly rounded edges was a fluid and a large gas bubble. None of these bubbles was mobile under normal viewing conditions.

Figure 6. A Biron synthetic emerald with a secondary "fingerprint" pattern consisting of a network of two-phase inclusions and a partially healed fracture. On the left, the partially healed fracture is almost invisible when viewed in dark-field illumination only. However, as is shown on the right, when fiber-optic illumination is used to vertically light this area, interference colors are seen. Magnified 40×.





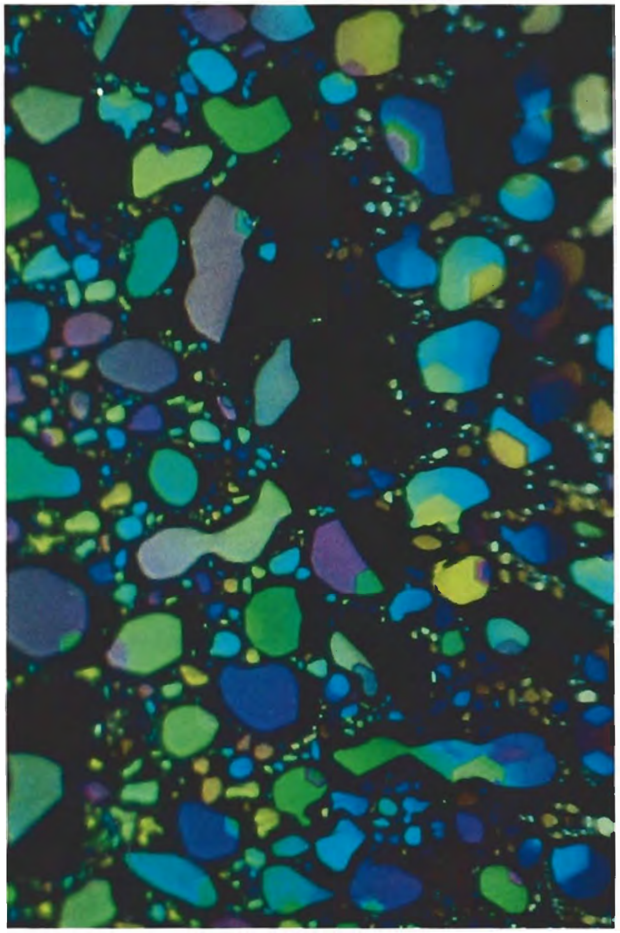


Figure 7. A natural emerald with ultra-thin films of two-phase (liquid and gas) inclusions. Such thin-film inclusions are occasionally observed in natural emeralds; however, they are generally quite distinctive and should not be confused with inclusions displaying a similar phenomenon in Biron synthetic emeralds, such as the one shown in figure 6. Vertical illumination with a fiber optic light source only, magnified 80×.

Figure 8. Captured within this Biron synthetic emerald is a large, well-formed, two-phase inclusion. Note also the fingerprint patterns at either end of the inclusion. Dark-field and oblique illumination, magnified 40×.

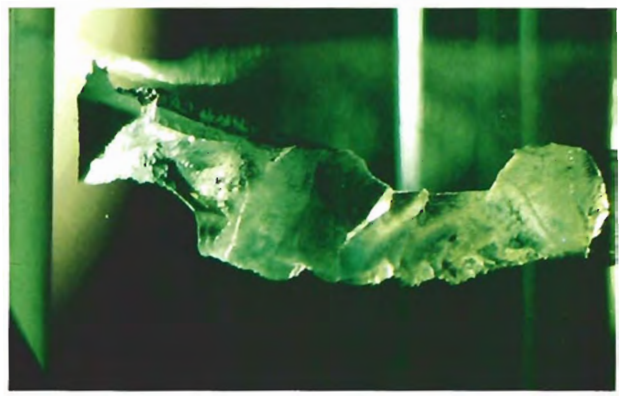


Figure 9. During the faceting of this Biron synthetic emerald, a very large two-phase inclusion was brought to the surface, releasing the liquid and gas phases and leaving only a deep void. The frosted appearance on the inner walls of the void is in part a result of residue left in the cavity. Dark-field and oblique illumination, magnified 25×.

Several of the faceted Biron synthetic emeralds contained large voids that broke the surface in a very small area of the stone; in a few stones, these voids extended almost the entire length from the table to the culet. They were identical in appearance to many of the voids that contained the two phases. Undoubtedly, when the inclusions were brought to the surface during faceting, the gaseous and liquid phases were released, leaving only a void or very deep cavity with a frosted white appearance on the inner walls (figure 9).

Nail-Head Spicules. Also common in the Biron synthetic emeralds is the presence of a fluid and a gas bubble contained within a cone-shaped void that frequently starts at its widest end on a crystalline inclusion and tapers gradually to a point. These inclusions, referred to here as nail-head spicules, have long been observed in hydrothermal synthetic emeralds from various manufacturers (Nassau, 1978, 1980; Anderson, 1980; Liddicoat, 1981; Sinkankas, 1981).

In the Biron synthetic emeralds, the "head of the nail" is formed by a single crystal, a group of phenakite crystals, or gold crystals (see figures 10 – 12). As is common with virtually all other hydrothermal synthetic emeralds, the nail-head spicules in the Biron synthetics are often observed in single or multiple occurrences that

Figure 10. This large nail-head spicule in a Biron synthetic emerald consists of a cone-shaped void that is filled with a fluid and a gas bubble. Although not visible at this viewing angle, the spicule is capped by a poorly developed, ghost-like phenakite crystal. Dark-field illumination, magnified 50×.

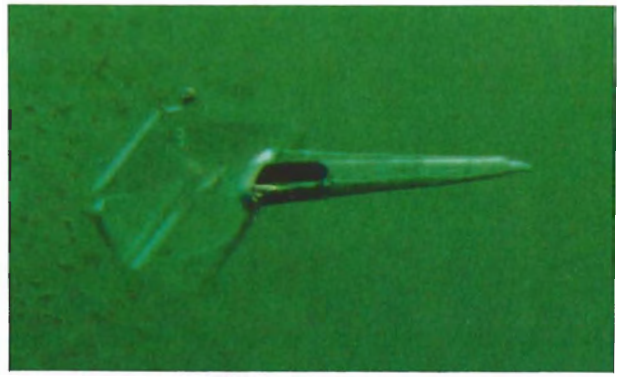


Figure 11. This Biron synthetic emerald contains a nail-head spicule with a large, distinct phenakite crystal at the base. Dark-field illumination, magnified 60×.

parallel the c-axis. Examination of both hydrothermal and flux synthetic emeralds revealed that nail-head spicules develop most readily when the synthetic emerald is initially started on a seed plate inclined at an angle to the crystallographic axes, as is the case with the Biron synthetic emeralds.

Gold. Several of the faceted Biron synthetic emeralds contained metallic-appearing inclusions. SEM-EDS analyses were performed on a number of these inclusions that reached the surface on each of five different faceted stones. These inclusions represented the range of sizes, shapes, textures, and colors of the metallic inclusions observed in the Biron synthetic emeralds that were studied. The analyses identified gold as the major constituent in

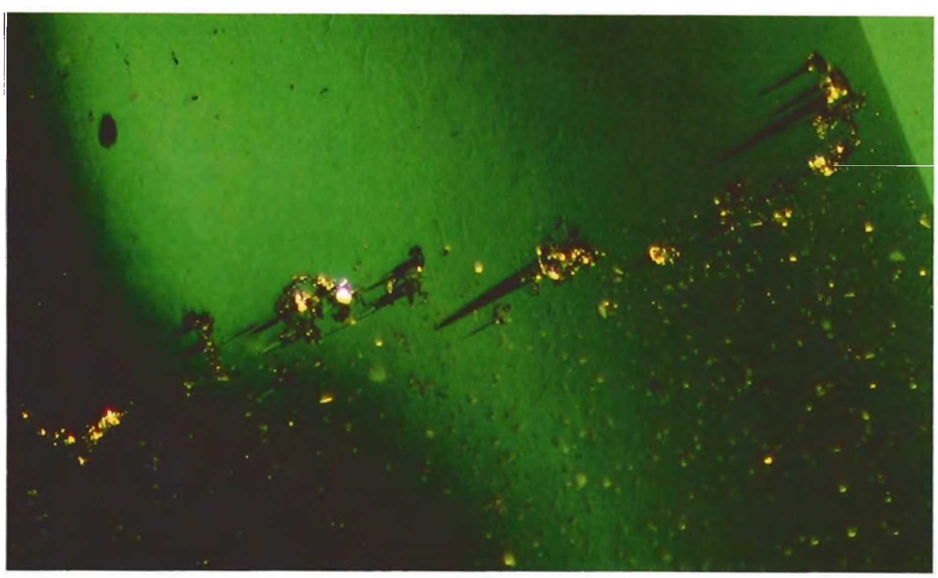
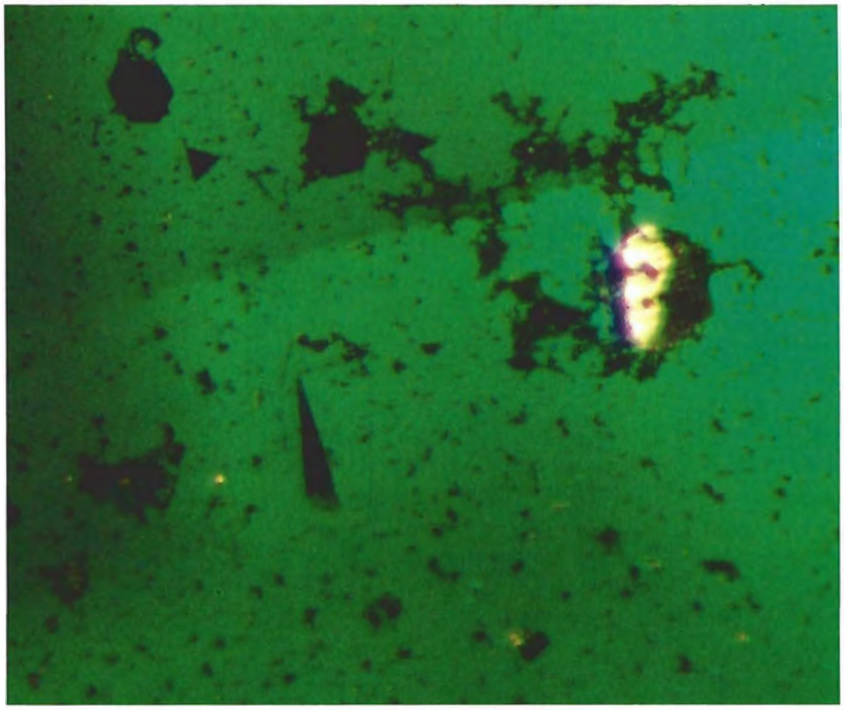


Figure 12. Multiple growth of nail-head spicules at the edge of a large plane of gold inclusions in a Biron synthetic emerald. Dark-field and oblique illumination, magnified 50×.



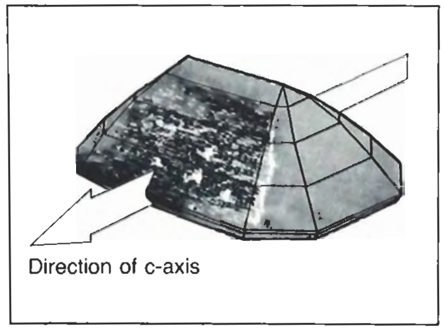


Figure 13. A close-up of several forms of gold inclusions concentrated in a large plane that occupies the entire length of this faceted Biron synthetic emerald, with a specific orientation to the c-axis of the host. Slight changes in dark-field illumination, supplemented by oblique illumination, often reveal the shiny, metallic appearance of the gold. Magnified 50×.

all of the metallic inclusions tested; minor amounts of nickel and copper were also detected. Evidence of platinum was found in a small number of the gold inclusions analyzed.

Metallic inclusions are typically associated with some synthetic gem materials—for example, platinum in Chatham flux-grown synthetic corundum (Kane, 1982), platinum crystals in the early Chatham flux-grown synthetic emeralds (Liddicoat, 1981, pp. 139–140, 170), and platinum inclusions (as observed by the authors) in the newer hydrothermal synthetic emeralds from the Soviet Union. For a material to occur as an inclusion, its constituents must be present in the growth environment. With hydrothermal synthetic growth of emerald, the steel pressure vessel (frequently referred to as a hydrothermal bomb, because it occasionally explodes) is lined with a nonreactive precious metal to prevent contamination from the steel. The Linde hydrothermal synthetic emerald process used gold to line the growth vessel (Flanigen and Mumbach, 1971). The presence of gold as an inclusion in the Biron synthetic emerald suggests that gold or a gold alloy is used as a vessel liner in the Biron process as well.

Although gold as an inclusion in hydrothermally grown synthetic emeralds is not common, it is not unknown. Gübelin (1960/1961) reported gold inclusions in Lechleitner's synthetic emerald overgrowth product.

The gold inclusions in the Biron synthetic emeralds were observed to occur in a rather surprising diversity of distinct forms and appearances (figures 12 through 14): thin, flat plates with hexagonal and triangular outlines, ranging from very symmetrical to distorted forms; flattened, slightly rounded needles in various lengths; large, rather dense planes composed of minute individual grains; and granular and dendritic-appearing aggregates and larger, slightly angular grains resembling natural "native gold." They ranged in color from "grayish silver" to black to distinctly "yellowish gold," depending on the viewing angle and lighting conditions. The true yellowish color of the gold inclusions could generally be seen by adjusting the viewing position while supplementing the dark-field illumination with a fiber-optic light source.

As is illustrated in figure 13, in many of the faceted Biron synthetic emeralds the metallic (and other) inclusions were observed to be concentrated in planes that occupied the entire length of the stone and were close to parallel with one of the long pavilion planes, with a somewhat specific orientation to the c-axis of the host (possibly related to growth parallel to the seed plate).

Phenakite Crystals. Observed in several of the Biron synthetic emeralds were various forms of transparent colorless crystals. These inclusions were identified as phenakite by their characteristic

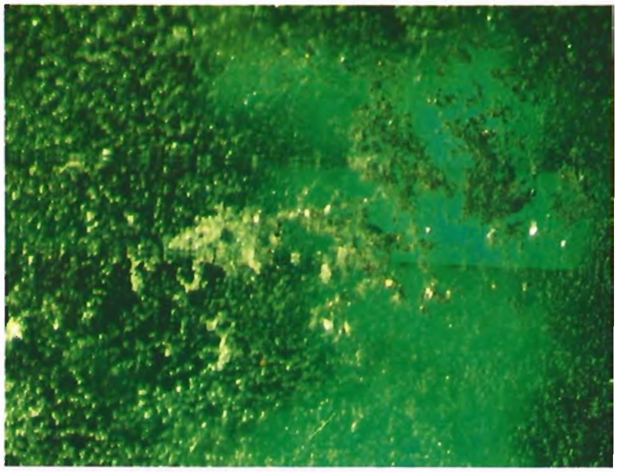


Figure 14. This faceted Biron synthetic emerald contains several large, dense planes of dendritic-appearing aggregates of gold inclusions that border both sides of a seed-plate area. Dark-field and oblique illumination, magnified 50×.

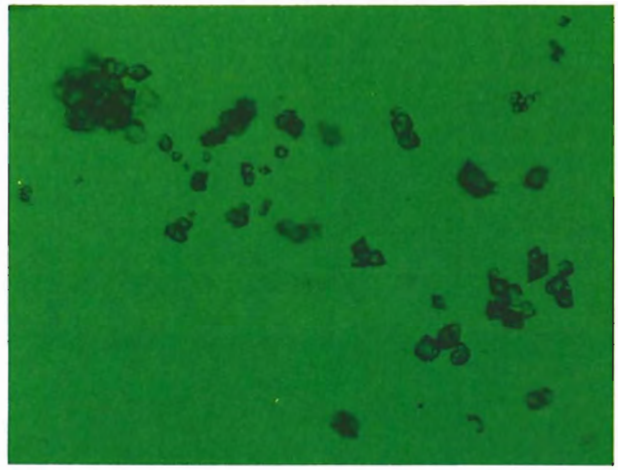


Figure 15. Small single crystals, groups, and aggregates of phenakite are confined to an area that almost parallels one of the long pavilion planes of this Biron synthetic emerald preform. Dark-field illumination, magnified 50×.

crystal habits and the visible difference in relief caused by the higher refractive indices of phenakite (1.654–1.670) compared to those of the synthetic emerald host material.

The formation of phenakite inclusions in synthetic emeralds is somewhat common and is easily explained by the fact that phenakite is a beryllium silicate with a chemical formula of Be_2SiO_4 that is closely related to that of beryl ($Be_3Al_2Si_6O_{18}$). Eppler (1958) stated that phenakite crystals form in synthetic emeralds because of a local deficiency of aluminum oxide (Al_2O_3) in the melt or solution at higher temperatures.

The transparent colorless phenakite crystals in the Biron synthetic emeralds ranged from minute crystallites to well-formed single crystals as large as 0.3 mm long, and were observed in several different forms. Both well-defined single phenakite rhombohedrons with minor prism faces and less-defined phenakite crystals were observed to form the base of some of the nail-head inclusions (again, see figures 10 and 11). Phenakite crystals were also encountered as small isolated crystals, as well as in groups and aggregates that were often arranged in a somewhat definite plane or confined to areas close to and parallel with one of the long pavilion planes of several of the Biron synthetic emerald preforms (figure 15). The small phenakite crystals often exhibit prominent rhombohedral faces with well-developed first-order or second-order prism faces.

Phenakite inclusions in synthetic emerald often display angular and varied crystal forms that might be confusing to the gemologist. If carefully examined with the microscope, however, these crystals should not be mistaken for other crystalline inclusions, such as calcite, that are common in some natural emeralds. In many of the Biron synthetic emeralds examined, the phenakite crystals exhibited very small but distinctive prism faces that distinguish these inclusions from what might otherwise appear to be calcite rhombohedrons, which do not possess such prism faces. Additional distinctions between calcite and phenakite inclusions in emerald are provided by the fact that calcite is highly birefringent (0.172), and will exhibit vivid high-order (brighter) interference colors when examined under cross-polarized illumination, in contrast to the weakly birefringent phenakite inclusions (0.016), which show slightly to obviously less-vivid colors. Calcite inclusions may also exhibit cleavages, which are absent in phenakite inclusions in synthetic emerald. Similar natural inclusions that have been identified as dolomite or dolomitic (E. Gübelin and J. Koivula, pers. comm., 1985; Cassadanne and Sauer, 1984) in emeralds from Santa Terezinha, Brazil, are nearly always closely associated with tiny black chromite grains.

The abundance and orientation of the phenakite inclusions in the Biron synthetic emeralds also provide evidence of synthesis. When numerous phenakite inclusions (as well as gold inclusions) are present, they are often oriented in closely spaced groups such as those illustrated in figure 15 (and again, see figure 13). Natural inclusions, such as calcite or dolomite in natural emeralds, generally do not occur in such concentrations and are frequently closely associated with other types of inclusions.

Once identified as phenakite, these characteristic inclusions provide proof of synthetic origin (either hydrothermal or flux), as phenakite inclusions are not known to occur in natural emeralds. In stones where the inclusions in question cannot be easily identified, other characteristics such as easily recognized typical inclusions and low refractive indices and birefringence should all be considered in making an identification as to whether the emerald is natural or synthetic.

Growth Features and Color Zoning. Observed in all of the Biron synthetic emeralds were various forms of growth features; in some, color zoning was also noted. The growth features vary greatly in appearance and prevalence. They were observed in one or a combination of the following forms: straight, parallel, and uniform; angular, straight, and intersecting; and irregular (see figures 16 and 17).

Because some of the faceted Biron synthetic emeralds contain only growth features, it is useful to be familiar with these inclusions and techniques of bringing them into view. Many of the growth features in the Biron synthetic emeralds are different from those previously known for other synthetic emeralds on the market, although some are remotely reminiscent of (but not as well defined as) those referred to as "Venetian blind" banding (Fryer et al., 1981). The growth features in the Biron synthetic emeralds ranged from being very difficult to observe under magnification

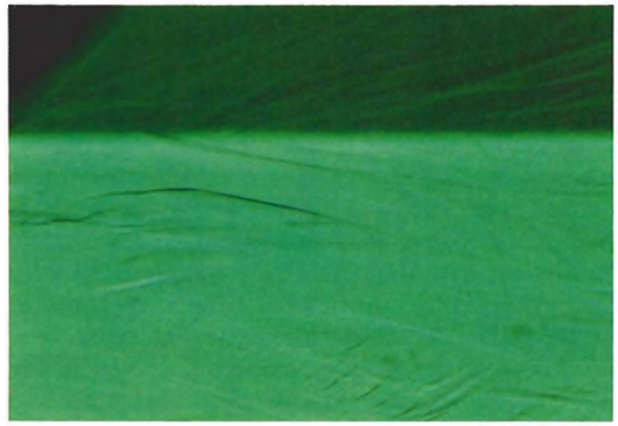


Figure 16. Growth features become evident in this faceted Biron synthetic emerald when the built-in iris diaphragm on the microscope stage is partially closed (over dark-field illumination) to create a shadowing effect. Magnified 50×.

Figure 17. Several forms of growth features surrounding an unusual two-phase inclusion in a Biron synthetic emerald are accentuated by shadowing dark-field illumination. Magnified 40×.

even when several different illumination techniques were used, to being easily seen with the unaided eye.

As is the case with most natural or synthetic materials, the nature of growth features can be very elusive. When a faceted stone is held in a certain manner and is viewed at specific angles, the growth features may be very evident. At other positions and viewing angles, they may totally disappear from view. Likewise, the appearance of an inclusion can be changed dramatically by employing different types of illumination. For routine examination, dark-field illumination usually provides the most effective means of lighting the interior of a gemstone. However, oblique, transmitted, and diffused illumination, as well as shadowing (often used in combination with one another or with dark-field), are most effective for examining color zones and growth features in many synthetic and natural gem materials.

Many of the growth features observed in the Biron synthetic emeralds are quite distinctive and different from those that occur in natural emeralds.

White Particles. Observed in many of the Biron synthetic emeralds were fine straight lines, irregular lines, and ill-defined v-shaped arrangements of stringers composed of minute white particles. Similar features, often referred to as "comet tails," also occur in other synthetic gems such as Kashan and Ramaura synthetic rubies (Kane, 1983) and in some natural gemstones, although very rarely if at all in natural emeralds. The comet-tail inclusions in the Biron synthetic emeralds were generally faint, in contrast to their appearance in synthetic rubies, where they are usually seen very easily in dark-field illumination. In many of the Biron synthetic emeralds, the comet tails were only visible when fiber-optic illumination was used (figure 18). They were observed to occur in several forms: trailing behind inclusions such as a fingerprint pattern; aligned with growth features, sometimes in multiple occurrences extending the entire length of the stone; and randomly oriented in one or two areas.

In many of the cleanest faceted Biron synthetic emeralds, the only inclusions were a few randomly oriented small, white, dust-like particles and faint growth features. The white particles were often sparsely placed in a random orientation throughout the synthetic emerald. Often one stone would contain particles of various sizes, ranging from minute at 45× to being easily seen at 45× (still visible, but quite small, at 10×). Although the white particles observed in many of the Biron synthetic emeralds are rather nondescript in appearance, they provide a good indication of synthetic origin. Natural emeralds that are flawless or very clean would not be expected to exhibit such inclusions.

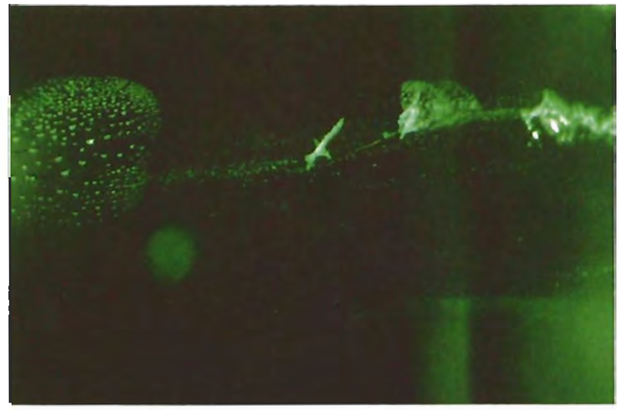


Figure 18. Typical of many Biron synthetic emeralds are these minute white particles arranged in stringers and "comet-tails," which may only become visible when viewed with fiber-optic illumination. Magnified 50×.

Seed Plates. A few of the faceted Biron synthetic emeralds contained what appeared to be seed plates. One stone contained a very lightly colored or near-colorless area that was free of inclusions, ranged in width from 0.8 to 1.1 mm, and extended through the entire stone. This zone was bordered on both sides by thin, dense planes of minute white particles and numerous larger gold crystals interspersed throughout the plane. On both sides of the seed plates, the planes of gold inclusions were very different in appearance; one is shown in figure 14. The other side exhibited larger, slightly angular gold crystals that were distinctly yellow in color. Extending through these planes of inclusions were nearly straight, parallel growth features. A few minute, white, nail-head spicules were observed extending away from one side of the dense inclusion planes, oriented at approximately 30° to the seed plate. This seed-plate area was chemically analyzed and is believed to be a natural beryl seed plate, as discussed below.

Another faceted stone showed a near-colorless zone, probably the seed plate, near the culet. From the many faceted Biron synthetic emeralds examined, it appears that the seed-plate areas are usually removed during cutting. It is likely, however, that the planes of gold inclusions and dense concentrations of minute white particles closely paralleled seed plates in the rough crystal.

CHEMISTRY

Microprobe chemical analyses of two of the faceted Biron synthetic emeralds showed consistency with previous data on other hydrothermal synthetic emeralds, in particular the Linde and Regency material, except with respect to vanadium content (see table 2). Earlier commercial hydrothermal synthetic emeralds contained no vanadium at all, whereas the Biron product contains appreciable amounts (more than double their chromium content). Because of the variable, but sometimes significant, content of vanadium in natural emeralds (Stockton, 1984), this in itself is not a satisfactory identification criterion.

Chlorine is present in the Biron synthetic emeralds, it was also reported by Hänni (1982) and Stockton (1984) in the Linde and Regency hydrothermal synthetic emeralds. The presence of chlorine probably comes from the chloride hydrate ($CrCl_3-6H_2O$) that is used to supply chromium as a coloring agent (Nassau, 1980, p. 151). As this element has not been detected in either natural or flux-grown synthetic emeralds, it serves as an identifying characteristic of the hydrothermal origin of the Biron synthetic.

A third faceted Biron synthetic emerald was analyzed in several different areas. An additional phase of beryl was identified and probably represents a natural beryl seed on which the synthetic emerald was grown. As compared to the analyses made on either side of the seed, which were in close agreement with those reported in table 2, this phase contains no Cr_2O_3, V_2O_3, or Cl, but does have appreciable FeO and minor amounts of Na_2O and MgO.

IDENTIFICATION AND SUMMARY

The "Biron process" produces single synthetic emerald crystals of remarkable size and clarity (see figure 1). This new hydrothermal synthetic emerald will be commercially available as preforms and faceted stones in substantial quantities before the end of 1985. As is the case with many new sophisticated synthetic gem materials, the Biron hydrothermal synthetic emerald possesses its own unique set of characteristics, some of which are not typically associated with synthetic emeralds. In this article, we have presented the key properties of this material (summarized in table 1). In doing so, we have found that some of the traditional gemological tests for the distinction of natural emerald from its synthetic counterpart do not apply. Specifically, the Biron synthetic emerald is inert to long- and short-wave ultraviolet radiation (as are most natural emeralds), and its specific gravity (2.68 to 2.71) overlaps with that of most natural emeralds.

There are, however, other means by which the Biron synthetic emerald can be identified from its natural counterpart:

1. *Characteristic inclusions.* Although by comparison to other synthetic emeralds, both flux-grown and hydrothermal, the Biron hydrothermal synthetic emerald possesses a much greater clarity (most of the stones in the study sample ranged from remarkably clean to slightly included), inclusions provide the most effective means of identification for the gemologist. To date, the following types of inclusions have been observed in the Biron hydrothermal synthetic emerald: fingerprints, veils, and fractures; single occurrences of large two-phase inclusions; nail-head spicule inclusions with gas and liquid phases; several forms of gold; phenakite crystals; numerous types of growth features; white particles in the form of comet tails and stringers or simply scattered throughout the stone; and (rarely observed) seed plates.
2. *The low refractive indices and birefringence.* [$\epsilon = 1.569$ and $\omega = 1.573$ ($+0.001$) and $0.004-0.005$]. These optical values are very unlikely to be observed in a natural emerald. However, an identification should not be made solely on the basis of this property, but in conjunction with the inclusions present.
3. *The characteristic chemistry, in particular the presence of chlorine (Cl).* The gemological laboratory with access to a microprobe or an energy-dispersive X-ray fluorescence spectrometry (EDXRF) system to analyze for Cl, which is present in Biron synthetic emeralds, can rely on this minor element as definitive proof of synthetic origin, inasmuch as Cl has not been reported in natural emeralds (it has not been found to occur in flux-grown synthetic emeralds either).

This study was conducted on over 200 samples of Biron hydrothermal synthetic emerald which were produced over the past few years. The manufacturer reports that he can control the clarity of the material and is currently synthesizing much "clean" material similar to many of the synthetic emeralds described here. Although some of the properties of the Biron synthetic emerald are different from those of other synthetic emeralds, and the Biron synthetics generally contain fewer inclusions, identification of this new synthetic does not have to be difficult. If the modestly equipped professional gemologist becomes thoroughly familiar with the inclusions and other properties of the Biron synthetic emerald, and employs meticulous study of even the most subtle internal characteristics, this new synthetic emerald can be identified.

REFERENCES

Anderson B.W. (1980) *Gem Testing*, 9th ed. Butterworth & Co., Boston, MA.

Bakakin V.V., Belov N.V. (1962) Crystal chemistry of beryl. *Geochemistry*, No. 5, pp. 484–500.

Brown G. (1981) Synthetic emeralds. *Wahroongai News*, October, pp. 15–19.

Brown G. (1983) Data on the Biron synthetic emerald. *Wahroongai News*, Vol. 17, No. 6, p. 23.

Brown G., Snow J. (1984) Inclusions in Biron synthetic emeralds. *Australian Gemmologist*, Vol. 15, No. 5, pp. 167–170.

Cassadanne J.P., Sauer D.A. (1984) The Santa Terezinha de Goiás emerald deposit. *Gems & Gemology*, Vol. 20, No. 1, pp. 4–13.

Chodos A.A., Albee A.L., Garcarz A.J., Laird J. (1973) Optimization of computer-controlled quantitative analysis of minerals. *Proceedings of the 8th International Conference of Electron Probe Microanalysis, New Orleans, Louisiana.*

Darragh P.J., Willing M.J. (1982) A new synthetic emerald. *Australian Gemmologist*, Vol. 14, No. 12, p. 344.

Ebelman J.J. (1848) Sur une nouvelle méthode pour obtenir des combinations cristallisées par la voie seche, etc. *Annales de Chimie et de Physique*, Vol. 22, pp. 213–244.

Eppler W.F. (1958) Synthetic emerald. *Journal of Gemmology*, Vol. 6, No. 8, pp. 360–369.

Eppler W.F. (1959) The origin of healing fissures in gemstones. *Journal of Gemmology*, Vol. 7, No. 2, pp. 40–66.

Eppler W.F. (1966) The origin of negative crystals in gemstones. *Journal of Gemmology*, Vol. 10, No. 2, pp. 49–56.

Flanigen E.M., Breck D.W., Mumbach N.R., Taylor A.M. (1967) Characteristics of synthetic emeralds. *American Mineralogist*, Vol. 52, Nos. 5 and 6, pp. 744–772.

Flanigen E.M., Mumbach N.R. (1971) Hydrothermal process for growing crystals having the structure of beryl in an acid halide medium. *United States Patent 3,567,643*, filed March 25, 1968, issued March 2, 1971.

Fryer C.W. (1969/70) New nonfluorescent high-property synthetic emeralds. *Gems & Gemology*, Vol. 13, No. 4, pp. 106–111.

Fryer C., Crowningshield R., Hurwit K., Kane R. (1981) Gem Trade Lab Notes—emerald. *Gems & Gemology*, Vol. 17, No. 1, pp. 43–44.

Fryer C., Crowningshield R., Hurwit K., Kane R. (1983) Gem Trade Lab Notes—emerald. *Gems & Gemology*, Vol. 19, No. 3, p. 173.

Goldman D.S., Rossman G.R., Parkin K.M. (1978) Channel constitutents in beryl. *Physics and Chemistry of Minerals*, Vol. 3, pp. 225–235.

Gübelin E.J. (1960/61) More light on beryls and rubies with synthetic overgrowth. *Gems & Gemology*, Vol. 10, No. 4, pp. 105–113.

Gübelin E.J. (1974) *Internal World of Gemstones*, 1st ed. ABC Editions, Zurich, Switzerland.

Gübelin E.J. (1982) Gemstones of Pakistan: emerald, ruby and spinel. *Gems & Gemology*, Vol. 18, No. 3, pp. 123–139.

Hänni H.A. (1982) A contribution to the separability of natural and synthetic emeralds. *Journal of Gemmology*, Vol. 18, No. 2, pp. 138–144.

Kane R.E. (1980/81) Unexpected absorption spectrum in natural emeralds. *Gems & Gemology*, Vol. 16, No. 12, pp. 391–392.

Kane R.E. (1982) The gemological properties of Chatham flux-grown synthetic orange sapphire and synthetic blue sapphire. *Gems & Gemology*, Vol. 18, No. 3, pp. 140–153.

Kane R.E. (1983) The Ramaura synthetic ruby. *Gems & Gemology*, Vol. 19, No. 3, pp. 130–148.

Koivula J.I. (1983) Induced fingerprints. *Gems & Gemology*, Vol. 19, No. 4, pp. 220–227.

Liddicoat R.T. Jr. (1981) *Handbook of Gem Identification*, 11th ed. Gemological Institute of America, Santa Monica, CA.

Linares R.C. (1967) Growth of beryl from molten salt solutions. *American Mineralogist*, Vol. 52, Nos. 9 and 10, pp. 1554–1559.

Nassau K. (1978) Did Professor Nacken ever grow hydrothermal emerald? *Journal of Gemmology*, Vol. 16, No. 1, pp. 36–49.

Nassau K. (1980) *Gems Made by Man*. Chilton Book Co., Radnor, PA.

Roedder E. (1962) Ancient fluids in crystals. *Scientific American*, Vol. 207, No. 4, pp. 38–47.

Roedder E. (1982) Fluid inclusions in gemstones: valuable defects. In *International Gemological Symposium Proceedings*, Gemological Institute of America, Santa Monica, CA, pp. 479–502.

Roedder E. (1984) *Fluid Inclusions*. Vol. 12, *Reviews in Mineralogy*. Brookcrafters, Inc., Chelsea, MI.

Schaller W.T., Stevens R.E., Jahns R.H. (1962) An unusual beryl from Arizona. *American Mineralogist*, Vol. 47, Nos. 5 and 6, pp. 672–699.

Sinkankas J. (1981) *Emerald and Other Beryls*. Chilton Book Co., Radnor, PA.

Stockton C. (1984) The chemical distinction of natural from synthetic emeralds. *Gems & Gemology*, Vol. 20, No. 3, pp. 141–145.

Takubo H. (1979) Characteristics of synthetic hydrothermal emeralds from USA and USSR. *Journal of the Gemmological Society of Japan*, Vol. 6, No. 4, pp. 3–18.

Taylor A.M. (1967) Synthetic vanadium emerald. *Australian Gemmologist*, Vol. 10, No. 7, pp. 10–13.

Tombs G.A. (1983) A new synthetic emerald. *Australian Gemmologist*, Vol. 15, No. 1, pp. 24–26.

Wyart J., Šćavičár S. (1957) Synthese hydrothermale du beryl. *Bulletin de la Société Française de Minéralogie et de Cristallographie*, Vol. 80, pp. 395–396.

Gem Trade LAB NOTES

EDITOR
C. W. Fryer
GIA, Santa Monica

CONTRIBUTING EDITORS
Robert Crowningshield
Gem Trade Laboratory, New York
Karin N. Hurwit
Gem Trade Laboratory, Los Angeles
Robert E. Kane
Gem Trade Laboratory, Los Angeles

CORUNDUM

Black Star Sapphire Doublet

Recently submitted to the Los Angeles Gem Trade Laboratory for identification were the stones illustrated in figure 1. Testing proved the cabochons to be natural star sapphires; interestingly, though, both cabochons were found to be assembled. Our client had submitted these to the laboratory for identification because of the ease with which the cabochon shown on the left in figure 1 broke during setting when just a small amount of pressure was applied. Examination with the microscope in reflected light revealed polishing lines in addition to a transparent colorless cement on both portions of the cabochon. The unbroken cabochon seen on the right in figure 1 showed a separation plane of transparent, near-colorless cement joining the two pieces together. This type of assembled stone can be easily identified by the obvious separation plane. Applying a hot point to the separation plane identified the cement layer, which melted easily, as a cellulose-base cement (for example, Duco Cement).

This is the first time we have seen this unusual combination of materials in an assembled stone; perhaps the top portion of the natural sapphire cabochon exhibits a finer asterism than would the base to which it is cemented. It is also possible that because black star sapphire is notorious for separating along natural parting planes, these stones were repaired after they had parted during cutting. *RK*

Figure 1. Assembled black star sapphires, each with a natural star sapphire crown and a natural sapphire base. The total weight of the two broken pieces on the left is 2.65 ct; the doublet on the right weighs 3.12 ct.

Surface-Induced Stars

The New York Gem Trade Laboratory recently was asked to report on two asteriated stones. One, a dark blue cabochon that weighed more than 40 ct, was determined to be natural corundum by virtue of its characteristic inclusions. However, when examined with the hand spectroscope, it did not show the iron line at 450 nm commonly seen in natural blue sapphire; and it did exhibit a chalky greenish white glow when exposed to short-wave ultraviolet radiation, which suggests that it had been heat treated. Under magnification, the appearance of the needles causing the star was peculiar, yet very similar to the phenomenon observed in the other stone, a light red 6-ct cabochon (figure 2). By immersing the stones in methylene iodide, we determined that the inclusions causing the star phenomenon in both stones were confined to the surface, a result of diffusion treatment. However, the "ruby" was found to be a flux-grown synthetic stone, not nat-

Editor's note: The initials at the end of each item identify the contributing editor who provided that item.

Figure 2. Coarse subsurface rutile needles in a 6-ct diffusion-treated synthetic star ruby. Diffused light, magnified 40×.

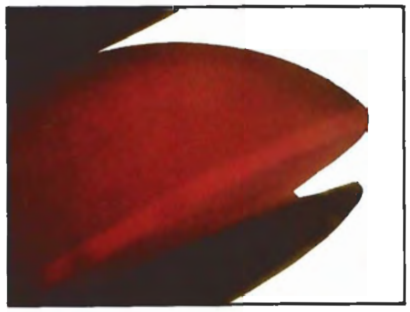


Figure 3. The surface layer containing the star-causing inclusions was removed by repolishing at the girdle of the diffusion-treated synthetic ruby shown in figure 2. Magnified 20×.

ural at all. The needles causing the star in this stone are much coarser than the very small, fine needles usually seen in synthetic star corundum. The stars seen in both stones are different from those usually seen in naturally asteriated stones, which have inclusions throughout the depth of the stone, not just on the surface. Figure 3 shows that the thin diffusion layer on the synthetic ruby was actually removed at the girdle when the stone was repolished after heat treatment. *RC*

DIAMOND for High Rollers

Recently submitted to the Los Angeles lab for identification was the gambling die shown in figure 4. Subsequent testing revealed that this 11.73-ct heavily included translucent faceted cube was a diamond. Our client explained that he had had the die fashioned from a large, industrial-grade diamond cube. The black square indentations were apparently formed with a laser similar to the one used for the laser-inscribing process employed by the GIA Gem Trade Laboratory. *RK*

Figure 4. This 11.73-ct gambling die was fashioned from industrial-quality diamond and the "dots" subsequently inscribed by laser. It measures 9.29 × 9.28 × 9.12 mm.

DIAMOND Simulants, Damage during Jewelry Repair

We feel it necessary to continue to bring to the attention of our readers the extreme importance of being absolutely certain of a stone's identity before applying heat from a jeweler's torch to it in the process of repair work. Recently, we have seen several examples of unfortunate accidents that occurred because the stones were assumed to be diamonds.

The first example is the pendant pictured in figure 5. This pear-shaped stone was left in the mounting during a repair job and, as a result of the heat, developed so many fractures that the stone is no longer transparent. It was subsequently brought to us for identification and determined to be cubic zirconia, which is extremely sensitive to heat.

Figure 5. This 5.9 × 4.1 × 2.5-mm cubic zirconia was damaged by the heat of a torch while the mounting was being repaired.

Figure 6 shows the results of heat that was applied during a repair job to a piece of jewerly set with a strontium titanate that was thought to be diamond. The stone not only shattered but crumbled into dust. Strontium titanate is so sensitive to trauma of any kind that it has been known to fracture in an ultrasonic cleaning bath. Heat from a torch will

Figure 6. Remains of a strontium titanate after a torch was used to repair a piece of jewelry set with this diamond simulant.

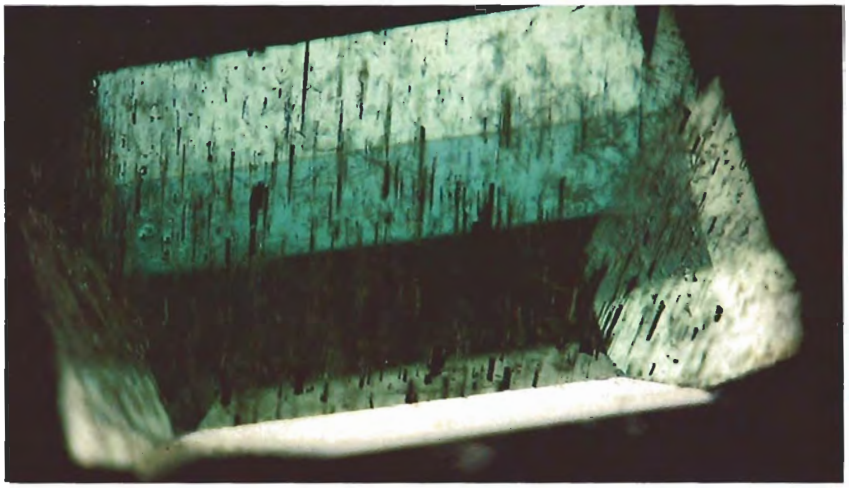


Figure 7. Heavy spicules in a 1.30-ct synthetic emerald. Magnified 15×.

guarantee the destruction of the stone.

Although the actual cost to the jeweler of replacing these diamond simulants may not be high, the loss of credibility and customer goodwill could be substantial. Another factor to consider is the time lost in searching out a stone that matches the one that was damaged.

You can avoid these unnecessary accidents by examining every stone carefully before performing repair work. If you are uncertain of the identity, take the stone to a laboratory for a determination. Better yet, remove it from the mounting. In any case, no stone should be heated with a torch with the possible exception of diamond, and then only after proper precautions have been taken; even diamond can be damaged by extreme heat from a torch. *Shane McClure*

Synthetic EMERALD

The New York Gem Trade Laboratory has recently identified several specimens that may represent either a new type of synthetic emerald or low-end material from an established crystal grower. It is not a material that we are familiar with.

The two heavily included, bluish green emerald-cut stones that we examined were approximately 1.30 ct each. The unusual inclusions noted were many long, triangular, negative parallel "spikes" typical of hydrothermal synthetics (figure 7). These spicules were easily seen with the unaided eye. Where they reached the surface, the openings were large enough to permit what appears to be polishing compound to partially fill them.

The low R.I. (1.555–1.560), low specific gravity (2.67), and dull red fluorescence to long-wave ultraviolet radiation provided further proof of synthetic origin. *RC*

Plagioclase FELDSPAR and Green Muscovite MICA, as Major Constituents in a Carving

Submitted to the Los Angeles laboratory for identification was a translucent to opaque variegated green-and-white carving of a bell, along with a broken piece from a previously connected chain link (figure 8).

When the two pieces were examined with the unaided eye, the most notable feature was the very uneven, poorly polished surface caused by the different hardnesses of the green and white portions of the material. The overall luster was dull and waxy. The broken portion revealed a dull, waxy, uneven granular fracture. Because of the poor polish, a refractive index reading was difficult to obtain; how-

Figure 8. Bell and broken connecting link of a plagioclase feldspar and green muscovite mica carving that measures 20.2–20.5 mm in diameter by 25.7 mm high.

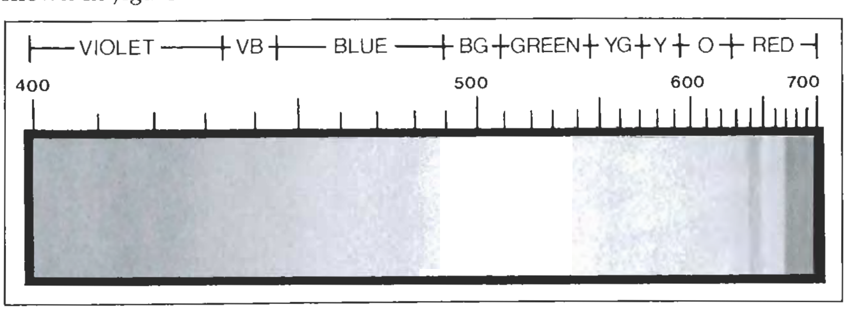
ever, a vague spot reading of 1.57 was observed. The specific gravity was determined by means of the hydrostatic technique. Using a Voland diamond balance equipped with the necessary specific gravity attachments, we obtained a value of approximately 2.85. The visible light absorption spectrum (400–700 nm), observed with a GEM spectroscope unit, is illustrated in figure 9.

The material was inert to long-wave ultraviolet radiation, but exposure to short-wave ultraviolet showed an extremely weak red fluorescence. The hardness of the white material was estimated to be around 6½ to 7 on the Mohs scale, and the green portions were found to be around 3.

It was evident from observation and our tests that the carving was a rock consisting of two or more different minerals. The refractive index, hardness, and red fluorescence to short-wave ultraviolet radiation, even though weak, suggested that the white material was a feldspar. Further testing was necessary, so a minute amount of powder was scraped from both the white and the green areas of the carving for X-ray diffraction analysis. The results of the X-ray powder diffraction tests revealed that the white material was a plagioclase feldspar, with the pattern being closest to that of anorthite. The X-ray diffraction pattern of the green material closely matched a standard ASTM pattern for vanadian muscovite. Although no vanadium was detected when the green portion of the carving was chemically analyzed by SEM-EDS, vanadium could still be present but below the detection limits of this system. Perhaps the green portion is a type of pinite, a massive form of muscovite. Pinite is a general term used to describe an alteration product that can occur from several different minerals, which include muscovite (see the Fall 1983 issue of *Gems & Gemology).*

The carving was identified as follows: "A rock consisting of two or more different minerals. X-ray diffraction reveals the major constituents to be a white PLAGIOCLASE FELDSPAR and a green MUSCOVITE MICA." *RK*

Figure 9. Absorption spectrum of the green mica portion of the carving shown in figure 8.



GARNET

Cat's-eye Demantoid

The Los Angeles laboratory recently had the opportunity to examine the 0.33-ct green cat's-eye illustrated in figure 10. The refractive index of this cabochon was over the 1.81 limit of the Duplex II refractometer. The stone was singly refractive in the polariscope. It was inert to both long-wave and short-wave ultraviolet radiation. When the absorption spectrum was viewed through a hand-held spectroscope, a very strong band was centered near 443 nm and a weaker but broad absorption "cut off" from 400 to 443 nm. Examination with the microscope revealed, in addition to a few small fractures, a straight, parallel arrangement of byssolite (asbestos) fibers throughout the entire stone, which were the cause of the chatoyancy. Byssolite fibers with a radiating arrangement (generally referred to as "horse-tail" inclusions) are typical of demantoid garnet and are well known to gemologists. This small cat's-eye demantoid was apparently cut from a portion of demantoid rough that contained a large "horse-tail" inclusion with relatively straight, parallel fibers. *RK*

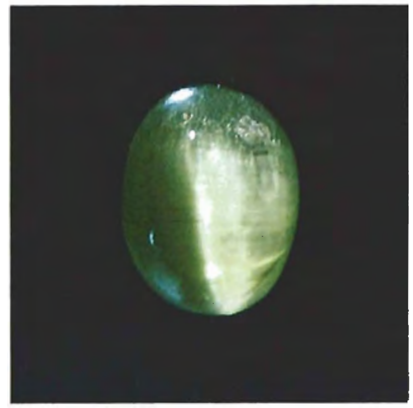


Figure 10. The eye in this 0.33-ct demantoid garnet was apparently caused by a relatively straight "horse-tail" type of inclusion in the original piece of rough.

Grossularite Garnet, an Update

In the Spring 1985 Gem Trade Lab Notes column, we had an item about a massive green grossularite carving. We stated that massive grossularite garnet of this size (7 × 6 × 2 cm) is extremely rare. We just received a letter from Dr. H. Schreuders of Capetown, South Africa, stating that several tons of the material had been exported to Hong Kong. Apparently it is not as rare as we had thought.

Dr. Schreuders further states that translucent chunks of up to 200 kg are still available, although nicer, greener material like the carving we identified usually does not occur in pieces larger than about 25 kg. Tonlots are also still available.

He also gives us information

indicating that the material probably comes from the massive grossularite outcrops that occur along the Merensky Reef, slightly to the west of Brits, which in turn is west-northwest of Pretoria. The Merensky Reef contains a substantial portion of the world's chrome reserves. The hanging wall of most of the chrome mines is virtually solid grossularite garnet. We would like to thank Dr. Schreuders for bringing this information to our attention. *CF*

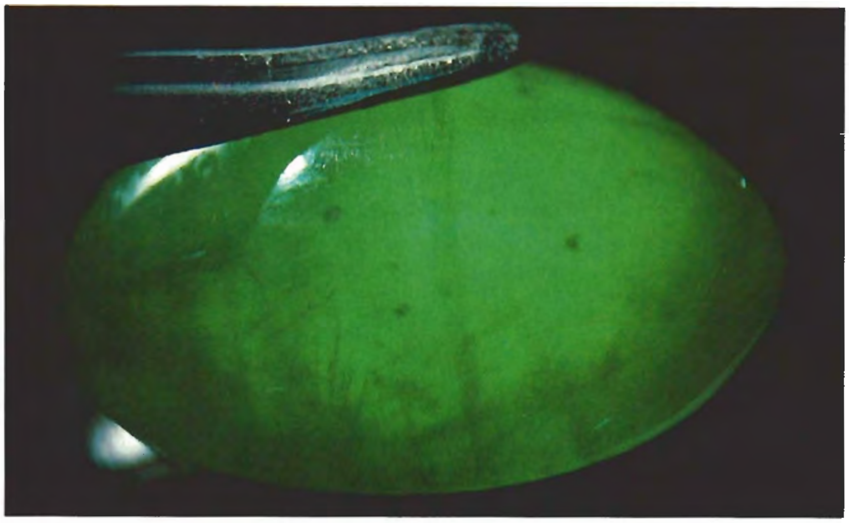


Figure 11. Unidentified acicular inclusions in a natural-color jadeite cabochon. Magnified 20×.

Figure 12. A translucent, colorless, blocky crystal of jadeite included in a lavender jadeite bangle bracelet. Magnified 20×.

JADEITE, with Unusual Inclusions

During routine testing we rarely encounter definite inclusions in jadeite. It was an aesthetically pleasant surprise to the New York lab when we recently had the opportunity to test a fine translucent green jadeite cabochon of natural color that had many long and short tufts of hair-like inclusions present. Figure 11 shows these inclusions, which resemble plants in an underwater scene. The identity of the inclusions has not been determined. *RC*

Another very unusual inclusion in jadeite, only rarely seen before at GIA, was a near-colorless solid "window" extending through a lavender jadeite bangle bracelet (figure 12). The "window" was large enough to test. It gave a spot refractive index reading of 1.66. When the piece was viewed with reflected light, no difference in luster was evident between the "window" and the host jadeite. There were no signs of either undercutting or relief when the inclusion was viewed in oblique reflected light, so we concluded that its hardness was the same as the host. After the above-mentioned testing, the "window" was determined to be a single translucent jadeite crystal trapped in the host material of massive jadeite. *John Koivula*

LAPIS LAZULI, Another Imitation

Figure 13 shows one of two hanks of more than 20 strands of very small

Figure 13. Plastic imitation lapis lazuli beads (approximately 1.0–1.4 mm in diameter).

(1.0–1.4 mm in diameter) blue, cylindrical beads that came into the Los Angeles Gem Trade Laboratory for identification. Examination with magnification showed quite a few small, rounded, metallic-appearing yellow inclusions similar in appearance to the specks of pyrite that often occur in lapis lazuli. However, further testing proved that the beads were made of a different material. Despite the small size of the beads, we were able to obtain a fairly good refractive index spot reading of 1.55. There was no fluorescence to short-wave ultraviolet radiation and no reaction to hydrochloric acid. These properties are all different from those of lapis lazuli. When we tested the material with the hot needle of the Thermal Reaction Tester, we noticed the distinct acrid odor characteristic of plastic, proving that these beads had been fashioned of this material—another lapis lazuli imitation that had not been encountered in our laboratories before. *KH*

Figure 14. Flattened, squarish, freshwater cultured pearls, reportedly from China.

Unusual Cultured PEARLS

The Los Angeles Gem Trade Laboratory also received an unusual necklace, reportedly from China, consisting of pearls that were flat or lenticular in cross section but round, square, or rectangular in outline shape (figure 14). They varied in color from yellowish green to greenish brown. When exposed to X-radiation, these pearls showed a fairly strong fluorescence that suggested freshwater origin. The X-radiograph of the pearls in the flat direction revealed a peculiar structure that was not conclusive (figure 15). Another X-radiograph with the pearls on edge showed the outline of a flat rectangular-shaped nucleus (figure 16). When we examined these cultured pearls with low-power magnification (10×), we were able to locate one bead on which part of the nucleus was exposed because of missing layers of nacre. Figure 17 shows a part of a gray banded piece of material that we were able to identify as shell. We concluded that flat pieces of shell, instead of the usual round beads, had been used as nuclei in the culturing process and thus determined the unusual shapes of these cultured pearls. *KH*

Figure 15. This X-ray, taken through the thin (flat) direction of the cultured pearls shown in figure 14, was not conclusive enough for proof of origin.

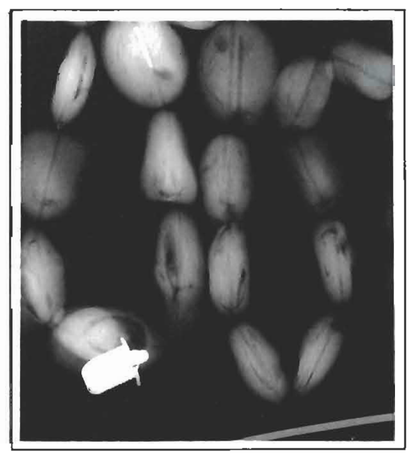


Figure 16. This X-ray taken with the cultured pearls shown in figure 14 on edge shows the flat nucleus.

SAPPHIRINE, a Rarely Encountered Cut Stone

A long-time friend of GIA thought that we in the Applied Gemology Division of the Research Department would be interested in examining what was thought to be a new color variety of a transparent gem material previously known in other colors, but never reported as occurring in this beautiful purplish pink hue (see figure 18). The 1.54-ct stone was reported to be transparent idocrase.

The refractive index was found to be 1.701–1.707. Although this seemed a little low, it was still within the reported R.I. range of idocrase. However, the reading indicated that the stone was biaxial negative with beta at 1.705 and a birefringence of 0.006. The stone also showed a biaxial optic figure, whereas idocrase is uniaxial. Specific gravity was found by the hydrostatic method to be approximately 3.51. There was no reaction to ultraviolet radiation and no characteristic absorption spectrum. The distinctive inclusions were an unknown white crystal and what appeared to be a small "book" of mica. Higher magnification revealed the phlogopite mica "book" seen in figure 19. The properties seemed to point toward sapphirine, a material that is very rarely encountered as a cut stone. An X-ray diffraction pattern obtained from a minute scraping of powder from the girdle confirmed that it was indeed sapphirine. We have not previously encountered sapphirine in this color. As a matter of fact, this is only the second or third cut sapphirine that the GTL has ever encountered. Sapphirine was so named because of its resemblance in color to blue sapphire, even though the two minerals have completely different chemical, optical, and physical properties. The purplish pink color of this specimen has not been encountered before in our laboratories. *CF*

Figure 17. A shell nucleus was found protruding from one of the oddly shaped freshwater cultured pearls. Magnified 10×.

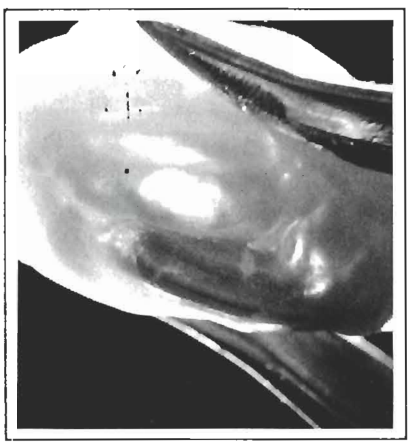


Figure 18. An unusual 1.54-ct purplish pink cut sapphirine.

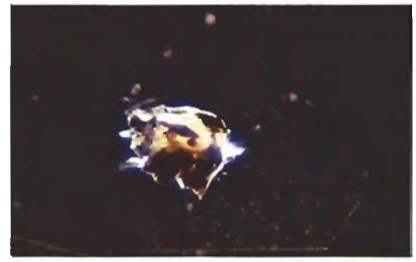


Figure 19. A phlogopite mica inclusion in the sapphirine shown in figure 18. Magnified 63×.

FIGURE CREDITS

Figures 2, 3, 7, and 11 were supplied by David Hargett. Shane McClure took the photos in figures 1, 4-6, 8, 10, and 13. John Koivula produced the photos in figures 12, 18, and 19. Karin Hurwit is responsible for figures 14–17. Robert Kane prepared figure 9.

GEMOLOGICAL ABSTRACTS

Dona M. Dirlam, Editor

COLORED STONES AND ORGANIC MATERIALS

The black pearl is back. H. Dennert, *Asian Jewelry,* January/February 1985, pp. 10–11.

Here, in an extremely brief overview, is a "who's who" and "what's what" of the black pearl industry. There is a smattering of information on sources, processing, and supply and demand. In addition, some of the important people involved in pearling in French Polynesia are named. The author aptly points out that black refers to the shell of the animal. The pearls range in color from dark gray to light yellow-green. However, the information on grading seems to be a thoughtful study in ambiguity: While four grades are mentioned, possible price ranges are given for only three of these.

Dennert breezes through the whole spectrum in a scant two pages, including illustrations, leaving the reader to wonder when a complete report will be forthcoming. For all of its brevity, though, this article is better than the dearth of information that has been available in the past. *Archie Curtis*

This section is designed to provide as complete a record as possible of the recent literature on gems and gemology. Articles are selected for abstracting solely at the discretion of the section editor and her reviewers, and space limitations may require that we include only those articles that will be of greatest interest to our readership.

Inquiries for reprints of articles abstracted must be addressed to the author or publisher of the original material.

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names.

Blue andalusite from Ottré, Venn-Stavelot Massif, Belgium: a new example of intervalence charge-transfer in the aluminum-silicate polymorphs. K. Langer, E. Halenius, and A. Fransolet, *Bulletin de Minéralogie,* Vol. 107, 1984, pp. 587–596.

Andalusite is an uncommon gemstone that is found either in metamorphic rocks or as a detrital mineral in sediments in Brazil, Sri Lanka, Burma, and other localities. It occurs in a range of colors (usually pinkish or greenish) and is often strongly pleochroic. Some attractive blue andalusite was recently found in the Ottré region of western Belgium. Here it occurs as tabular crystals up to 1 cm in length in metamorphosed sedimentary rocks in association with quartz, kaolinite, and pyrophyllite. The crystals have refractive indices of about $\alpha = 1.637$, $\beta = 1.642$, and $\gamma = 1.647$, and are distinctly pleochroic from blue in the ordinary direction to colorless along the other two axes. The blue color is caused by the tail of a strong absorption band centered at 770 nm. This absorption band is attributed to an $Fe^{2+}-Fe^{3+}$ charge-transfer mechanism. No indication is given in the article as to the abundance of these crystals or whether they could be faceted. *JES*

Eudialyt aus Kanada (Eudialyte from Canada). U. Henn, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 76–78.

Because of its higher zirconium content (about 30%), eudialyte occurs only in Zr-rich deposits. The refractive indices are $n_e = 1.600-1.601$, $n_o = 1.596-1.597$, with a birefringence of 0.004. Pinkish red eudialyte from Kippaw in Quebec, Canada, occurs in transparent, gem-quality material. Similar stones are also found in Sweden. Microprobe chemical analyses of both the Canadian and the Swedish material, as well as the optical absorption spectrum of the Canadian eudialyte, are provided. *MG*

Farblose Cordierite und Cordierit-Katzenaugen aus Sri Lanka (Colorless cordierite and cat's-eye cordierites from Sri Lanka). H. Bank, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 79–80.

The mineral cordierite (often called iolite by gemologists) commonly occurs in a blue color. However, it has now been found as a colorless stone in Sri Lanka. The iron content is very low, which further lowers the physical properties of the stone. The recorded refractive indices for the colorless cordierite are $n_x = 1.527$, $n_y = 1.532$, and $n_z = 1.536$, the lowest indices ever observed for gem cordierite. The specific gravity is 2.55 g/cm^3.

A rough grayish white stone that was also thought to be cordierite revealed a cat's-eye effect that is due to unidentified fibrous inclusions. *MG*

Glimpses of a Tertiary forest in amber. G. O. Poinar, *Pacific Horticulture*, Vol. 46, No. 3, 1985, pp. 39–41.

"The age of Dominican amber ranges from twenty to thirty million years, and no one knows what kinds of forests grew in that part of the world in the early Miocene." Professor Poinar, an entomologist at the University of California, Berkeley, shows how plant parts included in amber are helping to disclose that information. All sorts of biological matter, from bacteria to parts of angiospermous plants, can be found preserved in amber. A page of clear and delightful photographs by the author shows a petal, a leaflet, part of a flower, a twig, moss, and a seed. *FS*

An investigation of nephrite jade by electron microscopy. M. Dorling and J. Zussman, *Mineralogical Magazine*, Vol. 49, No. 1, 1985, pp. 31–36.

Nephrite jade is a form of the amphibole minerals actinolite and tremolite. Several specimens of nephrite jade from Wyoming were examined by transmission electron microscopy (TEM) in order to better understand the extreme toughness of this material. These examinations showed that the jade specimens consist of clusters of very small lath-like crystals. Within each cluster the c-axes of the cystals are approximately parallel, but the clusters themselves are randomly oriented. It is suggested that the clusters are the result of recrystallization of strained amphibole crystals, and that they inherit the crystallographic orientation of the original crystals. The extreme toughness of nephrite jade is attributed to a number of submicroscopic features, including the sizes, shapes, and orientations of the very small crystals within the clusters and the nature of the intervening grain boundaries. Two additional factors noted are the monomineralic nature of nephrite jade and the lack of secondary alteration minerals along grain boundaries. *JES*

Untersuchungen an Kornerupin und Sinhalit von Elahera, Sri Lanka (Investigations on kornerupine and sinhalite from Elahera, Sri Lanka). U. Henn, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 13–19.

During a recent visit to a new gem locality in the central-province of Sri Lanka, the author obtained samples of kornerupine and sinhalite for which he describes the chemistry, spectra, and inclusions. The chemical properties of both gemstones are almost identical to those reported by other investigators for stones from Sri Lanka. The inclusions found are typical two-phase feathers and zircons with haloes. Microprobe chemical analyses and optical absorption spectra for both materials are reported. Six photomicrographs are also included. *MG*

DIAMONDS

Aggregation and dissolution of small and extended defect structures in type Ia diamond. L. A. Bursill and R. W. Glaisher, *American Mineralogist*, Vol. 70, No. 5/6, 1985, pp. 608–618.

While much of this state-of-the-art discussion of nitrogen in type Ia diamonds will seem overly technical to most gemologists, it is nonetheless worth the extra effort that may be involved in disentangling the meat of the article from the scientific discourse. The article focuses on the distribution of nitrogen in type Ia gem-quality diamonds, which encompass approximately 95% of all gem diamonds.

The authors begin with an excellent discussion of the various ways in which nitrogen can be bonded into the atomic structure of diamonds. The accompanying diagrams and tabulated definitions take much of the confusion out of terms such as "N3 center" and "split-nitrogen interstitial" that are slowly finding their way into the gemological literature in association with discussions of the causes of color in diamonds. The report proceeds with a description of how nitrogen atoms migrate through the diamond structure to form one or another type of color center. These processes were reproduced in the laboratory at high temperatures and pressures, but they have by no means been reduced to standard recipes. While the extreme conditions under which these experiments were performed preclude any practical commercial applications, this is an example of the type of important research that is being done internationally on natural and artificially induced color mechanisms in diamonds, and that will no doubt benefit the gemological community in the determination of color origin in diamonds.

The article is accompanied by numerous diagrams, including excellent depictions of the diamond structure in various configurations of nitrogen, and fascinating high-resolution electron microscope photomicrographs of actual defects in diamonds that show structural features as small as several Angstroms in diameter.

CMS

Diamond mining: a South African adventure. J. Thompson, *Modern Jeweler,* Vol. 84, No. 5, 1985, pp. 24–33.

This panoramic view of South African diamond mining caters to jewelers who believe that broad product knowledge will enhance their careers. Employing just enough statistics and details to illustrate his points, Joe Thompson unravels the geography, geology, mining methods, and recovery techniques of the South African diamond kingdom. Such information equips jewelers to answer customers' questions and stimulate their interest.

The article covers the De Beers–owned/controlled mines in South Africa, Botswana, and Namibia, all of which together produced 23.3 million carats in 1984—more than half the world's total production. Thompson's facts may be a welcome review for many readers, but most will discover something new, such as "Fanakalo," a language derived from English, Afrikaans, and five native dialects that is spoken in the mines to overcome language barriers. Phrases such as "diamond fever" and "wonderland" typify the writer's ambition to imbue his topic with an adventurous, human character.

Richard F. Buonomo

Meet the king of minerals. K. Doyle, *Civilized Man,* Vol. 2, No. 8, 1985, pp. 54–67.

Doyle presents a rare and sympathetic view of the man who has guided Anglo American Corporation and De Beers over the past three decades: Harry Oppenheimer. The profile includes fascinating glimpses of Oppenheimer's family, his business career, his South African estates, his political philosophy, and even his manner of entertaining. Mr. Oppenheimer is portrayed as a lion of capitalism, convinced that the socialist governments of many countries neighboring South Africa have limited the choices of their inhabitants and made them poorer. A lifelong foe of apartheid, Oppenheimer opposes the disinvestment approach taken by some countries and companies to try to force change. He fears that the change some have in mind is to a socialist/Marxist government and that this can best be deterred by the strong presence of capitalist engagement. Readers of *Gems & Gemology* will enjoy this personal and pleasant article.

James R. Lucey

Siberian diamonds. R. V. Huddlestone, *Journal of Gemmology,* Vol. 19, No. 4, 1984, pp. 348–369.

Based on a 1983 lecture presented by the former director of London's Diamond Laboratory to the Gemmological Association of Great Britain, this article provides a fascinating glimpse of the Russian diamond industry.

Diamonds were first found in Siberia in 1829, but not until Larisa Popugayeva's 1954 discovery of the Zarnista (Thunderflash) and subsequent Mir (Peace) pipes was Russia's potential as a world-class producer realized. In 1958, Mir began production, and the nearby town of Mirny (built in 1957 expressly to support the mine) was occupied by the workers and their families.

Mir, along with a number of other primary and alluvial deposits (a map accompanying the article shows 12 Siberian deposits), has produced over 10,000,000 carats annually since 1977. Since 1978 (when Zaire production declined), the USSR has been the world's largest producer of diamonds. Huddlestone expects the Siberian mines to be productive for many decades. He estimates the quality to be 20% gem and 80% industrial. The average weight of the rough is reported at 0.50–0.55 ct, and a number of octahedral "glassies" are illustrated. The article does not specify to what extent the pipes are still open-cast mined or underground-shaft mined.

The separation plant at Mirny is perhaps the world's largest: the 14 windowless stories of roaring, almost totally automated, machinery that operates around the clock "sometimes produces enough diamonds in one day to pay for the annual operating cost of the plant." Ore from the Aikal (Glory) mine, in the Arctic Circle, is trucked across 250 miles of tundra also to be processed in Mirny.

Six thousand to 10,000 Russians are employed in the Soviet cutting industry. Russian cutting is reputed to be of very high quality.

Two controversies related to Russian diamonds are addressed. Huddlestone controverts Edward Epstein's 1982 claim that the Russians are synthesizing significant quantities of gem diamond. He contends that the same greenish, sharp-edged octohedra that Epstein finds suspiciously uniform are feasibly typical for a given natural deposit. Furthermore, the current cost of synthesizing gem diamond is at least 10 times that of mining the natural stones, and the sharp-edged octahedron would *not* be the most weight-effective shape to produce.

Huddlestone also argues, but with more conjecture, against the "rumor" that Russians occasionally "flood" the market with their polished goods. Since 1972, when Moscow modified, then terminated, their CSO (De Beers) contract, Moscow's marketing has been problematic; indeed, some Russian diamonds still find their way into London CSO sights. Huddlestone accepts a Russian official's statement that overselling could depress diamond prices and therefore would not be in Russia's best interest. This premise is perhaps too simple for a country that produces 25% of the world's total diamond output and yet also suffers well-publicized, cyclical, cash shortages. (For a more involved treatment of this topic, see: "An Interview with GIA's Glenn Nord," *Goldsmith*, February, 1985.) *Richard F. Buonomo*

INSTRUMENTS AND TECHNIQUES

Application de la radiographie en bijouterie-jaoillerie (Application of X-radiography in jewelry). J.-P. Poirot, *Revue de Gemmologie a.f.g.*, No. 82, 1985, pp. 15–17.

The author discusses the use of X-radiography in identifying natural and cultured pearls. First, the structural differences of natural and cultured pearls are explained. A natural pearl can be formed by any pearl-producing mollusk such as the pearl oyster (Meleagrina or Margaritifera) in saltwater or by various pearl-producing mussels in freshwater. An intruding parasite (usually a cestode) causes the mollusk to secrete concentric nacreous layers (a mixture of aragonite, a calcium carbonate, and conchiolin, an organic keratin) around the irritant. Occasionally, the nacreous layers will be richer in organic material, thus forming darker center layers that can slightly influence the appearance of the pearl. The term *blue pearl* is applied in this instance.

A cultured pearl is formed by the artificial insertion of a nucleus, which causes the mollusk to secrete nacreous layers around the irritant. In saltwater oysters, a round mother-of-pearl bead together with a piece of graft tissue will produce a round pearl. Freshwater mussels such as Dipsas plicatus (Lake Biwa) will produce irregular-shaped pearls around the organic material.

X-radiography reveals the structural differences between the different types of pearls so that natural versus cultured origin can be established. Specifically, organic material such as conchiolin is very transparent to X-rays, whereas nacreous layers that contain less organic material are more opaque. Therefore, on an X-radiograph, the conchiolin layers will show up as dark lines; a bead-nucleated pearl, however, will show one distinct demarcation line around the round nucleus, and a tissue-nucleated pearl will show an irregular void in the center of the pearl.

According to the author, the Laboratory of the Chamber of Commerce and Industry in Paris employs a Sécurix X-ray unit, which is operated for three minutes between 50 and 90 kV, depending on the size of the pearl. The X-ray film is Kodak type M. Seven X-radiographs of different types of pearls illustrate this informative article. *KNH*

Ein verbesserter Probenhalter und seine Anwendung auf Probleme der Unterscheidung natürlicher und synthetischer Rubine, sowie natürlicher und synthetischer Amethyste (An improved sample holder and its application to the distinction of natural and synthetic ruby and amethyst). K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft* Vol. 34, No. 1/2, 1985, pp. 30–47.

In normal gemological practice, the horizontal gem microscope with immersion fluid employs a stone holder. This can easily be rotated 360° vertically while the stone is immersed, and a great deal of information can thus be obtained. The improved version of the stone holder described in this paper can be rotated horizontally as well as vertically. The vertical axis is fixed with a dial that has 360° subdivisions. With the help of this new sample holder, the optic axis of a cut gemstone can be placed parallel to the microscope axis so that the angles between crystal faces can be determined. For example, natural ruby can be distinguished from most commonly available synthetic rubies by using the new stone holder to help determine characteristic angles between the growth planes of the material. The modified stone holder can also be used to determine the twinning nature in amethyst, which can lead to the separation of natural from synthetic stones. These techniques are apt to be difficult, however, for the gemologist not thoroughly familiar with crystallography.

The article is well illustrated with diagrams and 31 photographs. *MG*

Möglichkeiten und Grenzen der röntgenographischen Untersuchung von Perlen (Possibilities and limitations of X-radiographic investigations of pearls). I. Lorenz and K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 57–68.

Various X-ray methods have been used to distinguish between natural and cultured pearls for many years. Such methods can now be applied to most of the natural and cultured pearls that are currently available in the trade. To demonstrate the usefulness of these methods, the authors conducted a systematic investigation of pearls, using direct radiography as well as X-ray diffraction techniques and luminescence in response to X-ray excitation. A simple diffraction camera was developed that produces diffraction patterns of pearls at precise angles. The sample holder was constructed on the principle of a double-circle goniometer, such that rotations are possible in the horizontal as well as the vertical planes. With the use of an additional sample holder, diffraction patterns of one single pearl from a necklace can be produced. Unfortunately, during the investigation of freshwater pearls (natural and cultured) with X-ray diffraction techniques, it was found that radiation defects generate a dark spot on the pearl's surface.

Satisfactory results were obtained in the determination of natural freshwater pearls, natural saltwater pearls, cultured freshwater pearls (with or without seed), cultured saltwater pearls with seed, and Keshi pearls. Some difficulties were encountered in the distinction of a small number of Keshi cultured pearls from natural saltwater pearls and in the separation of a small number of non-bead-nucleated cultured freshwater pearls from natural freshwater pearls because of the overlap of their characteristic radiographic features. *MG*

New techniques in shaft sinking. J. Collings, *Optima*, Vol. 32, No. 3, 1984, pp. 116–125.

For the last half-century, there have been few important changes in the basic approach to sinking deep mining shafts. The conventional method employs a large crew operating hand-held rock drills at the bottom of the shaft. The holes are then packed with explosives. After the explosion, the rock is removed and the shaft is lined with concrete.

In the diamond and gold mines in South Africa, new methods are beginning to appear. One method uses pneumatically driven drills that are held in a rig called a "jumbo." Since more downward pressure can be placed on the drill, faster penetration is possible. At the Premier diamond mine, a method called sequential raise-boring is used. Here, a pilot hole is drilled to a tunnel below. Then a drill head is attached to the piping from below and brought upwards while rotating, which reams the hole to a larger dimension.

Experiments are currently being conducted on boring shafts without a pilot hole. Economics is the governing factor in developing new techniques in shaft sinking, so, to be successful, any new method must be at least no more expensive than conventional methods. This article is well illustrated with three color photographs and four drawings. *GSH*

Spectrophotometric measurements of faceted rubies. A. Banerjee, J. Himmer, and H.-W. Schrader, *Journal of Gemmology*, Vol. 19, No. 6, 1985, pp. 489–493.

In 1982, G. Bosshart described the separation of natural from synthetic rubies by means of a dual-beam spectrophotometer. However, effects brought about by refraction and reflection of the light beam by the facets on gems have reduced the usefulness of Bosshart's test. The immersion of faceted natural and synthetic rubies in methylene iodide is now proposed as a way to reduce light scattering and resulting noise on the spectrum. As the authors point out, methylene iodide absorbs virtually all light below about 440 nm, but very clean spectral diagrams are obtained and illustrated for the rest of the visible light range. Thus, the immersion method is shown to have distinct advantages.

Unfortunately, the distinction of natural from synthetic rubies as described by Bosshart depends on the accurate measurement of an absorption minimum found only in the ultraviolet range; the strong absorption of this region by methylene iodide effectively negates its value as an immersion liquid in the spectrophotometric distinction of natural from synthetic rubies. *CMS*

JEWELRY ARTS

The ancient ts'ung jade tube. L. Berglund, *Arts of Asia*, Vol. 4, No. 5, 1984, pp. 56–62.

Lars Berglund writes a refreshing article on ts'ung jade tubes, Chinese art objects of unknown function and symbolism, some of which may be over 4,000 years old. Since much mystery surrounds the purpose of the ts'ung jade tube, Berglund begins by first quoting Laufer's opinion that it is a symbol of Earth as a deity. He also presents Karlgren's theory that it is instead a stand for ancestral tablets of phallic origin. Berglund, however, feels that Laufer's theory has more validity—in fact, it paves the way for his own notion of what the ts'ung tube represents.

Laufer notes that much of Chinese philosophy is expressed by a fixed numerical system, and that Chinese art frequently reflects this mental construction. On the basis of these observations, Berglund proposes a new interpretation for the ts'ung tube: it is a fixed numerical system whose meaning is found in a magic square of three generally called the Lo Shu, that is, the diagram of the Lo River. This mathematical diagram is supposed to have been presented by a turtle of the Lo River to Yu, the heroic founder of the Hsia dynasty, as a model of government virtue and order. (The Hsia dynasty is still regarded as mythical, although indications that it did exist are being researched now.) The balance of Berglund's article is spent explaining the numerical form of the Lo Shu as well as other applications that the Lo Shu had in Chinese symbolism. Illustrated with many photographs of ts'ung tubes, and diagrams of the Lo Shu, this article presents an interesting theory that will undoubtedly stimulate much discussion among jade scholars. *JMW*

Francis Sperisen: master lapidary. J. Frosh, *American Craft*, Vol. 45, No. 1, 1985, pp. 40–43.

This article is a short biography of Francis Sperisen, the innovative San Francisco lapidary whose methods opened a new world of creativity to jewelers and designers. It reveals the special talents and interests that led to Mr. Sperisen's unique style of gemstone cutting. Because the lapidary arts in the early 1900s were usually trade secrets handed from father to son, Sperisen (whose father was *not* a gem cutter) taught himself the skill by observation and experimentation. In 1935, he founded the Mineral Society of San Francisco, whereby he contributed to the dispersal of the lapidary arts through teaching. Collaboration with innovative designer-jeweler Margaret De Patta inspired further originality in Sperisen's work and brought his creations to the attention of other jewelers, thus creating a demand and a market for nontraditional cuts. *GSH*

Gold. P. Linden, *Town & Country*, Vol. 139, No. 5061, 1985, pp. 130–131, 170, and 174.

This article highlights gold in history, fashion, and the stock market, with special focus on jewelry fashion. Passé fashions include tri-colored gold, charm bracelets, memorials, zodiac signs, and black and blue gold. Textures such as florentine, filagree, and hammer are also fashions of the past. The latest fashion trends in gold jewelry include the use of 18K gold and the combination of gold with a white metal such as white gold, platinum, silver, stainless steel, or titanium. Bright, highly polished surfaces or a smooth, matte finish put the finishing touches on the new look in gold jewelry. Dainty jewelry has given way to massive, overstated pieces. According to the author, this is a response to voluminous, exaggerated shapes in clothing. Jean-Claude Affolter, of Gübelin, foresees yellow gold set with pearls and colored stones as the newest fashion trend, or the very latest—brown diamonds.

The use of alloys to increase wearability or vary the color of gold, the origin of the word *karat*, and definitions of *solid gold*, *gold-filled*, *gold-plated*, and *Vermeil* are all clearly and simply explained.

According to the International Gold Corporation, untapped resources will carry us comfortably into the 21st century. The largest supplier of gold is South Africa (responsible for nearly half the world's supply). Russia provides an estimated 23%, Canada 5%, and the USA and Brazil 3.5% each.

Governments and "international monetary institutions" are the largest users of gold. Next is the jewelry industry, at approximately 750 tons a year, followed by dentistry and other industries. Gold coins, bullion, futures, options, and certificates are also mentioned, but details are not supplied by the author. In conclusion, the article implies that gold can be not only a financial investment, but also an investment in beauty and fashion. *Marcia Hucker*

Jewelry's new glitterati. R. Lubar, *United*, Vol. 30, No. 1, 1985, pp. 33–36.

Today's top women jewelry designers are producing pieces that are "assertive and sensuous—like the eighties woman." This article sketches the work (and backgrounds) of designers Paloma Picasso, Elsa Peretti, Angela Cummings, and Marsha Breslow. Their dynamic jewelry is equally brilliant whether it is worn at the office or a gala—or both. Priced from $40 to $110,000, these pieces can add color and a touch of drama to any woman's wardrobe.

Each of these designers has created a distinctive style; yet when all of these styles are viewed together, they reflect the depth and complexity of the modern woman. Picasso's cold, bold jade earrings collide with Peretti's slippery, free-form hearts, while Cummings's clean geometrics complement Breslow's sinuous chains and pearls.

Clearly, these individuals have been successful in expressing themselves through their work, and in doing so they have given more women the opportunity to express *themselves* through affordable high-fashion jewelry. *SAT*

Profile: Nancy Ancowitz. *Saturday Review*, July/August 1985, pp. 7–8.

The meteoric career of 25-year-old jewelry designer Nancy Ancowitz is highlighted in this brief article, which tells how the young woman, who had studied language and communications in college, started her own jewelry catalog-sales company at the age of 20. Five years and a Masters in Business Administration later, Ancowitz has parlayed her creative flair and her business acumen into a thriving profession. Her trademark is a rather fanciful combination of various decorative elements—such as the placement of gemstones within ball bearings to create bracelets and necklaces. Through an aggressive self-marketing program, Ancowitz succeeded in catching the eyes of jewelry retailers as well as of fashion magazine editors. Her gold-plated ball-bearing creations can now be seen in the pages of magazines such as *Glamour* and *New York*, often modeled by her dog, Moffat. The essay features three photographs that spotlight the jewelry, the artist, and her dog.

This article is part of the "Briefings" section of *Saturday Review*, a section that often features small articles on the jewelry arts. For example, elsewhere in the section (p. 20) is a note on the recent auctioning by Christie's of the Cartier "Mystery Clock," the first of a series of 12 animal clocks fashioned by Cartier in the 1920s and 1930s. The agate, mother-of-pearl, and rock-crystal timepiece (with a diamond-studded dial) had been "lost" for some 40 years, and fetched $264,000 at the recent auction. *JMB*

SYNTHETICS AND SIMULANTS

Farbloser Chrysoberyll—natürlich oder synthetisch? (Colorless chrysoberyl—natural or synthetic?). K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 6–12.

Natural chrysoberyls are colored by the presence of trace elements such as iron, chromium, or, in rare instances, vanadium. Those that contain iron are primarily yellow, yellowish brown, or brown. Iron and chromium are responsible for the most prized change-of-color variety, alexandrite. However, colorless chrysoberyl is seldom encountered in the trade and those stones found are said to be from Burma or Sri Lanka. The former, however, tend to have a light greenish tone and therefore cannot be classified as truly colorless chrysoberyl.

The two colorless samples investigated in this study were purchased in Sri Lanka. The physical and chemical properties of these two chrysoberyls were investigated in order to determine whether they were of natural or synthetic origin. The data for the two chrysoberyls were compared with those of natural near-colorless, yellow, brown, and change-of-color chrysoberyls from different localities such as Sri Lanka, Brazil, the USSR, Zimbabwe, and Tanzania. Further comparisons were done with synthetic alexandrite from three different manufacturers.

The refractive indices, color, chromium and iron contents, and inclusions were sufficiently similar for the two chrysoberyls and other comparison stones that no conclusion could be drawn as to origin. However, X-ray fluorescence analysis revealed the presence of gallium in all the natural specimens that were examined in this study; no gallium was found in the two colorless samples. This suggests a synthetic origin, but Dr. Schmetzer feels that this is insufficient evidence on which to base a firm conclusion. Five photomicrographs are included with the article. *MG*

Glass infilling of cavities in natural ruby. K. Scarratt, R. R. Harding, *Journal of Gemmology,* Vol. 19, No. 4, 1984, pp. 293–297.

The most recent ruby identification problem is surface cavities that have been filled with glass. The first of these rubies to show up at the British Gem Testing Laboratory had a very large filled cavity on the pavilion with large eye-visible gas bubbles. Subsequent stones have contained less conspicuous fillings with no bubbles.

Microprobe analysis of one of the fillings proved the substance to be essentially an alkali alumino-silicate glass. The refractive index was approximately 1.51 and the hardness less than six.

The best method for initial detection is to examine the stone in reflected light. If an area has an obvious difference in luster compared to an adjacent area, such as is seen in a garnet-and-glass doublet, then further investigation is warranted. Care must be taken not to confuse a filled cavity with a natural included crystal that breaks the surface. *SFM*

Man-made rubies (How to detect the latest synthetic gems—part 1) and Synthetic review (How to detect the latest synthetic gems—part 2). P. Read, *Canadian Jeweller,* Vol. 105, Nos. 9 and 10, pp. 21 and 29, respectively.

These two brief articles summarize the identifying characteristics of a number of synthetics that have appeared on the market since 1970.

The first deals with three synthetic rubies—the Kashan, Knischka, and Ramaura products. Inclusions, color zoning, and growth anomalies are keys to the identification of these materials, and are listed accordingly. In addition, the following can be of assistance: dichroism (Kashan), morphology and short-wave ultraviolet transmission (Knischka), and long-wave ultraviolet fluorescence (Ramaura).

The second part summarizes key identifying properties of several other man-made gems: Chatham synthetic orange and synthetic blue sapphire (inclusions; ultraviolet fluorescence in the blue synthetic sapphire); Lennix synthetic emerald (inclusions, refractive index, birefringence, specific gravity); Biron synthetic emerald (inclusions); Regency synthetic emerald (inclusions, short-wave ultraviolet transmission, ultraviolet and visible-light fluorescence); Creative Crystals synthetic alexandrite (inclusions, short-wave ultraviolet transparency); Seiko synthetic alexandrite, ruby, and sapphire (inclusions); Seiko synthetic emerald (inclusions, refractive index, birefringence, specific gravity); and Gilson synthetic fire opal (structure, ultraviolet fluorescence).

Included in each article are rough line drawings of some of the key inclusions mentioned. The articles, while they provide some excellent information, would have been even more useful had they contained some photomicrographs of characteristic inclusions. *RCK*

GEM NEWS

John I. Koivula, *Editor*
Elise Misiorowski, *Contributing Editor*

DIAMONDS

Australia

Although kimberlites have been discovered in the Brunette Downs region of the Northern Territory in Australia, it has not yet been determined whether they are diamondiferous. Drilling was done to investigate certain magnetic anomalies that were similar to kimberlite areas in South Africa. Partners in this venture are Ashton Mining NL, Aberfoyle Ltd., AOG Minerals, and Australian Exploration Ltd. (*Mining Journal,* April 26, 1985)

Botswana

Botswana produced more diamonds in 1984 than in 1983. The Jwaneng mine is responsible for about two-thirds of the total output, with a balance of both gem-quality and industrial diamonds. (*Mining Journal,* March 1, 1985)

Ghana

The government of Ghana is expanding its diamond-mining concessions to include the Birim River region situated west of their present concession in Akwatia. The diamonds, which are believed to have been deposited during the Pleistocene Age, are found in the surrounding deep flats, in tributaries, and in terrace gravels up to 36 m above the existing level of the Birim River. No kimberlites have been reported in the area, and the most important host rock for these alluvial deposits is identified as a breccia or coarse graywacke, with large sedimentary and volcanic fragments. (*Mining Magazine,* March 1985)

Namibia

Ocean Diamond Mining (ODM) and Golden Dumps are two companies currently doing underwater diamond mining off the west coast of Namibia. ODM's ship, the Calypso, is mining around the 12 offshore islands using controllable suction-dredging methods assisted by electronic underwater surveillance. The Calypso also has equipment for sorting the dredged sediment on board. Golden Dumps is mining the Dawn Diamond Concession—5B, which they had mined previously. Although they claim to be using revolutionary methods, they have not disclosed any details of their undersea mining operation. Both companies anticipate the recovery of gem-quality diamonds with an average size of 0.70 ct. (*Diamond News, S.A. Jeweller,* March 1985)

Sierra Leone

Three large diamonds (over 100 ct each) have been found by the Precious Minerals Mining Co. of Sierra Leone since they acquired a 49.5% share of Diminco from British Petroleum. Two of the diamonds, a 285-ct yellow diamond and an "exceptionally good" 142-ct diamond, were discovered on the Yingema lease area near Tankoro. (*Mining Journal,* July 12, 1985)

United States

Exploration for diamonds among the kimberlite deposits in northern Michigan continues. Kimberlites in Michigan were first discovered 14 years ago by two geologists who did not publish their findings. In 1981, a U.S. Geological Survey team reported kimberlite formations which prompted the first diamond exploration. Three companies have been involved individually in the search for diamonds over the last several years: Dow Chemical Co., Amselco Exploration Inc. of Reno NV, and Exmin Corp. of Bloomington IN.

Although none of the companies will discuss their findings, there is evidently enough material of interest to keep them looking. Progress is slow because much of the kimberlite areas are covered by glacial deposits hundreds of feet deep. (*Akron Beacon Journal,* July 16, 1985)

COLORED STONES

Information for the following reports on amethyst and aquamarine was provided to *Gem News* by Robert E. Kane following his trip to the I.C.A. Congress in Idar-Oberstein, West Germany, last May.

Amethyst. Significant quantities of "clean faceting grade" amethyst are coming from a relatively new find near Maraba, in Pará, Brazil, close to the gold fields. Much of the material is of good color, and some of the pieces weigh as much as 60 g. Very large crystals suitable for decorative display or carving are also being mined. Reportedly, the Maraba find has made a great impact on the market, and material is still available at "very favorable prices." Most of the large faceted stones weighed 30 ct or less. Much of the Maraba amethyst examined was in the form of partially "hammered" (broken) crystals. All exhibited some natural crystal faces, ruling out the possibility of broken pieces of synthetic amethyst rough being sold as natural.

Aquamarine. A steady supply of Nigerian aquamarine rough continues to be imported into Idar-Oberstein,

Figure 1. A "Star of David" sapphire from Yogo Gulch, Montana. No lapidary work was needed to bring out this star. The photo was taken in polarized light with a first-order red compensator. The true body color of the sapphire is a pastel blue. Magnified 2×.

West Germany, from the important deposits located in northern Nigeria, between the two towns of Khano and Jos. A portion of this material is resold as rough, while the remainder is being cut in Idar-Oberstein. Some of this aquamarine was offered for sale at the 1985 Tucson Gem & Mineral Show in February, by several different dealers.

Much of the aquamarine from this source possesses a very attractive, distinctive, intense blue color (some very slightly grayish), which apparently does not require heat treating. A source in Idar-Oberstein estimates that a few thousand kilos of Nigerian aquamarine have been purchased by Idar-Oberstein dealers in the past two years. However, because so much of the material is heavily included, only 5% is considered "clean facet grade;" 75% is used for carving, beads, and tumbling; and the remaining 20% is rejected.

Significant amounts of good-quality aquamarine continue to be available from Madagascar, Mozambique, Zimbabwe, Kenya, Zambia, and Brazil. Aquamarine is also being mined in Tanzania, but details regarding the quality and quantity produced were not available.

I.C.A. Congress. The International Colored Gemstone Association (ICA) was formed to promote colored gemstones. Their first congress, held in Idar-Oberstein on May 20–22, 1985, addressed topics of vital importance to the trade via seminars and open discussions. Over 200 delegates from 23 countries, representing all aspects of the gemstone trade, participated in the congress.

From the three-day sessions, several important points emerged. It was unanimously agreed that colored gemstones should not be marketed as investments but should be sold for their beauty alone, and that the term *cultured* should not be applied to synthetic gemstones. Education of consumers and the trade alike in regard to colored stones was also generally endorsed, and $100,000 was pledged to fund future promotion.

The question of gemstone treatments and their disclosure met with a divided house. American delegates, responding to pressure from consumers in the U.S., were in favor of full disclosure of all treatments, while European delegates took the stance that if treatment is permanent and undetectable by standard gemological equipment it need not be disclosed.

The detection and identification of synthetic gemstones was discussed, and a need for the sharing of information in this regard was voiced.

Color grading of gemstones was viewed as a paradox. While there is a definite need for universal color communication, dealers fear that the elements of color in gems are too varied and subtle to define precisely.

Most of the delegates felt that appraisals should be performed by qualified appraisers and that dealers without these qualifications should refer clients who desire appraisal certificates to those so qualified.

It was decided that facts about trade rules and regulations, taxes, and duties from the various countries should be compiled and distributed as guidelines to the members of the I.C.A. A panel to arbitrate problems of the trade within the trade, without involving international courts, was proposed as well.

Changes in gemstone nomenclature were discussed also. It was argued that the term *colored* suggested artificial coloration. The term *semiprecious* was universally condemned in keeping with CIBJO's rulings.

The elected officers of the ICA are: Roland Naftule (USA) president, Rashmikant Durlabhji (India) 1st vice-president, Konrad Wild (West Germany) 2nd vice-president, Stuart Robinson (USA) 1st secretary, Israel Eliezri (Israel) 2nd secretary, Claud Barguirdjian (France) treasurer.

This first ICA Congress was not convened to pass resolutions, but rather to establish open communications on these major issues and to find common ground to use as a base for future growth and understanding within the colored gemstone trade.

Pearls. Because of a less-than-optimum water temperature and the lack of rain, the 1984 pearl harvest in Japan was a disappointment. Deficient nutrition caused by the adverse weather conditions led to a high mortality rate for the oysters and had a detrimental effect on the nacre quality, color, and thickness of coating of the pearls that were harvested. At a recent pearl festival, the Pearl Cultivator's Association of Japan dumped much of the harvest into the sea in order to insure against poor-quality pearls being smuggled out of the country. It is estimated that about 20% of the 1985 pearl harvest will be disposed of in this way to maintain quality standards in the pearl market. (*Accent,* March 1985; *Jewellery World,* April 1985)

Phantom quartzes found. A new quartz mine near Buenopolis in Minas Gerais, Brazil, is producing spectacular crystals containing exquisite green phantoms of what appear to be a member of the chlorite group. Plates of hematite, rhombohedrons of dolomite or calcite, and rutile have also been tentatively identified as inclusions in these crystals. An article on this new find of phantom quartz crystals is in preparation.

Unique "Star of David" sapphire discovered. Sapphire crystals from Yogo Gulch, Montana, are known for their thin, tabular, window-like habit. Rough crystals will often display small triangular growth hillocks on their basal pinacoids (c-faces). The approximately 2.5-ct uncut Yogo sapphire shown in figure 1 is so thin and transparent that both opposite pinacoids are always in clear focus at the same time. What makes this crystal unique, however, is that two triangular growth hillocks on opposite pinacoids are 180° apart in rotation and exactly centered one over the other so that they form a perfect six-pointed Magen David.

ANNOUNCEMENTS

Fabergé Imperial Egg. The June 11 sale of a Fabergé Imperial Egg at Sotheby's, New York, attracted more than usual attention. Although generations of Fabergé craftsmen produced numerous ornamental eggs, only 55 were created for the Russian imperial family and presented yearly as Easter gifts. Only three of these eggs have ever been auctioned publicly, and this one was the first ever to be auctioned in America.

The "Cuckoo Egg" was presented by Czar Nicholas to his wife, Alexandra Feodorovna, in 1900. A fabulous clock, it is topped by a fine gold grille from which a singing rooster emerges. The main body is enameled with translucent violet over a patterned guilloché ground. Diamonds and pearls adorn the clock and are also found bordering areas of green, oyster, and lilac enamels.

When Mr. Malcolm Forbes successfully bid $1.6 million for the "Cuckoo Egg," he not only set an auction record, but he also helped place his collection (now totaling 11) one ahead of the 10 housed in Russia (at the Kremlin's Armory Museum in Moscow). This "11th Egg" may be seen at Forbes's Galleries at 62 Fifth Avenue, New York City. (*Richard F. Buonomo, GIA–New York)*

The 1986 Tucson Gem & Mineral Show will be held February 13–16 at the Tucson Community Center. For more information, write to the Tucson Gem & Mineral Society, P.O. Box 42543, Tucson, AZ 85733.

In conjunction with the Tucson show, the American Gem Trade Association (AGTA) will occupy the Doubletree Hotel in Tucson on February 8–13. During that time they will announce the winner of their Spectrum Award (a colored-stone jewelry competition). The deadline for entries is January 3, 1986. For details about the event and the competition, contact Stuart Woltz, P.O. Box 32086, Phoenix, AZ 85064.

At the request of the gem trade, the date of **Munich's INHORGENTA 86**—the 13th International Trade Fair for Watches, Clocks, Jewellery, Precious Stones and Silverware, and their Manufacturing Equipment, has been postponed and definitely fixed for February 7–11, 1986.

BOOK REVIEWS

Jeffrey M. Burbank, Editor

A FIELD MANUAL FOR THE AMATEUR GEOLOGIST

*By Alan M. Cvancara, 256 pp., illus., publ. by Prentice-Hall, Englewood Cliffs, NJ, 1985. US$12.95**

The purpose of this book is to serve as a companion and guide for rock and fossil collectors, naturalists, and travelers. Cvancara describes how landforms are affected by streams, glaciers, shorelines, wind, groundwater, landslides, and volcanism. A section on rock deformation is included as well. After nine chapters on various landforms, Cvancara devotes another entire chapter to keys for identifying them. One section, "Contemplating the Past," comprised of three chapters, proves to be philosophical but also valuable.

After 20 years of teaching geology at the University of North Dakota, Cvancara has condensed and incorporated his lecture notes into this handy paperback. It is valuable as a textbook, especially for first-year geology lectures and labs. A fine point of the book is that the important geologic terms are in boldface type. Cvancara writes simply, teaching and informing as he goes. Most importantly, he encourages his readers to think.

Cvancara's organization rates a high score. However, his list of earth-science museums at the back of the book is incomplete.

The book's print is easy to read for the traveler. The quality of its illustrations is fair overall, although photographs of many minerals get lost in the poor black-and-white reproduction. However, the mineral identification table makes up for what is lost in the photographs. The book does feature a reading list at the end of each chapter, but it does not have a glossary.

Overall, the format is one of a condensed geology lecture/lab without the academic trappings but with some pleasurable, useful "how-to" information for people on the run. Cvancara tells you "How to attack a geological problem; How to read geological maps; How to use a Brunton compass; How to make a mineral, rock, or fossil collection; How to field collect; How to sleuth stones in architecture or anywhere." The most pleasurable chapters for this reviewer were: How to Read Rock Weathering from Tombstones, How to Prospect for Gold, and Parks for Geological Observation. The author seems to have a little of something for everyone.

Since "how-to" books are very popular, this one should have a wide spectrum of readers. With a $12.95 price tag, the book is very reasonable for what it has to offer.

JUDY OWYANG
Fossils Etc.
Los Angeles, CA

THE SECOND RING: A JEWELER'S GUIDE TO COMPUTERS

*By S. M. Hickel, 285 pp., illus., publ. by Pimiteoui Publications, Rodney, MI, 1985. US$19.95**

At last there is a computer book written for jewelers by a jeweler who knows quite a bit about the subject. Hickel has set out to give jewelers a comprehensive and concise introduction to the world of computers, and to describe present and potential applications of computer technology in the jewelry store.

The book is divided into four parts: (1) What Can the Computer Do for You; (2) The "IJP," or Ideal Jewelry Program; (3) Computers—Languages, History, and Trends; and (4) The Computer's Future.

Part 1 is an excellent introduction to computers, with a wealth of sound information—both for those who are about to take the plunge and buy one and for those who are thinking about hiring a consultant. Hickel provides a good checklist of things to consider before making a decision.

He also tries valiantly to address the problem of the insider "lingo" that confronts the novice. Unfortunately, he does so by prefacing the pertinent chapters with a glossary in an effort to define terms before the reader wades into the text. I agree with his motives, but question his method: Few readers will take the trouble to master such terms until they encounter them in context.

Hickel certainly covers all the bases—and then some—in his discussion of the Ideal Jewelry Program (part 2). Much of what he includes on his "wish list" is already available as off-the-shelf software, but he has a lot of clever ideas about how it can best be used in the jewelry store, large or small. If you the jeweler have ever wondered how you might use a computer in your business, this part of the book alone is worth the purchase price. It includes a good discussion of how the computer can deal with the typical problems encountered in jewelry retailing, as well as in other areas of the business: job flow in the repair department, appraisals, inventory control, accounts receivable and payable, payroll, general ledger, customer mailing lists, and more.

I was somewhat disappointed with the organization of the book, which would have benefited from a good edit. Moving part 3 to follow part 1, for example, would have been a major improvement, since part 3 deals with important background material on computer history, languages, and trends. Part 4, "The Computer's Future," is a scant 30 pages on computer-aided learning and artificial intelligence that contributes very little to the book overall.

The book is illustrated with a number of amateurish line drawings that are of little value. The typewriter-quality print is readable, although typesetting would have

**This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404.*

been preferable (the author points out that the book was written on a word processor and printed on a laser printer). There is a fairly good index and glossary.

In all, I found this an informative and useful book. Although not a great permanent reference, it certainly is worthwhile for jewelers who are waking up to the fact that they will soon be at a serious disadvantage if they do not computerize their business. With *The Second Ring*, you'll have a sense of where to start when you embark on the adventure of buying a computer, and you'll know a lot of the questions to ask. Even if you are fairly computer literate, this book is worth your time. The $19.95 price tag seems a little steep, but it is inevitable for a limited-distribution book.

DENNIS FOLTZ
Manager, Home Study Education
GIA–Santa Monica

DES PIERRES PRECIEUSES AUX PIERRES FINES

*By Claire and Alain da Cunha, 95 pp., illus., publ. by Librairie Plon, Paris, France, 1984. US$24.95**

This book is aimed at the amateur who wishes to collect gems for a hobby or as an investment. Unfortunately, the book opens with a discussion of gem classification that is no longer used by gemologists and yet is emphasized by the very title of the book. Although the authors point out that the distinction between precious, "fine" (previously known as "semiprecious"), and ornamental stones is arbitrary and unclear, they also state that only diamond, ruby, blue sapphire, and emerald belong to the category of precious stones, or gemstones. The opening chapter briefly describes each of these four gems, including their durability, color, clarity, rarity, sources, and prices, and closes by citing a number of common misconceptions about gemstones.

Chapter 2 recommends various focal points for the beginning collector, such as investment value, mineral types, stone size, color, locality, and cut. The next chapter deals with storing, cataloguing, maintaining, and handling a stone collection. There is also a discussion of irradiated and heat-treated gemstones. The microscopic examination of gemstones is the subject of chapter 4. Chapter 5 ventures into the world of "the professionals," with descriptions of various techniques of gem identification and characterization. The final chapter covers the identification of common imitations such as glass and assembled stones, dyed and reconstituted materials, plastics, and synthetic gem materials. A table of 94 stones and their basic properties completes the book.

Obviously, one cannot condense all gemological knowledge into 95 pages, but the da Cunhas have done a remarkable job of surveying the topic in a way that is at once fascinating and technically involving. The reader is led to believe that he is as capable of gaining and utilizing these skills as anyone—which, *with* proper gemological education, is true. As an introduction to gemology, what could be more appealing?

The danger of this book lies in its scattered bits of misinformation. For example, the section on diamond color description tells us: "All the nuances of white are ranked on a scale from D to M, recognized internationally (the last letters vary from one country to another). The first three letters, A, B, C, have not been used and are reserved for diamonds even whiter than those of letter D (but which remain to be discovered)." Students and graduates of GIA will recognize the grading system alluded to in the first sentence. But given that the D grade refers to a complete lack of color (not whiteness) in a diamond, it is impossible to imagine any discovery that might exceed this. A, B, and C were in fact not used in order to avoid confusion with the abundance of grading systems that had previously made use of these letters.

Major errors aside, this book's primary role is merely as an introduction, not as a textbook. The photographs (all but two are by the authors) are plentiful, varied, colorful, and frequently more informative than the text. For the serious gemology student, this book is too basic; while for the amateur, who is less able to spot errors, its usefulness is hampered by its pitfalls. The book, written entirely in French, is not currently available in English.

CAROL M. STOCKTON
Research Department
GIA–Santa Monica

Suggestions for Authors

GEMS & GEMOLOGY is an international publication of original contributions (not previously published in English) concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments, gem localities, gem substitutes (synthetics), gemstones for the collector, jewelry arts, and retail management. Manuscripts may be submitted as:

Original Contributions—full-length articles describing previously unpublished studies and laboratory or field research. Such articles should be no longer than 6,000 words (24 double-spaced, typewritten pages) plus tables and illustrations.

Gemology in Review—comprehensive reviews of topics in the field. A maximum of 8,000 words (32 double-spaced, typewritten pages) is recommended.

Notes & New Techniques—brief preliminary communications of recent discoveries or developments in gemology and related fields (e.g., new instruments and instrumentation techniques, gem minerals for the collector, and lapidary techniques or new uses for old techniques). Articles for this section should be about 1,000–3,000 words (4–12 double-spaced, typewritten pages).

MANUSCRIPT PREPARATION

All material, including tables, legends, and references, should be typed double spaced on 8½ × 11" (21 × 28 cm) sheets. The various components of the manuscript should be prepared and arranged as follows:

Title page. Page 1 should provide: (a) the article title; (b) the full name of each author with his or her affiliation (the institution, city, and state or country where he/she works); and (c) acknowledgments.

Abstract. The abstract (approximately 150 words for a feature article, 75 words for a note) should state the purpose of the article, what was done, and the main conclusions.

Text. Papers should follow a clear outline with appropriate heads. For example, for a research paper, the headings might be: Introduction, Previous Studies, Methods, Results, Discussion, Conclusion. Other heads and subheads should be used as the subject warrants. For general style, see *A Manual of Style* (The University of Chicago Press, Chicago).

References. References should be used for any information that is taken directly from another publication, to document ideas and facts attributed to—or facts discovered by—another writer, and to refer the reader to other sources for additional information on a particular subject. Please cite references in the text by the last name of the author(s) and the year of publication—plus the specific page referred to, if appropriate—in parentheses (e.g., Liddicoat and Copeland, 1967, p. 10). The references listed at the end of the paper should be typed double spaced in alphabetical order by the last name of the senior author. Please list only those references actually cited in the text (or in the tables or figures).

Include the following information, in the order given here, for each reference: (a) all author names (surnames followed by initials); (b) the year of publication, in parentheses; (c) for a *journal*, the full title of the article or, for a *book*, the full title of the book cited; and (d) for a *journal*, the full title of the journal plus volume number and inclusive page numbers of the article cited or, for a *book*, the publisher of the book and the city of publication. Sample references are as follows:

Daragh P.J., Sanders J.V. (1976) Opals. *Scientific American*, Vol. 234, pp. 84–95.

Liddicoat R.T. Jr., Copeland L.L. (1967) *The Jewelers' Manual*, 2nd ed. Gemological Institute of America, Santa Monica, CA.

Tables. Tables can be very useful in presenting a large amount of detail in a relatively small space, and should be considered whenever the bulk of information to be conveyed in a section threatens to overwhelm the text.

Figures. Please have line figures (graphs, charts, etc.) professionally drawn and photographed. High-contrast, glossy, black-and-white prints are preferred.

Submit black-and-white photographs and photomicrographs in the final desired size if possible.

Color photographs—35 mm slides or 4 × 5 transparencies—are encouraged.

All figure legends should be typed double spaced on a separate page. Where a magnification is appropriate and is not inserted on the photo, please include it in the legend.

MANUSCRIPT SUBMISSION

Please send three copies of each manuscript (and three sets of figures and labels) as well as material for all sections to the Editorial Office: *Gems & Gemology*, 1660 Stewart Street, Santa Monica, CA 90404.

In view of U.S. copyright law, a copyright release will be required on all articles published in *Gems & Gemology*.

No payment is made for articles published in *Gems & Gemology*. However, for each article the authors will receive 50 free copies of the issue in which their paper appeared.

REVIEW PROCESS

Manuscripts are examined by the Editor, one of the Associate Editors, and at least two reviewers. The authors will remain anonymous to the reviewers. Decisions of the Editor are final. All material accepted for publication is subject to copyediting; authors will receive galley proofs for review and are held fully responsible for the content of their articles.