Gems & Gemology

The quarterly journal of the Gemological Institute of America

Gems & Gemology

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ABOUT THE COVER: Cat's-eye chrysoberyl is one of many fine gemstones found on the island of Sri Lanka, the subject of Peter Zwaan's article in this issue. This fine 9.57-ct cabochon from Sri Lanka is pictured here against a 19th century lithograph by Dr. von Kurr of a twin chrysoberyl crystal. This stone, part of the Hixon Collection, is at the Los Angeles County Natural History Museum. Photograph © 1978 Harold and Erica Van Pelt— Photographers, Los Angeles, CA.

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Gems & Gemology

SRI LANKA: THE GEM ISLAND

By Peter C. Zwaan

Sri Lanka, formerly Ceylon, remains one of the single most important sources for fine gemstones. Especially notable are blue sapphire, pink sapphire or ruby, and yellow sapphire; alexandrite and cat's-eye chrysoberyl; and almandite and hessonite garnet. Spinel, tourmaline, zircon, moonstone, and quartz are also relatively common; they share their country of origin with several rarer gemstones as well. Most of the gem-quality material is found in alluvial deposits throughout the island, which are mined by primitive methods. In many instances, the Sri Lankan origin of the gemstone can be determined by characteristic inclusions, several of which are also discussed in this article.

ABOUT THE AUTHOR

Professor Zwaan is director of the National Museum of Geology and Mineralogy, Leiden, Netherlands.

The gem riches of Sri Lanka have been legendary for centuries. One of the earliest descriptions is that of Nearchus, who in 334 B.C. mentioned an island not far from Persia where beautiful translucent gems had been found. Without a doubt, this island was the present Sri Lanka. Much later, at the beginning of the 16th century, Portuguese sailors discovered the island and returned to Europe with some of its gemstones; seamen from Holland did the same some hundred years later.

Over the centuries, tens—probably hundreds—of thousands of carats of fine sapphire, ruby, chrysoberyl, spinel, and other familiar as well as unusual gemstones have been mined in Sri Lanka. Yet many questions continue to surround the geology of the deposits, and mining methods remain, for the most part, very primitive.

During the course of the author's eight trips to Sri Lanka, he has traveled all over the country and inspected the major mining areas—beginning in 1958 with the historically important Ratnapura area and completing most recently, in February and November of 1981, a study of the newer Tissamaharama area.

The author has drawn from his experiences and investigations to provide this overview of the geology of Sri Lanka and its mining and cutting practices, as well as special features of the various gem materials found there. Also examined are inclusions characteristic of Sri Lankan gemstones and production figures for the area.

GEOLOGY

Sri Lanka is one of the most important localities for gemstones in the world. Almost all of these gems, however, occur in alluvial deposits, and their original source remains unknown today.

A geologic sketchmap (figure 1) shows that the island is almost entirely underlain by Precambrian rocks. These rocks can be divided into three groups based on their lithology, structure, and age, as described below.
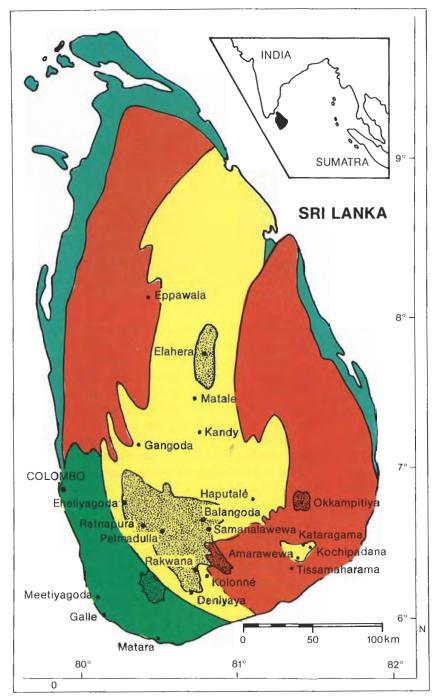
Figure 1. Geological sketchmap of Sri Lanka, with the main gem-producing areas identified.

The oldest unit on the island is the Highland group, which contains rocks of the metamorphic granulite facies, such as hypersthene gneisses (charnockites), sillimanite-garnet gneisses (khondalites), biotite-garnet gneisses, and marbles in which forsterite and spinel occur. Most of the gem deposits are located within this group.

The second unit is the Vijayan complex. This unit is characterized by rocks of the almandite-amphibolite facies, such as biotite-hornblende gneisses.

The overlying Southwest group consists of rocks that belong to the cordierite-granulite facies. It contains both cordierite gneisses and khondalites.

Although most of these rocks, as well as numerous pegmatites found throughout the country, contain gem materials, it is remarkable that

Figure 2. Gem pits in Meetiyagoda.

few of the minerals found thus far in situ are of gem quality. Yet numerous alluvial deposits on the island contain pebbles of the same gem minerals, many of which are of gem quality. There is no doubt that the latter originated in rocks not far from their present localities, but up to now the host rocks have not been found.

It would be particularly interesting to establish the original source of blue sapphire, the most important gemstone in Sri Lanka. The only known location of gem-quality blue sapphire in situ is in a pegmatite located near Kolonné in the Ratnapura district, where the blue sapphire is found together with diopside (Gunaratne, 1976). The only other gemstones found in host rock are moonstone, which occurs in Meetiyagoda, near Galle, and some almandite garnet, which occurs in several places throughout the island.

GEM DEPOSITS

As mentioned above, almost all of the gem-quality minerals from Sri Lanka occur in alluvial deposits; the main gem-bearing area is the Ratnapura district in Sabaragamuwa Province, some 97 km (60 miles) southeast of Colombo. The gems are concentrated in more-or-less horizontal layers at different depths in the alluvium, which consists primarily of sand and gravel. The most notable localities are Ratnapura (the name means "city of gems"), Pelmadulla, Balangoda, and Rakwana.

Similar deposits are found near Elahera in the Central Province, in particular in the valley of the Kaluganga River. Here, the gem minerals are not concentrated in specific levels, but are almost uniformly distributed throughout in a laterite-rich deposit of sandy gravel and clay.

Another gem deposit of interest is near Okkampitiya in the province of Uva. This deposit is very similar in appearance to those in the Ratnapura district. It is well known for its large production of hessonite garnet.

About three years ago, gem-bearing deposits were discovered in the Tissamaharama area (also called the Kataragama area) in Southern Province. The major localities are Amarawewa, about 10 km from Tissamaharama in the direction of Kataragama; and Kochipadana, about 5 km east of Kataragama. In this region, gem minerals occur in alluvial deposits at a depth of about 1 m.

Although certain areas in Sri Lanka may be wetter than others, it is usually not difficult to visit the various gem-mining districts. The traveler is advised, however, to ask the assistance of the State Gem Corporation in arranging a guide, a necessity for every foreigner and particularly so for the first-time visitor. The author was cautioned to exercise some care when visiting the Elahera district, but his personal experience with the people there was very good.

GEM MINING

Gem mining in Sri Lanka is primitive. Usually, pits are dug to the depth of the gem-bearing gravel layer. Depending on the level of the groundwater, and on whether the area is wet or dry, some method of drainage is used. The pits are strengthened with wooden bulwarks to avoid caving. The workers are protected from the sun by a thatched roof (figure 2).

It is not unusual for some of the deeper pits to extend a short tunnel from the bottom, although such a tunnel is dangerous, especially in wet areas like the Ratnapura district. In this area, pits vary in depth from 5 to 15 m. The gem rough is very rounded, which indicates either intensive rolling or long transport.

In the Elahera area, the depth of the gem-bearing gravel ranges from about 3 to 9 m. Mining is less complicated than in the Ratnapura district because this part of Sri Lanka is very dry. Although the gem minerals in the laterite-rich deposits are rounded only slightly, distinct, well-developed crystal faces are seldom seen.

In the Tissamaharama area, not only is the material rounded only very little, but many specimens (in particular, corundum and tourmaline) have well-developed crystal faces (figure 3). It is apparent that these crystals have been transported by nature a considerably shorter distance than gem minerals found elsewhere in Sri Lanka, which suggests that their original source is relatively close.

In all of the gem deposits, the gem-bearing gravel, which is locally called *illam*, is placed in baskets that are usually hoisted up from the pit by means of a rope. Large quantities of this illam are heaped near the pit.

To wash the gravel, the worker stands waist deep in muddy water, shaking and rotating a cone-

Figure 3. Corundum crystals from Kochipadana. For scale note that the crystal in the center at the bottom is 17 mm long and weighs 14.9 ct.

shaped, plaited basket (figure 4). Recovery rates are thought to be quite high with this method. In a short time, most of the mud is washed away, and the larger pebbles, most often opaque or translucent, are picked out and thrown away. After further swirling, the washed gravel, which is locally called *dullam*, is examined for gem-quality material by the supervisor; in most cases, this is the owner of the mine.

LAPIDARY TREATMENT

Cutting is done by means of a wooden apparatus that has a horizontal axis and a vertical wheel at
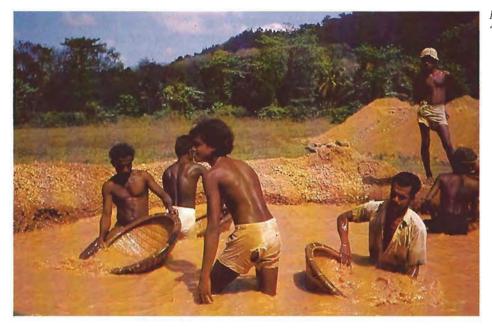
Figure 4. Washing of the "illam" in Ratnapura.

Figure 5. Gem cutting in Ratnapura.

one end. The axle can be rotated with a cord that is moved to and fro with one hand while the stone is pressed against the wheel with the other (figure 5). Commonly, stones faceted in Sri Lanka are very irregular, as can be seen in figure 6, which represents a parcel of Sri Lankan gems. With the emphasis on cutting for size rather than symmetry, much of the material is spoiled. For this reason, many stones cut in Sri Lanka are not suitable for sale in other countries without recutting.

Some years ago, machine cutting was introduced, mainly through the influence of the State Gem Corporation, and is now becoming very popular. It is a significant move in the right direction.

IMPORTANT GEMSTONES

Without doubt, *blue sapphire* is the most important gemstone found in Sri Lanka (figure 7). It is

Figure 6. Gemstones cut in Sri Lanka. For scale, the green zircon at the top left weighs 9.04 ct.

important not only commercially, but also for its unique beauty, especially its fine color. Although blue sapphire is found in a number of places in Sri Lanka, the occurrence at Rakwana in the Ratnapura district is particularly important, while the Tissamaharama area also promises to become a major source. A milky-white variety, suitable for treatment to obtain a fine blue color, is called "geuda" (Gunaratne, 1981).

The *red corundum*, or "Ceylon" ruby, is fairly common in most of the gem-bearing areas, but its color is never as saturated as that of the Burmese ruby. In fact, ruby from Sri Lanka tends to be pink rather than red.

Sri Lanka is one of the few sources for *yellow sapphires* (figure 8). They occur primarily in Balangoda. These stones typically range in hue from very pale to dark yellow. Some orange stones are occasionally seen as well. Deep-orange corundum, with the "color of the sunrise," is rare, and, therefore, highly prized. The name "padparadscha" has been applied to these rare stones.

Star corundum is common in Sri Lanka. Such stones occur in different colors, but bluish grey, pale violet, and milky white are most common. Star rubies and star sapphires of fine color are rare, but some important pieces have appeared (figure 9).

Another important Sri Lankan gem is *chrysoberyl*, especially the rare varieties alexandrite and cat's-eye. Good qualities of both varieties are scarce, and hence highly prized. Most alexandrites are rather clear and light green; their color range is moderate. The best cat's-eyes have a

Figure 7. This 6.24-ct blue sapphire represents
the fine color that comes from Sri Lanka. Photo
by Tino Hammid.

honey-brown color, a sharp whitish chatoyancy,
and are truly fine gemstones. Yellow to brown
chrysoberyls also occur in Sri Lanka.

Among the *garnets*, two varieties are com-
mon: (1) a member of the pyrope-almandite se-
ries, and (2) the orange-brown grossular, known
by its variety name hessonite. The pyrope-
almandite garnet has the characteristic rose-red
color of "rhodolite," intermediate between py-
rope and almandite, with a magnesium content
that is higher than its iron content. Hessonite is
mainly found in the southeastern part of the is-
land, near Okkampitiya and Kataragama in
particular.

Spinel occurs in different colors, especially
purplish red and dark greenish blue. Iron-rich,
dark green spinel from Sri Lanka is called ceylon-

Figure 8. Yellow sapphire from Sri Lanka,
1.42 ct. Photo by Tino Hammid.
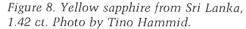
Figure 9. The 138.7-ct Rosser Reeves star ruby
from Sri Lanka. Photo by Dane Penland,
courtesy of the National Museum of
Natural History, Smithsonian Institution,
Washington, DC.

ite or pleonast, while a zinc-rich, blue spinel with
the name gahno-spinel is also a typical Sri Lankan
gemstone. Over the last four years, interest in spi-
nels has increased enormously.

Although many colored gemstones in Sri Lanka
are called *tourmaline*, this mineral seems to oc-
cur here in brown only and, in fact, is much
less common than generally thought. Most so-
called tourmalines are *zircons* which occur in
many colors, such as reddish brown, yellow-
brown, light to dark green, and olive green. The
"low-type" zircons all have a green color, which
may be considered characteristic for zircons from
Sri Lanka.

Rather common are some *quartz* varieties such
as rock crystal, amethyst, rose quartz, smoky
quartz, and cat's-eye quartz. Stars occur mainly
in rose-colored and greyish material; the asterism
is caused by included sillimanite (Woensdrecht et
al., 1980).

The island is one of the few sources of gem-
quality *moonstone* (figure 10). Stones with a fine
blue sheen are now rare. Although the south-
western part of Sri Lanka, especially Meetiya-

Figure 10. Cat's-eye moonstone, about 12 ct, from Sri Lanka. The two rhodolite garnets are also from Sri Lanka. Ring courtesy of Fannie M. Mann. Photo by Tino Hammid.

goda, is famous for this variety of feldspar, the mineral is also found in the Tissamaharama area.

Yellowish and colorless varieties of *topaz* occur in the Ratnapura district. In comparison with topaz from other countries, the Sri Lankan stones in general are not very attractive and, therefore, are less important.

UNUSUAL GEMSTONES

Unusual gems also occur in conjunction with the commercially important stones in several localities. Some of these, in fact, have not been found outside Sri Lanka and may be considered extremely rare.

Andalusite is occasionally found in the Ratnapura district and may be discovered in parcels of cut "tourmalines" because its hardness is very similar to that of tourmaline and zircon (which, as mentioned above, also appears in such parcels). Andalusite may be recognized by its extremely strong pleochroism in greenish-brown and red stones.

Apatite is one of the principal minerals in a carbonatite from Eppawala, which lies about 65 km northwest of Elahera. Brownish crystals up to about 1 m in length have been found, but they usually are not of gem quality. Some greenish to bluish-green apatites are found in Eheliyagoda and Balangoda; those found in the Ratnapura district are often of cutting quality.

In 1961, a new metamict mineral from Sri Lanka was mentioned in the literature for the first time (Gübelin, 1961). It was named *ekanite* in honor of Mr. F. L. D. Ekanayake, a gemologist in Sri Lanka at that time. Ekanite turned out to be extremely rare, and cut stones are encountered only occasionally. Thus far, Sri Lanka is the only known source of this calcium-thorium silicate.

Iolite (cordierite) is not an important jewelry gemstone, since its properties are very low, but it is an attractive stone for collectors. It is very common in the cordierite-gneisses that outcrop at many places throughout the island, but gem-quality material is found only in the Ratnapura district. It is usually called "water sapphire" by the local inhabitants. Its very strong dichroism may be observed with the naked eye; the yellow is characteristic and unknown in blue sapphire.

Some years ago, *kornerupine* was regularly discovered in "tourmaline" parcels. Most often, the stone is green, but frequently some brown stones can be seen together with the green. About five years ago, cat's-eye kornerupine came on the market in Sri Lanka (Korevaar and Zwaan, 1977). Today, these cat's-eyes are considered common, although large stones are rare. They are said to originate in the Galle district, while the green stones without chatoyancy are from the Ratnapura district and from Matale in Central Province.

Sillimanite, or fibrolite, with a light blue color occasionally occurs in the Deniyaya district near Rakwana. A large gem-quality piece, recently found in Balangoda, is now in the collection of the State Gem Corporation.

A rare gem mineral that occurs at different places in the Ratnapura district is *sinhalite*, a magnesium-aluminum borate. Its properties bear some resemblance to those of peridot, and, in fact, many brown "peridots" in old collections have been identified as sinhalites on close examination. The material was described as a new mineral in 1952 (Claringbull and Hey, 1952). The stone may vary from almost colorless through light yellow to dark brown with increasing iron content.

Although *sphene* (or titanite) was mentioned many years ago as a possible gemstone from Sri Lanka (Gübelin, 1968), only very recently was gem-quality sphene reported from the Tissamaharama area (Zwaan and Arps, 1980; Zwaan, 1981). Because of its high optical properties, sphene is very attractive; yellow and brown are the predominant colors in sphene from Sri Lanka.

A pale violet mineral, *taaffeite*, is found very rarely in parcels of spinel; it has similar properties but a distinct birefringence. Taaffeite was named in honor of its discoverer, Count Taaffe of Dublin, Ireland (Anderson, 1952). Thus far, only about 10 specimens have been reported; their exact source, somewhere in Sri Lanka, has not been identified.

Other unusual gemstones are regularly seen, for instance, a pale green spodumene from the Tissamaharama area (Zwaan, 1982). It is very likely that other rare or remarkable gemstones will be found in view of the complex geology and mineralization of the island's basement rocks.

INCLUSIONS CHARACTERISTIC OF SRI LANKAN GEMS
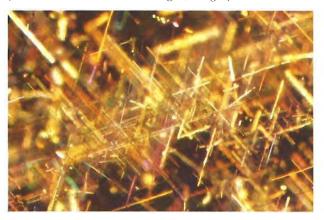
Examination by the author of the inclusions in different gemstones from Sri Lanka showed some of them to be characteristic of the locality, as described below.

With regard to solid inclusions, needle-like rutile crystals are often seen in almandite garnet (figure 11), sapphire, and other gemstones. The needles are arranged in three directions, making angles of about 60° with each other; they usually are very long and run through the whole stone. These rutile inclusions often give a silky appearance to the stone, and they are responsible for asterism in many varieties of corundum.

Coarse-grained rutile also occurs in various garnets and may be present in cat's-eye kornerupine. Most often, the rutile has no distinct crystal faces, has a black color, and shows a high metallic luster.

In 1964, the author examined large idi-

omorphic crystals in a blue spinel from the Ratnapura district (figure 12) which were found to be apatite (Zwaan, 1965). Since then, apatite crystals, formerly thought to be quartz crystals, are now recognized in garnet, corundum, and spinel. They seem to be diagnostic of the Sri Lankan origin of these species.

Inclusions of zircon crystals, surrounded by halos, are also very common in different gemstones, especially in garnet and corundum.

Hessonite garnets from Sri Lanka characteristically contain numerous, somewhat rounded crystal inclusions (figure 13) of both diopside and apatite. This occurrence is not strange because both are calcium minerals, as is hessonite garnet.

Liquid inclusions, resembling thumbprints and often called liquid feathers, are characteristic in
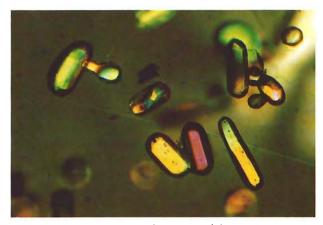
Figure 12. Apatite crystals in spinel from Sri Lanka. Polarized light, magnified 30×.

Figure 11. Rutile crystals in almandite garnet from Sri Lanka. Polarized light, magnified 30×.

Figure 13. Apatite and diopside crystals in hessonite garnet. Magnified 30×.
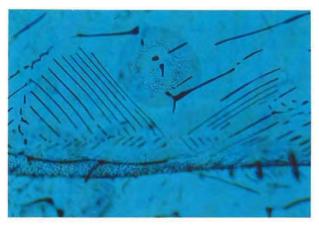
Figure 14. Liquid feathers in sapphire from Sri Lanka. Magnified 30×.

many gemstones from Sri Lanka, including the corundums (figure 14).

Both these solid and liquid inclusions are of great importance when the origin of a gemstone has to be taken into consideration. From the author's investigations, they seem to be characteristic for Sri Lankan gemstones.

PRODUCTION IN SRI LANKA

As recently as the beginning of this century, little information was available on the amount and value of the gem material produced in Sri Lanka. Gem mining was thought to be limited to the Ratnapura district and the area near Galle. Not until 1923 was the discovery of good-quality material in Pelmadulla reported. But precise figures were impossible to obtain.

Even today, reliable figures are not available because many private miners sell their stones illegally to foreign buyers. During the author's first visit, in 1958, he was told that the annual figures reported by the government represented only about 10% of the real production. To provide some idea of the quantities involved during this period, in his 1965–1966 Administration Report, the director of the Geological Survey of Ceylon stated that exports of all types of gemstones amounted to a little over 61,000 ct. These export figures were, however, only from customs returns.

With the establishment of the State Gem Corporation (SGC) in the early 1970s (both to improve the country's gem industry and to help curb the large-scale smuggling of gems), the export figures improved considerably. In 1971, before the SGC had taken control, total sales of 3.4 million

Rs (1982 exchange: approximately 8 rupees per U.S. dollar) were reported. By 1973, after the SGC had established itself, the figure had ballooned to 152.9 million Rs, with a total production of 478,000 ct of material. The most recent figure available to this author, for 1975, was 188.9 million Rs. in gem exports. One can only assume that this number will continue to rise as the SGC furthers its efforts both to give some guidance to the gem industry and to search for new gem-bearing deposits.

SUMMARY

Sri Lanka is one of the most important sources in the world as far as the number of different gemstones it produces is concerned. It is remarkable that no explanation can be given as to where these gem minerals were formed originally, because they are all found in alluvial deposits.

The island consists almost entirely of Precambrian rocks, which may be divided into three groups: the Highland group, the Vijayan complex, and the Southwest group. Although gem minerals occur in different rocks of these series, few are of gem quality.

Historically, the most important gem-bearing area is the Ratnapura district in Sabaragamuwa Province. The gem minerals are concentrated in more-or-less horizontal levels at different depths in the alluvium. Similar deposits are found near Elahera, near Okkampitiya, and in the Tissamaharama area.

Mining methods are still primitive, as are the ways of washing and cutting the material. Machine cutting has been introduced, though, and significant improvements are anticipated. Very recently some machines were brought in to help with mining in the Balangoda area; in Pelmadulla, in particular, tunneling and river dredging for gems may be seen. Another mechanized mining project is going on in Samanalawewa at the moment. It may be expected that mining methods will be modernized rapidly, resulting in an enormous increase in the annual production.

Blue sapphire, ruby, yellow sapphire, and alexandrite and cat's-eye chrysoberyl are among the most important gemstones found in Sri Lanka. Also found in quantity are some garnets, spinel, and several varieties of quartz. A number of more unusual gemstones have also occurred in Sri Lanka. In fact, cat's-eye kornerupine is now very common.

Typical inclusions in Sri Lankan gemstones are long, needle-shaped rutile crystals, arranged in three directions, that often cause a silky luster and are common in pyrope-almandite garnet and in corundum. Apatite crystals are often seen in garnet, corundum, and spinel, while zircon crystals surrounded by halos are also very common in garnet and corundum as well as in other Sri Lankan gems. Finally, liquid feathers are characteristic of many Sri Lankan gemstones.

Although production figures are not always reliable, they seem to be rising significantly now that the State Gem Corporation is supervising the industry. The efforts of the State Gem Corporation will undoubtedly result in the discovery of new gem-bearing deposits, as the country's supply of fine materials seems inexhaustable.

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THE IDENTIFICATION OF ARTIFICIAL COLORATION IN DIAMOND

By Kenneth V. G. Scarratt

Since Robert Crowningshield's discovery in the late 1950s that diamonds that have been artificially colored by irradiation and subsequent annealing could be identified by their characteristic absorption spectra (in particular, the band at 595 (592) nm, much more information has become available about the radiation-related bands seen in the visible spectra of diamonds. The introduction of cryogenics has made the observation by hand spectroscope or the recording by spectrophotometer of a diamond's visible spectrum less troublesome. But it has also opened the eyes of the gemologist to the fact that virtually any band that can be artificially induced in the spectrum of diamond by irradiation and subsequent annealing can also occur naturally. This makes identification of the source of color in some diamonds, particularly fluorescent green and some yellow stones, very difficult.

ABOUT THE AUTHOR

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Diamond combines a magnificent brilliance and durability with a wealth of differing colors, characteristics that make it unique among gemstones. Recently, diamonds with a definite body color have become very popular, so that the volume of work concerned with these stones over the past few years has increased out of all proportion at the Gem Testing Laboratory of London. If this can be taken as an indication of current trends, then at long last the gem-buying public is finding out not only that *black diamond* is not another term for coal, but also that it is possible for diamonds to occur in superb shades of yellow, green, brown, pink, and blue (figure 1) that often make other colored gemstones seem quite dull in comparison.

It is hardly surprising, therefore, that as with other highly prized gemstones man has found it necessary to try to exert his influence on the poorer examples to "improve their quality," a practice that many gem merchants and customers find unacceptable. And it follows that the trade has requested the advice of gemologists to distinguish a natural from an artificially colored stone. Because of the great difficulties that can be involved, though, most gemologists have tended to leave the problem in the hands of the relatively few laboratories or individuals who have been able to specialize in the subject.

In some cases, the trader can himself determine the origin of color in a diamond fairly quickly and simply. Two methods involving the application of a diamond merchant's normal instrumentation are discussed below. In those more difficult cases where radiation treatment and subsequent annealing are involved, spectroscopy is the most useful technique. There are some cases, though, which will also be discussed below, in which even absorption spectra enhanced by cryogenic spectroscopy may not be able to prove conclusively the origin of color in a diamond.

Figure 1. A suite of colored diamonds. The light pink (0.68 ct) and light blue (0.56 ct) stones are naturally colored. The yellow, orange, and green stones have been treated to improve color, although yellow and orange hues similar to those shown here are known to occur naturally. Photo by Tino Hammid.

SOME SIMPLE METHODS OF DETERMINING WHETHER THE COLOR OF A DIAMOND IS NATURAL OR MAN INDUCED

Virtually all diamond merchants possess some form of instrument to examine their stones at various magnifications—be it a hand lens or a microscope—and a source of ultraviolet radiation. With some experience, the merchant often can use the information gleaned from the stone with these instruments to determine whether the stone in question is naturally colored or has been treated.

In many cases, colored diamonds have very distinctive internal features. For example, the color in many natural brown stones is zoned (Kane, 1980), alternating between brown and colorless (not unlike the zoning seen in some sapphires). In other natural brown diamonds, the color zoning may appear to be angular. When some natural pink diamonds are examined with a lens, their color can be seen to be associated with the internal structure of the stone, which appears in the form of pink zoning on a colorless background (figure 2).

Although cyclotron-treated stones often display a form of zoning, natural zoning is usually associated with growth phenomena and, therefore, is aligned with the original crystal form. The zoning in a cyclotron-treated stone is associated with the shape of the cut stone; that is, it may appear as a color concentration at the culet, which looks something like an opened umbrella, or as a color concentration at the girdle (figure 3).

When natural type II_B blue diamonds are bathed in short-wave ultraviolet radiation, they reveal characteristics that are distinctive of this type of diamond. Such stones either have a relatively weak fluorescence or are virtually inert, but they have a phosphorescence that is among the strongest observed in any type of diamond. They are also usually relatively clean internally and quite large. Very large pink diamonds are usually quite light in color and are type II stones, which allow short-wave ultraviolet radiation to pass, exposing any photographic paper on which such a stone may be placed.

Figure 2. The color in some naturally pink stones can be seen to be associated with their internal structure. Here it reveals itself on a colorless background as thin pink lines crossing crown facets. Magnified approximately 80×.
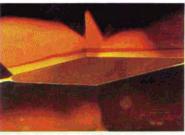
Figure 3. Zoning in a cyclotron-treated diamond appears as a concentration of color associated with the shape of facets of the cut stone. Left = color zoning paralleling the edges of the crown viewed through the pavilion, 40×. Right = color zoning paralleling the edge of the culet viewed through the table, 30×. Photos by Robert E. Kane.

In the majority of cases, though, the internal features of the stone and its reaction to radiation are inadequate for the conclusive determination of the source of color. This is particularly true with diamonds that have been irradiated and then annealed to enhance or change the natural color by methods other than cyclotron treatment.

DETERMINING THE SOURCE OF COLOR IN DIAMONDS THAT HAVE BEEN IRRADIATED AND SUBSEQUENTLY ANNEALED

Man first learned that he could influence the color of diamond at the beginning of this century, when it was discovered that a green color could be induced by intimately exposing the stone to radium (Webster, 1972). However, stones treated in this manner retained radioactivity at levels that were easily detectable with a Geiger counter (a test that continues to be of importance in the examination of green diamonds today).

It was not until halfway through the century that it was discovered that a number of other forms of atomic bombardment could be used commercially to "treat" diamonds and that after subsequent annealing the irradiated green stones would alter once again to yellow and brown. These resulting colors were found to be strong and, in the main, deep penetrating and stable. From this point on, the task of identifying the nature of color in diamond became in some cases very difficult, because these irradiated stones do not retain any detectable radioactivity for a significant length of time, nor any other obvious indications of treatment. We were indeed fortunate that at this juncture Robert Crowningshield, director of gem identification of the GIA Gem Trade Laboratory in New York, came to the rescue of gemologists (Crowningshield, 1957). After observing the visible spectra of thousands of these irradiated and annealed diamonds, he determined the presence of an absorption band at 595 (592)* nm in almost every instance.

Since that time, determination of whether the color in a particular diamond is due to a process of nature or to man's intervention is usually based on the information obtained by the observation of that stone's visible spectrum. Over the years, however, other factors have come to light which make detection by this manner in some colored diamonds extremely difficult.

Spectrum Changes Induced by the Process of Irradiation and Annealing. A number of changes occur in the visible spectrum of a diamond during the process of irradiation and subsequent annealing. Knowledge of these changes is essential to the understanding of the source of color in a given stone.

Depending on the diamond and on the conditions of irradiation, during the initial irradiation process the stone usually turns some shade of green and a group of absorption bands are induced into the spectrum at varying strengths. These bands have been "numbered" by physicists and given the prefix GR (general radiation). The principal band and the one observed most often by gemologists is the GR1, at 741 nm (Clark and Walker, 1972). Upon annealing, at least two other absorption bands are induced. Typically, one of these is the sharp band at 595 nm. Also apparent may be either the band at 503 nm or the one at 496 nm, and very often both are seen. Any naturally occurring absorption that was evident in the spectrum prior to irradiation, such as the band at 415 nm, remains unaffected (figure 4).

The relative strengths of the induced bands are affected by the annealing temperature (Collins, 1978). As the temperature increases, the GR1 reduces in strength until it disappears at around 800°C. The 595 nm band increases to its maximum at around 800°C, but above this temperature the 595 weakens until it disappears at around

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*This sharp absorption band is observed between 592 and 595 nm. The tradition in American gemology has been to refer to this feature as the 592 nm absorption center.
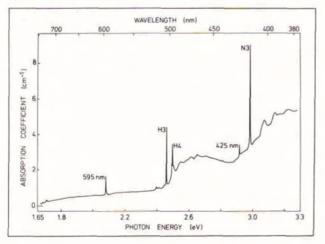
1000°C. The band at 503 nm, which has the greatest effect on the color of the irradiated diamond, remains comparatively unaffected at least until several hundred degrees beyond the position where the band at 595 nm "anneals out."

It follows then that it is possible to produce an irradiated diamond with a strong yellow color in which the only indication of radiation treatment may be the bands at 503 and 496 nm. Inasmuch as these two bands can and very often do occur naturally, identification of treatment in such stones may be very difficult.

Another way in which the 595 nm band is temperature dependent is sometimes evident from its behavior when the spectrum is being examined. If the stone is heated much above room temperature, very often the band will broaden and, if it is weak to start with, the band will become undetectable with the hand spectroscope until the stone has cooled. This has led gemologists to seek methods by which they can keep the stone cool while under examination (see, for example, Hofer and Manson, 1981).

Low-Temperature Spectroscopy. The most successful cooling method to date entails the use of liquid nitrogen or the gas produced from it. The method used at the London Gem Testing Laboratory ensures a temperature in the region of −160°C for the period of examination. This temperature is reached gradually over approximately a quarter of an hour. The stone is first set in soft metal and then placed into a double-walled glass vessel. The space between the two walls is evacuated in a manner similar to a thermos flask. The nitrogen gas is then allowed to pass through the vessel and thus cools the stone (figure 5).

The size of the vessel used depends on the size of the stone. For the examination, the vessel is set in the center of an optical bench with the light source at one end and the spectroscope at the other.

This system not only ensures that if the band at 595 nm is present, it will not disappear, but it also makes the band sharper and therefore easier to see when it is at its weakest, say, after the stone has been annealed to 900°C. In fact, this cooling of the stone sharpens all the radiation-related bands to such an extent that observation becomes quite easy. This point is brought home when one realizes that with the stone held at a low temperature it is possible to observe the GR system, with its main band at 741 nm, using the hand spectroscope (Scarratt, 1979). While this method of observation has in many respects made the task of color identification easier, it has also raised a number of other questions. Of particular importance is the discovery in some cooled nat-

Figure 4. Absorption spectrum recorded at about −160°C for a yellow diamond that has been irradiated and then annealed. The 503, 496, and 415 nm lines have been labeled by physicists as H3, H4, and N3, respectively. The small peaks around 741 nm are part of the GR system.

Figure 5. One of the glass vessels used to hold a colored diamond at about −160°C, at which temperature any absorption lines that may be present in the stone's visible spectrum are seen at their sharpest. The stone is held in soft metal in the center; the nitrogen gas enters via an insulated pipe on the left, flows over the stone, and exhausts through the metal tube on the right.
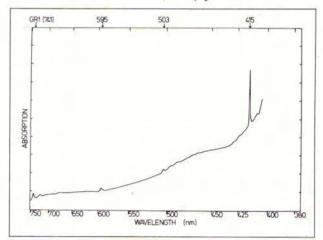
ural stones of absorption bands formerly believed to appear only in artificially colored stones.

NATURAL IRRADIATION IN COLORED DIAMONDS

B. W. Anderson first noted the 595 nm absorption band in a colored diamond in 1943 (Crowningshield, 1957). This was not in the spectrum of a treated stone but in that of a natural uncut brown stone from the Central African Republic (figure 6). This stone was one of a pair given to Mr. Anderson. We have since been able to examine both diamonds at low temperatures, and found not only that the 595 nm band was present in the spectrum of *both* stones but also that the GR system was still present in the one that did not show the 595 nm band at room temperature. When it was determined that the color of these stones was confined to the surface (figure 7) and would, therefore, be removed with faceting, gemologists tended to ignore this natural occurrence of the 595 nm line. However, these stones do give us some background information that is of great help in our understanding of colored diamonds.

Specifically, the presence of the GR system tells us that the brown surface coloration in this pair is due to natural radiation. We also know that these stones have been subject to an annealing process, both because of the presence of the 503

Figure 7. Brown natural radiation "staining" on the surface of a diamond crystal from the Central African Republic. Magnified approximately 50×.

and 595 nm bands and because of the brown rather than green coloration (Mendelssohn et al., 1979). This information helped us a few years ago in our understanding of one particular faceted stone, with a fluorescent green body color. All naturally colored diamonds of this type reveal very similar spectra: that is, the presence of the 503, probably the 496, and certainly the 415 nm bands. But when the spectrum of this stone was examined at −160°C (figure 8), the 595 nm line was also seen to be present. In fact, the spectrum was indistinguishable from that of a normal

Figure 6. Absorption spectrum recorded at about −160°C for an uncut brown diamond from the Central African Republic, with color confined to the surface (see figure 7) because of natural radiation damage and annealing. The GR1 and 595 nm lines are clearly present.

Figure 8. Absorption spectrum recorded at about −160°C for a naturally colored, fluorescent-green faceted diamond. The spectrum is indistinguishable from that of a normal treated yellow stone (see figure 4).

treated yellow stone, and yet we know from the stone's history that the color must be natural.

We know that the lines at 503 and 496 nm can be induced by the annealing of a stone that has been irradiated, so we should not have been too surprised at recording the 595 nm band in this type of stone. To our knowledge, though, it was the first time it had been seen in a natural *faceted* stone.

At least this particular stone revealed evidence of natural radiation damage and annealing in the form of brown radiation stains on an uncut portion of the girdle (figure 9), but the fact that the 595 nm band has been observed in this stone makes the identification of the origin of color in these fluorescent green stones very difficult.

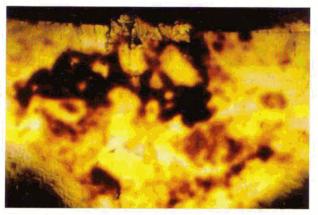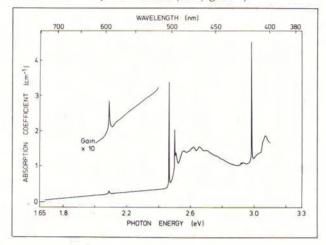Of late, we have also been observing the GR system in the spectrum of very large, naturally colored, brown type II stones. Because of the increased popularity of colored diamonds, any diamond with a definite body color, almost regardless of quality, is being sorted out as a possible fancy stone. As a result, in addition to the attractive canary yellow stones that have been traditionally sought after (figure 10), we are seeing many more type I_B stones which, not many years ago, would have been rejected by the trade as undesirable. Many of these stones are easily recognizable because of their characteristic large areas of cloud-type inclusions, and because their yellow body colors usually have some other component present, that is, green or brown.

In the past, color identification in this type of stone presented no problem for the gemologist, because normally the true canary yellow (like any other natural type I_B diamond) shows no sharp changes in transmission in the visible spectrum

Figure 10. Naturally colored canary yellow diamond, 0.63 ct. Photo by Tino Hammid.

at room temperature. The color is due to the gradual absorption of wavelengths that are shorter than 550 nm.

The appearance in the lab of more of these stones and the advent of low-temperature spectroscopy caused us considerable worry a year or so ago when, in addition to the normal gradual absorption of the shorter wavelengths, we noted at low temperatures the occurrence of the radiation-related peak at 637 nm and sometimes the 503 nm band (figure 11).

Figure 11. Absorption spectrum recorded at about −160°C for a naturally colored yellow type 1_B diamond, showing the peaks at 637 and 503 nm and the typical 1_B type absorption of wavelengths shorter than 550 nm.

Figure 9. Natural radiation "staining" on an unpolished portion of the girdle of the stone referred to in figure 8. Magnified approx. 70×.
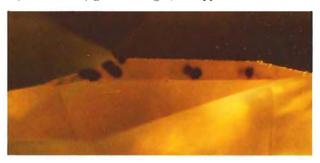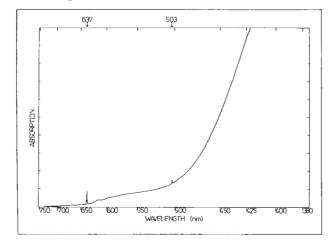
Researchers have found that the 637 nm band occurs primarily in diamonds that contain a high percentage of the nitrogen impurity in isolated substitutional form, that is, in type I_B diamonds. It has been proved experimentally that irradiation and subsequent annealing induce the 637 nm band in synthetic type I_B diamonds, during which process the color of the stone is altered from its original yellow to pink (Davies, 1977). In fact, the 637 nm band had previously been reported only in treated diamonds, particularly in treated pinks (Liddicoat, 1969), and so the diagnostic value of this line when seen at low temperatures in yellow type I_B stones had to be determined.

After recording the absorption curve in the nine stones of this type in which we had observed the 637 nm band, we noted that in each case the line was extremely weak, and it soon became apparent that the obvious cause of the body color was the gradual absorption of the shorter wavelengths. This being a natural phenomenon, we decided that if these stones had been artificially subjected to radiation and annealing it could only have been in minimal amounts and as such had no effect on the color of the stone. In fact, our view was that this was yet another case of the natural occurrence of a radiation-related peak and that under these circumstances it should be reported accordingly.

IN CONCLUSION

I emphasize that the foregoing problems affect only a small percentage of colored diamonds. Certainly, as discussed above, reliable methods for the detection of cyclotron-treated diamonds are now readily available to diamond merchant and laboratory gemologist alike. And in the "vast majority" of cases where a yellow diamond has been irradiated and annealed by man, it is virtually always possible to recognize this fact with the adept use of the hand spectroscope in conjunction with a cold light source.

However, I can foresee a time when, at least with some of this small percentage of colored diamonds, the methods currently available will not be adequate to determine whether the color is caused by man's interference. It is likely that the problem of differentiating between irradiation by man and irradiation by nature will continue to arise and with even greater frequency.

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HEAT TREATING CORUNDUM: THE BANGKOK OPERATION

By Jack S. D. Abraham

Following up on Nassau's 1981 article on the technical aspects of heat treating ruby and sapphire, the author reports his personal observations of the actual heat treatment process in Bangkok. He discusses the potential effects that this process can have on a stone—both positive and negative—and emphasizes the importance of the natural make-up of the stone itself to the success of heat treatment.

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A Bangkok gem dealer buys a 10+-ct ruby for a six-figure sum and heats it hoping to improve its color and value. After one heating, the stone dulls and cannot be sold for half of its original price. But a few tries later the stone is so improved that a major European dealer buys it for almost five times the original amount—knowing that it has been heat treated.

Another Thai dealer pays a large sum for a 600-ct piece of sapphire rough. He then cuts it into four sections and heats each. For the largest piece, which is over 100 ct, he receives 20% more than he paid for the entire original stone—again from a buyer who knows the stone is heated.

A third dealer, however, heats a sapphire for which he has paid a six-figure sum but instead of enhancing the color, the treatment causes the stone to break into several pieces. It is now worth a fraction of its original price.

Such incidents suggest that the heating of ruby and sapphire has become a fully accepted, if very risky, fact of life in the Far East. It is generally acknowledged in Bangkok that over 95% of the rubies and sapphires exported from the Far East have been subjected to heat treatment (figure 1). For a combination of reasons, including increased demand for corundum gems and the inadequacy of traditional sources, ruby and sapphire dealers worldwide are now dependent on heat treatment to generate meaningful market supplies.

This surge in interest in the heat treatment of corundum has led to a number of articles discussing manners and methods of treatment as well as the detection of treated vs. nontreated sapphire by the gemologist (Nassau, 1981; Crowningshield and Nassau, 1981). To date, however, very little has been published regarding the actual treatment of these stones in Bangkok and relating some of the practical aspects of the treatment process. The purpose of this article is to fill this void.

Figure 1. This 80-ct blue sapphire from Sri Lanka and the five Thai rubies (averaging 3.2 ct each) that surround it are representative of the stones heat treated in Bangkok in recent years.

In the course of three recent visits (the last of which was in Spring 1982), the author explored this subject with friends and associates in Bangkok who are connoisseurs of the art of heat treating corundum, a secret that is very well guarded. During these visits, the author was able to study several Bangkok treatment operations firsthand and had detailed discussions about the processes with several leading dealers. These experiences form the basis of this article and should serve to augment the previous, more detailed and technical papers on the heat treatment of corundum cited above. It is important to note that Bangkok is not the only center for heat treating corundum, inasmuch as Sri Lanka, Australia, and Hong Kong have treatment operations as well. This article will deal only with the author's observations in Bangkok, however, and only with those stones that are heated to duplicate processes that could occur in nature.

THE OBJECTIVES OF HEAT TREATMENT

There are historical references in the literature that discuss the heat treatment of corundum from a purely scientific point of view (Mawe, 1813; King, 1870; Bauer and Spencer, 1904; Church, 1905). It is questionable, though, whether the treatment of sapphires was known to the commercial world prior to a few years ago, when gem dealers learned that they not only could enhance the existing color of some sapphires, but also could transform near-colorless sapphire with

inherent latent qualities into fine fancy-colored stones, including yellow and green as well as blue. More recently, they found that excessively dark blue material could be lightened through heat treatment. They also found that some rubies could be improved with heating.

It soon became evident that heating could also result in cracked or shattered stones, or in the dulling of color or other damage. Furthermore, because color in a stone depends on the presence of trace amounts of certain elements (e.g., iron and titanium), the heating process will do absolutely nothing to improve color if these elements are absent from the original material.

Often, the heating of sapphire induces as much as an 80% to 90% color change, from grayish white or milky to various shades of blue. But all types of sapphire, from chalk white to ink black, are sent to the ovens. The specific objectives of heat treatment vary according to the quality of the sapphire being treated and the country of its origin (Sri Lanka, Thailand, Cambodia, Burma, Kashmir, or Australia). In general, it is easier to deepen the color of a stone than to lighten it. Specifically, a 70% color change from light blue to deep blue is less difficult to attain than a 10% reduction in color in an overly dark blue stone. This fact explains why some light, near-colorless pieces of Sri Lankan rough may sell for several times more than most deep blue Australian rough. In fact, the most desirable whitish-blue Sri Lankan rough commands prices comparable to those paid for blue rough five years ago. But reducing color,

as in Australian stones, and darkening color, as in Sri Lankan stones, is not all that heating does. The process is often used to reduce and even eliminate "silk and asterism" in Burmese sapphires and, at the same time, enhance their color (Nassau, 1981).

Likewise, for ruby, heating is done to eliminate silk, to reduce secondary colors, and to increase the purity of the primary red. A mere 5% increase in red can mask unappealing secondary colors by the same amount. And a decrease, say, in purple by just 5% can mean a dramatic increase in quality.
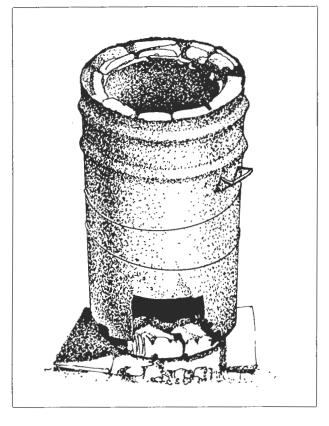
It must be emphasized that the heat-treatment process described here is designed to duplicate heating processes that could occur in nature; it can only bring out latent inherent qualities in the stone. In the author's experience, there has been no loss of color over time in heat-treated blue Sri Lankan sapphires and in rubies. This process should not be confused with diffusion treatment, which provides a colored synthetic coating to a natural stone (Nassau, 1981); this coating may be removed in polishing. The proposed Federal Trade Commission guides for the jewelry industry (submitted by the Jewelers Vigilance Committee on December 31, 1981) do not require disclosure of heat treatment if it is not detectable by a gemological laboratory, as is the case with most heat-treated corundum. However, the use of a colored synthetic coating, as in diffusion treatment, must be made known to the buyer. Knowledgeable labs can readily detect diffusion treatment (again, see Nassau, 1981) and already disclose it on their gem identification reports.

THE HEAT-TREATMENT OPERATION

Heat treatment in Bangkok is becoming more sophisticated. The design of the ovens and kilns has improved and the use of natural gas, various petroleum derivatives, and in some cases electricity allows these ovens and kilns to reach higher temperatures than the heat sources used in earlier ovens. For the most part, sapphires—which require oxygen to produce a color change—are treated in open-fire kilns using coal, natural gas, or petroleum derivatives. Rubies are likely to be treated in more sophisticated electric ovens. With the exception of the electric ovens used for rubies, there is still no thermostatic control. This means that the operators must keep close and constant watch during the entire treatment operation, particularly since the successful heat treatment of

corundum can require temperatures close to the melting point of the gem. The fire kilns are usually no more than oil drums that have been lined with bricks, clay, or concrete with a side door toward the bottom through which fuel is pumped (figure 2). The hollow center of the drum holds the crucible containing the gem rough. Loose bricks control the flow and direction of the fire to ensure that the crucible is totally engulfed in flame. In the case of charcoal-burning kilns, the crucible is surrounded by the charcoal itself.

Prior to heat treatment, the gem rough is cleaned and any heavily cracked or included portions are removed by trimming. These cracks and internal imperfections can affect the durability of the stone during heating and can often lead to breakage. Many of the gems are actually preformed during the trimming process. Following

Figure 2. The basic drum often used for heat treating corundum. The hole at the bottom may serve to accommodate the fuel source (e.g., gas or other petroleum derivatives) or as the access point to control the flames when charcoal or wood is used. Illustration by Susan Kingsbury.

Figure 3. In some instances, the stones are coated with a borax-based solution before they are placed in the smaller crucible, which is then inserted into the larger crucible for heating. In other instances, the stones are left untouched and the small crucible itself is sealed with a borax solution. Some operators use no solution at all. The stones on the left have been heated to maximum color and recut. Those in the center have been heated and await recutting. Corundum slated for heating or reheating appears on the right.

Figure 4. These groups illustrate the various results of heat treatment. It is evident that many of these stones lack the natural elements needed to attain good color. Note especially the mass of melted corundum to the left of the large blue sapphire in the center row.

cleaning and trimming, a few of the operators soak their stones in a borax-based solution (which varies according to the person who controls the operation) that is believed to form a "protective shell" on the stone to prevent damage (figure 3). The stones are then placed in ceramic crucibles and put into the kiln or oven, where they are heated up to 1600°C and maintained at that temperature for 24 hours or longer for sapphires and four to eight hours for rubies. Occasionally, higher temperatures are used, depending on the character of the stones, the oven used, and the skill of the operator. When the heating process is completed, the temperature is gradually reduced or the kiln is shut off and the gems left to cool slowly. This heating procedure may be repeated several times on a given stone until the stone attains what the operator feels is its best potential color and appearance; some stones are heated every time they change ownership. This, of course, can be very risky and improper heating may result in the shattering, cracking, dulling, overdarken-

ing, or even melting of a stone (figure 4). One can only imagine the great sums of money that are lost annually because dealers push their luck and their stones to the breaking point or misjudge color possibilities.

The heat treatment of corundum is as much an art as a science. The practitioners of this art, in Bangkok at least, all follow different rules, procedures, and formulas. These variations in technology and technique often make the difference between success and failure. For this reason, details of successful procedures remain jealously guarded, the backbone of a fascinating industry.

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NOTES
· AND ·
NEW TECHNIQUES

PINPOINT ILLUMINATION: A CONTROLLABLE SYSTEM OF LIGHTING FOR GEM MICROSCOPY

By John I. Koivula

Pinpoint illumination uses a highly flexible but extremely durable glass fiber-optic bundle that incorporates six easily interchangeable light wands of various shapes and cross-sectional thicknesses down to one millimeter in diameter. The wands are hand held and can be used to illuminate hard-to-reach areas in complex jewelry mountings. With the pinpoint illuminator, a gemstone can be examined from any angle; the light source is placed exactly where it is needed, minimizing glare and unwanted external or internal reflections.

The pinpoint illuminator has its earliest roots in medicine, specifically microsurgery. The author adapted the lighting system first for use in mineral microscopy, to examine the pits, seams, and vugs that occur in certain rocks for interesting mineral crystals. The hand-held illuminator, with its interchangeable light wands, enables the microscopist to probe these rocks as far as 3 cm or more into very small openings and provides the light necessary to examine otherwise hidden crystals. When the author subsequently applied this lighting system to gems, he found that it was extremely useful in revealing inclusions, examining mounted goods, and reviewing damaged stones. The illuminator can also be polarized to provide this special lighting effect in otherwise hard-to-reach areas, and offers greater control over thin films and other reflected light phenomena.

THE APPARATUS

The pinpoint illuminator consists of a highly flexible, rubber-coated glass fiber bundle that is 175-cm (69 in.) long and approximately 2.5 mm in diameter; six separate, easily interchangeable light wands that slip onto one end of the fiber bundle; and an adapter that attaches to the other end for quick conversion of the standard fiber-optic light source shown in figure 1 into the pinpoint illuminator illustrated in figure 2.

The probe wands, the backbone of the pinpoint system, are constructed of glass fibers with protective stainless steel shrouds and high-impact, heat-resistant, white plastic sleeves for easy attachment to the main fiber bundle. Each light wand is approximately 11.5 cm long. The inside diameter of the glass-fiber bundles varies from 3.0 mm for the largest to 0.5 mm for the smallest. The thickest probe is 4.0 mm, and the thinnest is 1.0 mm, in outside diameter.
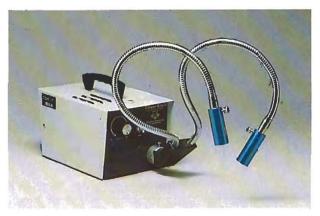
Figure 1. A standard bifurcated quartz-halogen, illuminated, fiber-optic light source.

Figure 2. The quartz-halogen illuminator adapted for pinpoint illumination.

APPLICATIONS

With the pinpoint illuminator, the gem micros-copist has at his fingertips a system of highly con-trollable illumination for practical application in gemology. The hand-held probes make it possible to put the light source exactly where it is most needed for a variety of different tasks (see table 1 and discussion below).

Viewing Inclusions. With this lighting system, groups of gas bubbles such as those in figure 3 (or pinpoint-sized included crystals) are illuminated readily and efficiently. Larger included crystals (as in figure 4) can be examined from every angle, revealing surface-growth details not seen before that are free from the extraneous hot spots and

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TABLE 1. Possible applications for the pinpoint illuminator.

Searching for tiny, otherwise invisible, inclusions such as bubbles

Studying the surface details of included crystals to determine habit and possible identity

In the close examination and study of fluid inclusions

To illuminate gems in closed-back or intricate metal mountings

Assessing the nature and extent of damage to gemstones

As a maneuverable source of cool polarized light

As an oblique illuminator to discover and study thin films

As an additional highlighting source for dark-field, transmitted, and polarized light photomicrography

As a source of illumination for detailed jewelry manufacturing

As a watchmaker's light source

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glare produced by the more traditional light sources. Fluid inclusions can be studied quite handily by a point-source-transmitted light, al-lowing close scrutiny of their gaseous, liquid, or sometimes solid contents.

Examining Mounted Goods. By placing one of the light wands at the edge of a stone set in a closed-back mounting, the entire interior of the gem is illuminated without any of the harsh reflections that make overhead sources of light virtually use-less for this task. Separation planes in assembled stones can be illuminated by simply placing a light probe at the edge of the plane at an angle slightly off parallel to the plane (figure 5).

Reviewing Damaged Stones. Determining the na-ture and extent of damage to gemstones is yet an-other area where the controllable pinpoint illu-minator excels. Surface fractures, pits, chips, and abrasions can be carefully examined for draglines or percussion marks by placing the light source right on the damaged area at the proper angle for optimum viewing of the subject.

Polarized Light. The illuminator can be polarized as well, and if an analyzer is placed in the usual position over the microscope objectives, then we have a pinpoint source of maneuverable, control-lable, polarized light that can be used in the same way a standard polarizing stage is used, but with added flexibility. The results of polarized pin-point illumination, shown in figure 6, look iden-tical to those achieved by conventional polarizing systems (Koivula, 1981). The difference lies, again, in the greater flexibility of this system and the ability to illuminate areas that would otherwise remain hidden.

Figure 3. A flowing stream of gas bubbles in a blue synthetic glass illuminated from the side by pinpoint illumination. Magnified 60×.
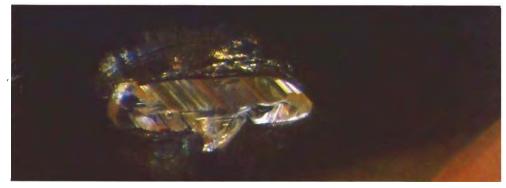
Figure 4. An elongated included crystal of olivine in an orange-brown diamond. Note the lack of glare and extraneous reflections normally encountered in diamond photomicrographs. Pinpoint illumination, magnified 45×.
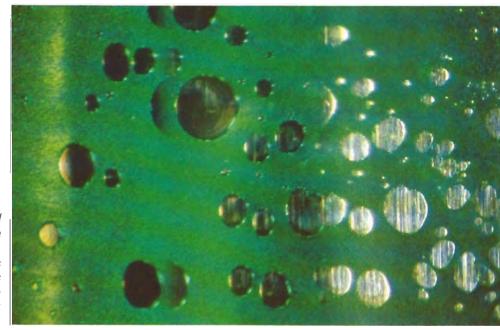
Figure 5. A series of flattened bubbles in the cement plane of an assembled synthetic spinel triplet. The change of viewing angle through different facets is responsible for the change in appearance of the bubbles. Pinpoint illumination, magnified 50×.

Figure 6. An included crystal in a natural Burmese pink spinel is lit by polarized pinpoint illumination. The clarity of this photograph is startling considering the difficult angle of illumination and the degree of magnification, 100×.

Figure 7. The lace-like pattern of this healing fracture in a Thai ruby under dark-field conditions is given additional life in the form of a brightly colored thin film. The thin-film interference colors resulted from the application of the pinpoint illuminator in an oblique position. Magnified 45×.

Thin-Film Effect. Thin films, like the one shown in figure 7, and other reflected-light phenomena (Koivula, 1980 and 1981) are more easily discovered and studied with the pinpoint illuminator because of its maneuverability. The unit is used for oblique illumination in the same way as the bifurcated fiber optic illuminator shown in figure 1 (Koivula, 1981). However, it is considerably more difficult to place the metal cable of the larger fiber optic illuminator in the precise position necessary to achieve an iridescent thin-film effect in a gemstone.

LIMITATIONS

Since the pinpoint illuminator is designed to be a hand-held instrument, it is not an ideal source of illumination for photomicrography unless one uses a modified bench stand such as a "jeweler's third hand" to hold the illuminator in a stable position during the entire cycle of a photographic exposure. This was in fact done to obtain the photomicrographs shown in figures 3 through 7. The main limitation of the pinpoint illuminator is that it is not completely portable. With a 175-cm reach, it can be used almost anywhere it is needed within the confines of a standard gemological laboratory, but use elsewhere depends on the availability of an electrical power outlet. Also, the in-

strument is not easily packed for long-distance travel. If the illuminator were freed from its power source and adapted for use in a portable gemological laboratory, this one limitation could be completely overcome.

CONCLUSION

The pinpoint illumination system has applications for the gem microscopist, the skilled manufacturing jeweler, and the master watchmaker. Anywhere a pinpoint source of cool, bright, controllable light is needed, the pinpoint illuminator can be useful. This author sees a broad acceptance of the pinpoint illuminator in the future of gemology.*

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RADIOACTIVE IRRADIATED SPODUMENE

By George R. Rossman and Yuanxun Qiu

During routine testing, a parcel of spodumene imported from Brazil was found to be radioactive. Detailed analysis showed that individual stones had levels of gamma ray emission far above those acceptable for jewelry purposes. Gamma ray spectroscopy revealed that they had been irradiated with neutrons. The colors of these stones are similar to those observed in citrine and have no counterpart in untreated spodumene. They range from brownish orange through orange to orange-yellow and greenish yellow.

A parcel of approximately 3,000 carats of faceted stones purchased as citrine in Sao Paulo, Brazil, was brought for examination to the Los Angeles office of the GIA Gem Trade Laboratory after it was observed during recutting that one of the stones did not respond like quartz. At the laboratory, the parcel was found to contain approximately 700 ct of spodumene; the remainder was citrine. The citrine-like color of the spodumene was unusual for that species, ranging from brownish orange through orange to brownish yellow and orange-yellow with an occasional greenish-yellow stone (figure 1). Additional testing with a Geiger counter revealed that the lot of spodumenes was radioactive. No radioactivity was detected in the citrine. Three representative spodumenes that showed readily detectable levels of radiation were removed from the parcel and forwarded to the laboratories of the California Institute of Technology for detailed analysis. They consisted of two emerald-cut stones, one greenish yellow and one orange-yellow, weighing 5.97 and 2.90 ct, respectively, and one orange oval-cut stone weighing 31.8 ct (again, see figure 1).

RADIATION MEASUREMENTS

All three stones indicate radioactivity when tested with a Geiger counter survey meter. The most radioactive stone, the greenish-yellow spodumene, registered 0.7 milliroentgens per hour, or 420 counts per minute (cpm) when in contact with the detector. The large, orange stone had one third the activity, while the orange-yellow stone had one tenth.

The observed count rate varies among different Geiger counters because it is highly dependent on the volume and efficiency of the detector and the geometrical proximity of the detector to the stone. For example, the stone that gave 420 cpm with a hand-held Geiger counter survey meter gave 6400 cpm with a more sensitive, large-volume, stationary Geiger counter. Because other types of laboratory radiation-detection instruments are even more sensitive than Geiger counters, detailed radiation measurements were performed with a 100-cubic-centimeter liquid nitrogen–cooled germanium detector, and an 8-in.-diameter sodium iodide scintillation detector. With the germanium detector, the 5.97-ct stone registered 43,680 cpm; with the scintillation detector, the same stone registered 152,880 cpm. When the observed count is corrected for the efficiency of the detector, the calculated true emission rate of the stone becomes 870,000 cpm, coming from both beta and gamma radiation.

Because the persistence of the radioactivity will depend on the half-lives of the radioactive species, and the penetration power of the radiation will depend on its energy, the identity of the radioactive elements was determined with a gamma ray spectrometer employing the germanium detector.

The gamma ray spectrum of the greenish-yellow spodumene showed that the isotope scandium-46 (half-life: 84 days) is the primary cause of the radioactivity. Minor amounts of man-

Figure 1. Samples of radioactive neutron-irradiated spodumene. The large orange stone at the top (31.8 ct) was emitting about 249,000 gamma rays per minute at the time of the photograph. The greenish-yellow emerald-cut stone directly below and to the right (5.97 ct) emitted 870,000 gamma rays per minute. The third stone discussed in this article, a 2.90-ct orange-yellow emerald-cut spodumene, is directly below and to the right of the greenish-yellow stone studied.

ganese-54 (half-life: 303 days) and tin-113 (half-life: 115 days) were also observed. The activity from the smaller, orange-yellow spodumene came, in decreasing order, from manganese-54, tin-113, zinc-65 (244 days), iron-59 (45 days), antimony-125 (2.8 years), antimony-124 (60 days), and cobalt-60 (5.2 years). The large, orange spodumene contained manganese-54, tin-113, zinc-65, antimony-125, iron-59, and tantalum-182 (115 days). All of these isotopes emit energetic, penetrating gamma rays.

Although the radioactivity from the scandium-46 will largely decay within three years, the presence of the longer half-life isotopes ensures that these stones will be weakly radioactive for many years to come. The isotopes in these spodumenes and their half-lives indicate that the stones had been treated fairly recently with neutrons in a nuclear reactor, apparently the same treatment given to the radioactive topaz described by Crowningshield (1981).

COLOR

When irradiated, the lavender variety of spodumene, kunzite, turns green, but the color is unstable and fades rapidly in sunlight. Other varieties of spodumene show little or no response to gamma radiation, which is usually used for such treatment. Gamma irradiation does not leave residual radioactivity. The orange color of the neutron-irradiated material is unusual and without natural counterpart in spodumene. It resembles the color of citrine. The absorption spectrum shows Fe^{2+} features in the infrared portion and an absorption edge beginning at 720 nm and rising steadily toward shorter wavelengths (figure 2). A narrow, barely visible Fe^{3+} absorption band superimposed at about 438 nm is the only other feature observable. The initial test of the stability of this color to light produced no visually apparent fading after six hours' exposure to direct sunlight. Under the same conditions, green spodumene would have faded completely.

DETECTION

Any spodumene with a citrine-like color should be tested for radioactivity. Large parcels of radioactive stones can be readily detected by Geiger counter survey meters, as can individual stones of comparatively high activity. However, casual investigation with a Geiger counter of a single stone of relatively low radioactivity may fail to detect its radioactivity. In conducting tests with a Geiger counter, it is necessary to hold the probe close to the stone and give the counter enough time to respond (several seconds). In our tests, a flat, "pancake" style probe for the Geiger counter was more than twice as sensitive as the cylindrical probe because of the greater sensitivity of the flat probe to beta radiation, and its larger sensitive area.

Because gamma radiation is highly penetrating, it deposits very little energy over the thickness of a photographic film. In a test with an instant film, 20 hours' exposure to the most radioactive stone did not produce an autoradiograph. This contrasts with the response of the old radium-treated diamonds, which produced autoradiographs rapidly (Hardy, 1949). They emitted alpha particles which had very limited penetra-

tion ability and thus deposited most of their energy in the layer of film. Specially formulated dosimeter films with enhanced sensitivity to beta and gamma radiation exist, but they require special processing and are not available at photographic supply companies. Given that an irradiated gemstone emitting gamma rays will not affect a film whereas an irradiated diamond emitting alpha rays would, the reader should not rely on this test as assurance of the safety of a stone.

DISCUSSION

An emission rate of nearly one million gamma rays per minute from a gemstone is undesirable and should be a matter of concern for both buyers and sellers. Although the levels of radiation are comparatively low, the use of these stones would represent a source of radiation to the body that is both unnecessary and avoidable. To put into perspective the level of radiation that an individual stone represents, it is useful to compare the most intensely radioactive spodumene to natural background levels of radiation. If the stone that emits 0.7 milliroentgens per hour were worn in direct contact with the skin for 10 hours per day, 5 days per week, in about 2½ weeks it would expose the wearer to an amount of radiation that would normally be received in one year from natural sources such as cosmic rays and radiation from soil and air. If it were worn 24 hours per day, seven days a week, in one year the total dose absorbed by the body would be about 4.2 rem[*]. This is above the United States federal standard for radiation dose to the general population (0.5 rem per year) but below the federal standard for occupational exposure of workers (5 rem per year whole body dose, or 18.75 rem per quarter year for dose to the extremities such as fingers). A statement from the Nuclear Regulatory Commission to the effect that these stones would not be desirable for extended personal wear was reported by Crowningshield (1981).

While some investigators conclude that occasional exposure to such low doses does not constitute a significant health risk, others are of the opinion that even very low doses of radiation present a statistical risk of biological effects (Upton,
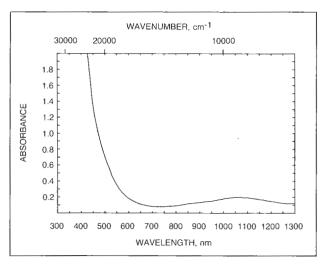
Figure 2. Optical absorption spectrum of orange, irradiated spodumene taken with unpolarized light through a 1.2-cm path.

1982). Even though the medical implications of such a stone are debatable and a matter of current controversy, it would be prudent to avoid the unnecessary exposure to radiation that these stones represent. This is particularly true for items designed to be worn on the chest or neck which could expose internal organs to radiation from the penetrating gamma rays. A dealer who unknowingly handles hundreds of radioactive stones at a time is faced with a much less desirable situation. The dose he receives would depend on many factors, such as length of exposure and proximity of the stones to the body, but in a day it could reach the level that an individual with a single stone would reach in a year. Even though the authors understand that several efforts are being made by U.S. regulatory agencies and commercial interests to stop the production of radioactive gemstones, the importance of the recommendation by Crowningshield (1981) that jewelers who handle large parcels of gemstones should check their stones with a Geiger counter is reinforced by the commercial availability of radioactive spodumene.

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*A source emitting 1 roentgen of gamma radiation will cause the body to absorb a dose of about 1 rem (a rem refers to the biological effects of the radiation).

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TUGTUPITE: A GEMSTONE FROM GREENLAND

By Aage Jensen and Ole V. Petersen

The red variety of the mineral tugtupite, a rare silicate closely related to sodalite, has been used as a gemstone since 1965. This article presents the history of the mineral and details of its mineralogy and gemology. A recently discovered light blue variety of tugtupite is also described. Thus far, tugtupite has been found in only two localities: (1) Lovozero, Kola Peninsula, U.S.S.R., where it occurs as very small grains; and (2) Ilímaussaq, South Greenland, where it has been located at several places within the Ilímaussaq intrusion. Gem-quality tugtupite has come almost exclusively from one occurrence, a set of hydrothermal albite veins from the Kvanefjeld plateau in the northwestern corner of the Ilímaussaq intrusion.

The mineral that is now known as tugtupite was discovered in 1957 by Professor H. Sørensen in the coastal cliffs of Tugtup agtakôrfia on the north coast of the Tunugdliarfik fjord, South Greenland. It was first mentioned under the provisional name "beryllium sodalite" in the reports of the International Geological Congress, Norden (Sørensen, 1960).

Tugtup agtakôrfia lies within the geologically famous Ilímaussaq alkaline intrusion. This approximately 150-km² nepheline syenite intrusion is situated on both sides of the Tunugdliarfik fjord a few kilometers to the east of the town of Narssaq. Close to 200 different minerals have been described from this intrusion in the period from 1823 to the present.

Coinciding with the presentation of this new mineral from South Greenland, a description of an apparently identical mineral called beryllosodalite was published by Semenov and Bykova (1960). The material they described came from the Lovozero intrusion of the Kola Peninsula, U.S.S.R. At this locality, the mineral is rather rare and has never been found in masses larger than 3 mm.

Additional data were published by Sørensen (1963). He concluded that the mineral was a new species and proposed the name tugtupite, which is derived from the locality where the mineral was first found. In 1965, the Commission on New Minerals and Mineral Names of the International Mineralogical Association approved both the mineral and the name.

Danø (1966) described the crystal structure of tugtupite. A detailed description of the crystal habit, the pseudocubic penetration trillings, and the numerous localities where tugtupite had been found from the time that it was first traced at Tugtup agtakôrfia until 1971 (including the only one that has produced gem material of any significance) was presented by Sørensen et al. (1971). Another type of twin, pseudotrigonal contact trillings, was subsequently described by Petersen (1978).

The tugtupite from the type" locality was described as white, but Sørensen (1960) mentions that the color changes to light pink when the mineral is exposed to strong sunshine. In 1962, pink tugtupite was found at Kangerdluarssuk, South Greenland; but it was only when a deeper red tugtupite was found at Kvanefjeld, South Greenland, in 1965 that tugtupite attained gemological interest (figure 1). Thus far, the material used in jewelry has come almost exclusively from the locality at Kvanefjeld. Cabochons of red tugtupite were introduced as a new gem material by the jewelry firm A. Dragsted of Copenhagen in 1965, and presented at the Eleventh International Gemmological Conference in Barcelona in 1966.

In the first years after its introduction tugtupite was mounted almost exclusively in gold. In recent years, however, silver mountings have also become common, as illustrated in figure 2.

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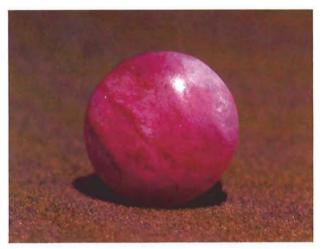
Figure 1. Red tugtupite cabochon, 2.51 ct. Photo by Mike Havstad.

Figure 2. Tugtupite mounted in silver. This cabochon measures approximately 30 × 15 mm.

MINERALOGY

Most tugtupite is massive; only a few well-developed crystals of this rare mineral have been found, growing on walls of cavities in massive tugtupite. Such crystals are short, prismatic, and transparent, they are colorless or pale pink, and they range in size from 1 × 1 × 1 mm to 3 × 2 × 2 mm. Tugtupite belongs morphologically to the crystal class $\overline{4}2m$: figure 3a shows a drawing of a slightly simplified idealized crystal; figure 3b illustrates an idealized contact trilling of tugtupite.

Optical and Physical Properties. The color of "red" tugtupite varies from light pink to dark cyclamen red (figure 4). Red tugtupite is pleochroic, showing two different hues of dark red, one with a weak bluish tint and the other with a weak orange tint.

The color of red tugtupite fades when the stone is kept in darkness but is regained when the stone is exposed to sunshine; the color is quickly restored when the stone is exposed to ultraviolet radiation. Red tugtupite has been used in jewelry since 1965. Some of the early customers have returned jewelry with faded tugtupite to the firm of A. Dragsted, where the problem was solved by exposing the stone to long-wave ultraviolet radiation for 15 minutes. No customer has had this treatment performed more than once (Ove Dragsted, personal communication).

So far only the red tugtupite has been used in jewelry; the white variety has shown no potential as a gem. Recently, a light blue variety of tugtupite has been found at the Kvanefjeld plateau that might be of gemological value, but it is very scarce.

To the authors' knowledge, fewer than 10 cabochons of blue tugtupite have been cut; five small cabochons (1–5 ct each) have been made in the polishing laboratory of the Institute of Mineralogy of the University of Copenhagen. Pleochroism has not been observed in the light blue material.

Tugtupite has a vitreous luster. It has a hardness of 6½ on the Mohs scale. There is a weak cleavage parallel to {101} and {110}. The fracture is uneven. Tugtupite is generally rather opaque, but small amounts of red tugtupite have proved to be transparent enough to be faceted (again, see figure 4).

Tugtupite is optically positive and is most often uniaxial, though axial angles as large as 10° have been observed.

Figure 3. Drawings of (a) an idealized crystal of tugtupite and (b) an idealized contact trilling of tugtupite.

The refractive indices of tugtupite (which were determined by means of the $\lambda - T$ variation method on pure material) are: for white tugtupite from the type locality at Tugtup agtakôrfia, $n_\epsilon = n_\gamma = 1.502 \pm 0.002$, $n_\omega = n_\alpha = n_\beta = 1.496 \pm 0.001$ (Sørensen, 1960); and for the red tugtupite from the Kvanefjeld plateau, $n_\epsilon = n_\gamma = 1.499 \pm 0.001$, $n_\omega = n_\alpha = n_\beta = 1.495 \pm 0.001$ (Sørensen et al., 1971). The values 1.495 and 1.499 are generally obtained when polished bases of cabochons are measured on the refractometer. However, faceting-quality material yields slightly lower refractive indices. Measured on the refractometer, polished bases of the light blue cabochons give $\omega = 1.495$ and $\epsilon = 1.499$.

Sørensen et al. (1971) gave the density of red tugtupite as 2.33 ± 0.01 and the calculated density as 2.35. Sixteen cabochons of red tugtupite in the possession of the Geological Museum vary in density between 2.27 and 2.44 due to porosity and the presence of minerals other than tugtupite in the cabochons. The five light blue cabochons vary in density between 2.33 and 2.36.

The fluorescence of red tugtupite has been described by Dragsted (1970) as apricot colored when the stone is exposed to long-wave ultraviolet (U.V.) radiation and salmon red when exposed to short-wave U.V. radiation. Povarennykh et al. (1971) reported that red tugtupite fluoresced yellow-orange to long-wave U.V. radiation. Having investigated most of the red tugtupite in the possession of the Geological Museum of the University of Copenhagen (more than 100 specimens in total), the present authors prefer to describe the fluorescence of red tugtupite as dark cyclamen red with short-wave U.V. radiation and varying from cinnabar red to light cyclamen red with long-wave U.V. radiation. Light blue tugtupite fluoresces light orange-yellow to long-wave U.V. radiation and light carmine red to short-wave U.V. radiation, rather similar to some of the red tugtupite exposed to long-wave U.V. radiation.

It is important to note that the exposure of light blue tugtupite to U.V. radiation must be of short duration (no more than 30 seconds), or the light blue stone will turn light red. This light red color is not stable, but on fading it leaves a reddish-blue hue that is less attractive than the original light blue of the stone. The bottom row of figure 4 shows, from left to right, two unexposed light blue tugtupites, two light blue tugtupites that were exposed to ultraviolet radiation the day before the photo was taken, and one light blue tugtupite that was exposed to ultraviolet radiation two months before the photo was taken.

Crystallography. According to Danø (1966), tugtupite belongs to the tetragonal crystal system, with space group I$\overline{4}$. The crystals display positive piezoelectric effect and lack a positive pyroelectric effect. The unit-cell parameters of tugtupite show insignificant variations. The unit-cell pa-

Figure 4. Upper row: four cabochons of dark red tugtupite. Middle row: two cabochons of light red tugtupite and three faceted dark red stones. Bottom row: two untreated cabochons of light blue tugtupite, two cabochons of light blue tugtupite that were exposed to ultraviolet radiation the day before the photo was taken, and one cabochon of light blue tugtupite that had been exposed to U.V. radiation two months before the photo was taken. For scale, the center stone in the bottom row measures approximately 7 mm × 10 mm.
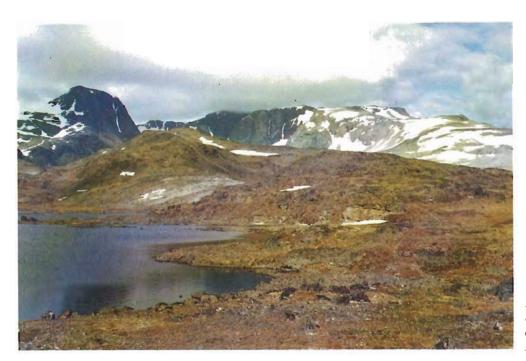
Figure 5. View to the east from the tugtupite occurrence on the Kvanefjeld plateau.

rameters of red tugtupite from the Kvanefjeld plateau are: $a = 8.637 \pm 0.001$ Å, $c = 8.870 \pm 0.002$ Å (Sørenson et al., 1971).

The crystal structure of tugtupite is very closely related to that of sodalite. The formula for tugtupite is $Na_8Al_2Be_2Si_8O_{24}(Cl,S)_2$, while that of sodalite is $Na_8Al_6Si_6O_{24}Cl_2$. A comparison of the two reveals a substitution of BeSi for AlAl in the sodalite structure; this accounts satisfactorily for the lower symmetry of tugtupite.

OCCURRENCE

Since tugtupite was first discovered in 1957, in very sparse amounts, at Tugtup agtakôrfia, it has been found in a rather large number of places all over the Ilímaussaq intrusion. Thus far, though, only one site—in the northwesternmost part of the intrusion—has produced gem material of any significance.

When this gem-quality material was first discovered in 1965, access to the locality included a rough ride by car from the town of Narssaq, along the Narssaq River, to the foot of the Kvanefjeld plateau. From here, a half-hour walk, including a 300-m ascent along a well-marked path, brought one to the top of the scenic plateau in the immediate vicinity of the occurrence. Figure 5 shows the view to the east from the occurrence. In 1979 the road was extended in connection with prospecting activity in a potential uranium deposit. It now winds in narrow steep curves, close to the old path, up to less than 100 m from the top of the plateau. The entire occurrence covers an area no more than 25×5 m, with the tugtupite scattered in a set of highly irregular hydrothermal veins, up to 0.5 m wide, intersecting the augite syenite country rock. These veins are mainly composed of fine-grained albite; they may be zoned, with tugtupite concentrated in the central part, but tugtupite can also be found disseminated in the immediately surrounding syenite. The intense cyclamen red tugtupite occurs as angular patches up to as large as 10 cm across. Figure 6 shows the major horizontal vein as it appeared in July 1968.

Of the numerous other minerals found in the vein, the most important are aegirine, epistolite, sphalerite, pyrochlore, neptunite, and chkalovite.

Figure 6. The major vein for gem-quality tugtupite, July 1968.

Substantial amounts of tugtupite were taken from this locality in the years immediately following its discovery, and particularly large amounts of material were taken by the Geological Museum, Copenhagen, in 1969 and 1975.

THE CURRENT STATUS OF GEM TUGTUPITE

No private claims cover the occurrence of tugtupite at the Ilímaussaq intrusion. Prior to 1979, when home rule for Greenland was established, the area was under the jurisdiction of the Danish government, which held the rights to the uranium deposit inside of which tugtupite occurs. However, a special paragraph in the mining law gave residents of the area the right to use certain types of raw material, and intense juridical considerations were devoted to this subject with no definitive settlement. Today all rights, except for collecting under the auspices of the Geological Survey of Greenland for scientific purposes, belong to the community council of the town of Narssaq.

Collecting and mining of tugtupite have been carried out by anyone able to get near the occurrence. All types of mining methods have been used—picking chips with nothing but bare hands, using hammer and chisel, bringing in drilling equipment, and even dynamiting. Consequently, it is virtually impossible to estimate the amount of gem material that has been mined. Judging from the pieces of jewelry with tugtupite that can be seen in Greenland and Denmark, we are dealing with relatively large amounts.

More tugtupite, blue as well as red, occurs in the area, but right now the locality where gem-quality material has been found seems to be exhausted. However, renewed mining undoubtedly will unveil new veins with more gem tugtupite. Once the decision is made to start mining for uranium on the Kvanefjeld plateau, hitherto unseen opportunities to find new occurrences will arise.

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CARVING GEM-QUALITY OPAL

By Theodore Grussing

Gem-quality opal poses special problems for the carver that are not encountered when working with low-quality material. Herein the author uses three examples to explore these differences and the implications for success or failure in the final piece.

Traditionally, opal carvings have been created from low-quality, commercial-grade opal that has little or no play of color and is relatively inexpensive. Consequently, neither orientation to maximize the play of color nor weight loss is a source of concern. In the carving of low-grade opal, the primary objective is to display the artist's skill; all other considerations are secondary. Indeed, some carvers prefer to work on low-grade opal because they feel that a substantial play of color tends to obscure the details of the carving, which is a hallmark of their skill.

Opal dealers also have generally shied away from having their gem-quality rough carved. To begin with, gem-quality opal represents a very small percentage of all opal mined, and large pieces (generally 30 grams and up) are rare. The gemstone market usually snaps these pieces up quickly because they yield large stones and matching sets of gemstones for jewelry. Few gem materials are as difficult to match stones in as opal because of the highly distinctive colors, which vary in intensity and pattern from stone to stone. The larger piece of gem rough will usually yield matching stones, and will frequently give a higher percentage of recovery than small pieces. By contrast, there is often no ready market for large pieces of low-grade opal, and carvings have been one of the best utilizations of this type of material.

In recent years, a number of collectors have begun to seek gem-quality opal carvings in their desire to have a prized work of art that is also a fine gemstone. The carving of gem-quality opal, however, has special problems that are usually not encountered with the lower-quality material. Several of these are examined below together with a description of three examples of success—and failure—in sculpting this material.

KEY CONSIDERATIONS BEFORE CARVING BEGINS

Once the decision has been reached to carve a large piece of gem-quality opal, several problems not normally associated with the carving of opal arise. First, the subject matter must be oriented in the material to maximize the play of color and yet not unduly detract from the detail of the carving. Second, the carving should be designed in such a way that it will retain the maximum amount of this valuable material. Selection of a highly skilled gem carver is also of paramount importance, particularly one with whom you can effectively communicate, given the seriousness of the project. The author has worked closely with carver Shan Gimn Wang on a number of pieces; Mr. Wang shared many of the details of carving opal described below.

THE CARVING PROCESS

In carving opal, most carvers, including Mr. Wang, employ a variety of sintered and plated diamond tools in a flex shaft or permanently mounted arbor to rough out the shape of the carving. The piece is kept cool with water, as overheating of opal at any stage can be disastrous given the risk of vaporizing the natural water content of the

Figure 1. One side of the Royal Peacocks. The carving weighs 504 ct and measures 86 × 34 × 57 mm. Photo by Tino Hammid.

material, causing it to crack or pop. After the carving has been roughed out, with particular attention paid to the orientation of the color in the subject matter, the carver begins the polishing process. Some carvers prefer to use diamond paste for the entire procedure; others use a variety of Cratex wheels and water for coolant, and then finish with a slurry of cerium oxide on felt and loose cloth wheels. Fine results may be obtained with either method, but more care must be taken when diamond paste is used, again because of the risk of overheating the material. Cerium oxide tends to erode detail in the carving, so not infrequently the carver must go back and redo small detail areas when cerium oxide is used as the polishing agent.

Generally speaking, the greatest amount of time spent on a gem-opal carving is in prelim-

inary study of the material and in roughing out the carving. In the first instance, the carver must attempt to "read" the rough material to determine where the color bars go, whether the material is clean, and, if not, where faults and/or imperfections in the stone are located. After the stone has been charted, a subject must be chosen that will best fit the material, take optimum advantage of the play of color anticipated, and remove flawed areas. After an acceptable subject is sketched both on paper and on the opal rough, the diamond bits are used to begin the carving. As the stone is opened up, the carver must be prepared to alter design and orientation depending on what he actually finds inside. Once the actual carving is completed, the final step is simply a matter of polishing. In a carving like "The Royal Peacocks" (figure 1), fully 75% of the approxi-
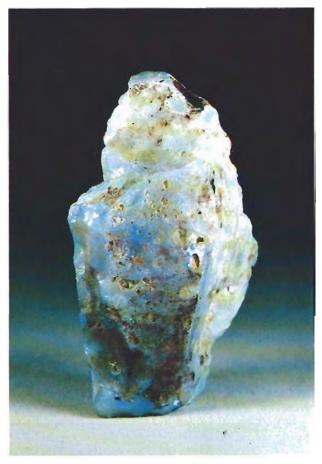
Figure 2. Gem-quality opal rough from which the Royal Peacocks was carved. Photo by Tino Hammid.

Figure 3. Design sketched on partially carved opal rough of the Royal Peacocks. Photo by Tino Hammid.

mately 100 hours that went into this piece was spent on charting the stone and roughing out the subject.

The balance of this article will deal with three carvings: The Royal Peacocks, by Shan Gimn Wang, who carves for Lapidary International, Inc., of Anaheim, California; a black opal snuff bottle, by Hing Wa Lee of Whittier, California; and one that will be referred to here as the "Disaster," by an unnamed but hopefully wiser carver. Each example illustrates a different aspect of carving gem opal.

THE ROYAL PEACOCKS

This very fine piece, shown in figure 1, weighs 504 ct and measures 86 × 34 × 57 mm. The piece of rough from which it was created weighed slightly more than 700 ct and is shown in figure 2. The opal was mined in 1978 by Paul "Gopher" Fraser and Ian "Gunna" Fraser from the Black Flag field in Coober Pedy, South Australia. The Black Flag field encompasses an area of approxi-

mately 365 m × 914 m (400 yards × 1000 yards) and is bisected by the road to Adelaide. Until about 1972, the field was little more than an auto dump. Because of its close proximity to the city (about 1 km from the saloon) and its location along the major road into town, the city fathers had the area cleaned up. The rough that was eventually transformed into the Royal Peacocks was found in a freak pocket at about the 1.25-m level on top of the Hard Band level (a layer composed of jasper and gypsum that is difficult to penetrate; the opal levels are generally below this layer).

The rough was purchased by the author in the summer of 1981 as a high-risk piece: although the opal showed numerous, potentially beautiful thick red bars, there were indications that the bars might be sandshot (i.e., granules of sand or dirt would be lodged in the silica gel of which opal is comprised). No amount of "candling" with a strong light behind the stone helped, and the only way to know for sure was to cut into the material.

Because of the doubt about the cleanliness of

the red bars, the author sold the piece to a friend who was willing to take the risk. Shortly thereafter, the decision was made to carve the material.

Shan Gimn Wang was commissioned to do the carving, through Lapidary International. After studying the opal for several weeks, Mr. Wang proposed several viable plans based on his knowledge that the central area, as previously mentioned, was comprised of numerous thick, straight red bars and the sides of the piece were potch (common opal, no play of color) with several undulating bars and swirls of intense blue and green in them. The idea that appeared most promising was to use both outer sides in a heavy relief carving, and to cautiously expose the underlying red bars; if the finished carving was to reach its maximum potential, these bars would have to be exposed substantially and they would have to be good, clean material, not sandshot. Peacocks were selected as the subject matter of the relief carving. Mr. Wang determined that peacocks would give him the greatest artistic freedom to use the undulating color bars and, too, that the colors in this area of the opal were very similar to those found in the live birds. Also of great importance was the ability to adjust the positioning of the peacocks depending on the colors and their orientation. Figure 3 shows the design on the opal shortly after the rough carving process had been started.
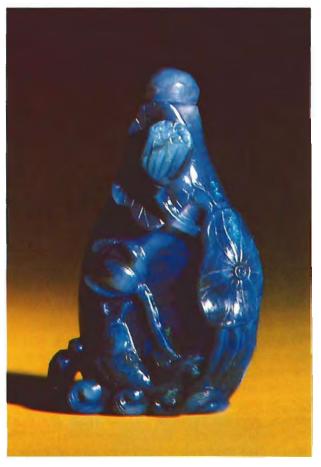
Soon after work began, the choice was confirmed, and it also became apparent that the red bars were clean, not sandshot. One major surprise was the uncovering of a thin, but extremely intense, lime-green color bar, which serves as the background for the peacock on the other side of this piece.

This carving illustrates the extraordinary skill required in carving gem opal, an intertwining of the sculptor's art and the very strong play of color of the stone. The weight retention was nearly 72%. This carving is currently on loan to the Los Angeles County Museum of Natural History.

BLACK-OPAL SNUFF BOTTLE

Some time ago, a friend of the author purchased a snuff bottle of black opal that was so poorly carved and polished that almost no play of color was present on its face. There was, however, a strong, reasonably thick color bar of blue, green, and some red on the sides running under the face of the bottle. It did not appear that the bar had

been exposed, but it was obvious that the original carver had at least partially hollowed it out. Two questions arose: (1) Would there be sufficient thickness left when the piece was recarved to expose the color bar? and (2) Would the bar display strong play of color? After examining the piece, skilled carver Hing Wa Lee reported that there was a reasonable possibility of salvaging it and exposing the beauty of the hidden color bar. The result of his reworking of this piece is pictured in figure 4. The color bar is now exposed and the bottle takes on new life: strong electric blues and greens roll across the surface, with some reds as well. It has been estimated that the value of the carving was increased by a factor of seven even with a weight loss of over 25%. This black-opal carving, weighing just over 100 ct, is currently on loan to the Los Angeles County Museum of Natural History.

Figure 4. Black opal snuff bottle after being recarved, 100 ct. Photo by Tino Hammid.

Figure 5. Although the actual workmanship on this piece is good, the carver has eliminated the play of color and thus destroyed the impact of the opal. Photo by Tino Hammid.

Figure 6. In this opal carving, the carver has fully utilized the play of color in the stone to highlight the subject matter; $34 \times 31 \times 14$ mm, 130 ct. Photo by Tino Hammid.

THE "DISASTER"

The play of color in opal is the primary source of its value as a gem material; this factor is further refined into intensity of color, number of colors, which colors, color patterns, percentage of coverage in color, trueness of color, whether or not the color is directional, and so on, but in the end it all boils down to color.

In the previous two examples, Messrs. Wang and Lee optimized the value of the opal entrusted to them by using their highly refined skills to work *with* the opal. This last example shows how a person, though skilled in the art of gem carving, proved inept in dealing with the play of color in fine opal and caused irreparable harm to a collector's piece.

The anonymous carver was given a fine piece of Olympic material (Olympic field, Coober Pedy, South Australia) to work with. The rough opal weighed approximately 800 ct and was a solid chunky piece with numerous strong color bars in it. It was anticipated that a magnificent carving would emerge, displaying strong and uniform play of color. The result was, literally, a disaster: the collector who owned the piece received a very fine carving, from the point of cleanliness and detail, but the stone had virtually no play of color. Indeed, it appeared that the carver had set out to destroy color wherever it surfaced and left it buried under potch wherever he was unable to drill it out. The weight loss of over 65% was greater than would have occurred if the stone had been cut into cabochons. The result (shown in figure 5) is a nicely carved piece of opal that shows very little play of color and is worth a fraction of what it could have been. Figure 6 illustrates the results in similar material when the carver (in this case, Mr. Wang) makes full utilization of the play of color.

CONCLUSION

The carving of gem-quality opal requires a highly skilled artisan who knows how to utilize the play of color in his art. In the final analysis, it is the play of color in opal that determines its value, and one who is skilled in bringing this color out and properly orienting it in his carving will greatly enhance the value of the finished piece.
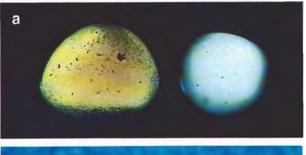
TWO NOTABLE COLOR-CHANGE GARNETS

By Carol M. Stockton

*T*wo garnets exhibiting unusually strong changes of color are discussed. Changes in color appearance are observed to occur not only between different light sources but also between reflected and transmitted illumination from the same light source. The gemological properties and chemical compositions of these two stones are noted and compared.

In the course of the study on garnets currently being pursued by the GIA Department of Research, we have had the opportunity to examine many color-change garnets. Recently we were shown two exceptionally fine examples from East Africa that are worthy of special note. Both of these stones were in the form of water-worn pebbles; stone A weighs 5.72 ct and stone B weighs 3.50 ct and is one of the finest examples of alexandrite-like garnet we have seen. Both stones show change in color from diffuse daylight or fluorescent light to diffuse incandescent light. In addition, both stones change color depending on whether the light is transmitted through the specimen or reflected from its interior surface, an observation first made by D. V. Manson. Stone A changes from greenish-yellowish brown in transmitted fluorescent light (figure 1a, left) to purplish red in reflected fluorescent light (1b, left). In incandescent light, it changes from reddish orange in transmitted (1c, left) to red in reflected (1d, left) light. Stone B, with fluorescent illumination, is light bluish green in transmitted light (1a, right) and purple in reflected light (1b, right); in incandescent light, it changes from light red in transmitted (1c, right) to purplish red in reflected (1d, right) light.

It must be noted that the combination of the sensitivity of these stones to subtle changes in the wavelengths of lighting and the difficulty of
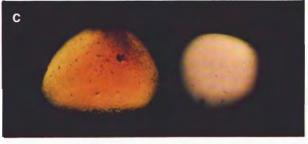
Figure 1. Color-change garnets A (left) and B (right) in transmitted fluorescent light (a), reflected fluorescent light (b), transmitted incandescent light (c), and reflected incandescent light (d).

accurately reproducing color on photographic film resulted in some anomalies between the appearance of these stones in this article and their natural appearance to the eye.

The other properties of these stones are shown in table 1, and reveal some very interesting dif-

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TABLE 1. Data for the two color-change garnets.

Properties	Stone A	Stone B
Gemological		
Refractive index	1.773	1.763
Specific gravity	3.98	3.89
Spectra (nm)		
Absorption bands	504.5	505.5
	692.5	694.0
Maximum transmission	526.0	505.5
	676.0	683.0 →
Maximum absorption	← 450.0	450.0
	563.0	573.5
Oxide composition (%)		
MgO	2.25	9.03
CaO	7.83	7.10
MnO	25.59	19.09
FeO	5.12	3.06
Al_2O_3	21.33	21.55
V_2O_3	0.15	0.38
Cr_2O_3	0.23	0.66
SiO_2	38.04	39.80
TiO_2	0.20	0.07
End-member composition (%)		
Schorlomite	0	0.16
Andradite	0	0.91
$Mn_3V_2Si_3O_{12}$	0.55	1.38
Uvarovite	0.71	2.07
Pyrope	7.51	30.11
Spessartite	59.02	43.16
Grossular	20.33	16.22
Almandite	11.83	6.37

Figure 2. Graphs of the absorption spectra of garnets A and B.

ferences and similarities. Both stones have significant amounts of V_2O_3 and Cr_2O_3, which translate to $Mn_3V_2Si_3O_{12}$* and $Ca_3Cr_2Si_3O_{12}$ (uvarovite), but stone B contains considerably more of these two components. Both garnets contain more spessartite than any other end member. Both also have unusually high amounts of grossular for stones that would otherwise be considered members of the subgroup pyralspite. However, the two garnets differ markedly in pyrope and almandite content. Stone A has more almandite than pyrope, but stone B has considerably more of the latter. The lower refractive index and specific gravity obtained for stone B undoubtedly result from the high pyrope and lower spessartite and almandite contents of this sample.

With the use of the hand spectroscope, we observed complete absorption at the short wavelength end of the spectrum up to about 445 nm,

as well as a definite thin band of absorption at about 690 nm, probably associated with the presence of chromium. Stone A, but not stone B, also shows a strong absorption band at 500 nm. Use of the spectrophotometer enabled us to locate these bands more accurately (figure 2). The general shape of both spectral curves resembles those observed elsewhere (Schmetzer et al., 1980). Maximum absorption occurs in two areas: (1) extending from about 450 nm to the short wavelength end of the visible spectrum; and (2) at around 560 to 575 nm between two major regions of transmission, one centered around 500 to 530 nm and the other increasing in transmission from about 670 nm to the long wavelength end of the visible spectrum. This pattern has been observed in the past with color-change garnets that were primarily pyropes in composition, whereas these two stones contain more spessartite than any other component.

These unusual two stones will also be included in a thorough study of color-change garnets to be presented at a later date.

Technically speaking, $Mn_3V_2Si_3O_{12}$ is not an end member, as it has never been observed to comprise more than 50% of any naturally occurring garnet, but for convenience of description we use it as though it were a garnet end-member composition.

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Gem Trade LAB NOTES

ALEXANDRITE

An unusual feature was noted during the examination of an 8.12-ct natural alexandrite in our Los Angeles lab. When this stone was viewed with the microscope, the number 15 was seen, scratched on a pavilion facet (figure 1). This questionable method of marking is employed by some private collectors, institutions, and even museums to catalogue their collections of gemstones and carvings. Fortunately, it is rare that we in the laboratory see stones marked this way. Surely an accurate description, together with three measurements to the nearest hundredth of a millimeter and the weight to the nearest point, would serve to positively identify a stone. There is no need to damage it by such inscriptions.

Figure 1. Identifying numbers scratched on a pavilion facet of an alexandrite. Magnified 25×.

Figure 2. A cyclotron-treated diamond of unusual color. Magnified 10×.

DIAMOND

Gem testers must remember to look for evidence of cyclotron treatment in fancy-shaped stones, especially if the color of the stone does not appear to be treated. For example, the yellow-green of the pear-shaped diamond seen in figure 2 is a color not normally expected of cyclotron treatment. All fancy orange-brown diamonds should routinely be examined for evidence of top-only cyclotron treatment since this color is frequently encountered in stones treated by this method. When the

stone is viewed through the pavilion, this type of treatment shows up as a line of color just in from the table and star facet edges. In most cases, no spectroscopic evidence is present in these top-treated stones. If such a stone is mounted, particularly in a gypsy setting, it is entirely possible to overlook the telltale evidence and pronounce the stone naturally colored in the absence of an identifying absorption spectrum.

It should come as no surprise to gemologists who have been keeping up with advances in diamond irradiation and annealing to occasionally see treated brown or yellow stones that lack the 592 nm* absorption line in the spectrum at ordinary room temperature.

EMERALD FAKES

Some time ago a small lot of emeralds was submitted to the Los Angeles laboratory for identification. Subsequent testing showed all but one of the stones to be natural emeralds with minor amounts of oil present. The exception proved to be a natural beryl that was coated with a green substance that imparted most, if not all, of the color to the stone.

This treatment was seen very easily under magnification when the gemologist looked through the stone and examined the opposite surface, as shown in figure 3. The areas where the coating has worn off reveal the near-colorless nature of the original stone, whereas the green areas indicate where the treatment still remains.

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*In accordance with standard international practice, GIA has adopted the use of nanometers (nm) in place of angstrom units (Å) for the measurement of wavelengths in the visible light region of the electromagnetic spectrum. Note that the conversion is 1 nm = 10 Å.
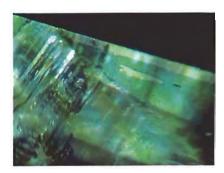
Figure 3. Green coating on near-colorless beryl, imitating emerald. Magnified 36×.

Figure 4. Beryl crystals treated in a manner similar to the stone illustrated in figure 3.

The green coating flaked off very easily with the pin end of the brush probe, and it melted when checked with a thermal reaction tester. When the stone was then tested with a cotton swab saturated with acetone, a very noticeable green stain appeared on the cotton swab. The indications are that the coating is some type of paint (like that used on glass) although similar results have been obtained with green cement or plastic.

Several months after this cut stone was tested, we had the opportunity to examine two rough beryl crystals (weighing 15.1 and 10.91 ct, respectively) that had been treated in a very similar manner (figure 4). On these crystals the green coating had been partially removed from the flat surfaces and was present mostly in surface fractures, cavities, and depressions. As with the cut stone described above, the coating flaked off with the brush probe, stained the acetone-soaked swab, and melted in response to a thermal reaction tester.

GROSSULARITE GARNET

We had nearly forgotten that translucent grossularite garnet occurs in pink as well as green until a beautiful strand of the material, with alternating green and pink beads approximately 9 mm in diameter, was submitted to the New York laboratory for testing (figure 5). It had been offered to the client as "rare jade."

Figure 5. Strand of pink and green grossularite beads, each approximately 9 mm in diameter.

JADEITE, Dangers of Heating during Jewelry Repair

The Los Angeles laboratory received for identification a lady's ring set with a 14.95 × 10.85 × 2.80 mm mottled white-and-green oval cabo-chon center stone and several diamond side stones (see figure 6). The client explained that the center stone had changed color, in this case from a relatively even medium green to predominantly white with splotches of green, while the ring was being

Figure 6. Loss of color in heat-damaged jadeite ring. Stone measures 14.95 × 10.85 × 2.80 mm thick.

repaired with a torch. Subsequent testing proved the stone to be natural-colored jadeite. This accident could have been prevented if the jeweler had possessed a fuller understanding of the effects of heat on jadeite.

To circumvent unnecessary accidents such as these, a good rule of thumb to follow is never to heat any gemstone other than diamond and then only when the proper precautions have been taken, such as cleaning the diamond thoroughly and giving it a protective coating. Most diamonds that are in frequently worn jewelry accumulate foreign substances, such as oils and soaps, particularly on pavilion surfaces. When they are subjected to high temperatures, such as would be encountered in retipping a prong, the foreign substances often become charred. These charred surfaces usually have to be boiled in a sulfuric acid bath to be removed; in more severe cases, where the surface of the stone is oxidized, the diamond must be repolished.

KORNERUPINE with Apatite Inclusions

The Santa Monica laboratory examined a 1.68-ct grayish-green, oval, mixed-cut kornerupine. The gem contained numerous slightly rounded, transparent, near colorless—appearing hexagonal prisms (see figure 7)

that looked very similar to the apatites often found as inclusions in almandite garnet. One of the larger crystals came to the surface of the gem's pavilion; it was possible to scrape this inclusion and obtain enough powder to make a spindle for X-ray powder diffraction. The diffraction pattern showed that the inclusions were in fact apatite.

OPAL

Flow Structure in Opal

A large, natural, transparent to semi-transparent, brownish-orange opal double cabochon brought to the Santa Monica laboratory for identification proved to be quite interesting. The central portion of the opal contained a large, semitranslucent, white subspherical inclusion, which occupied approximately 50% of the entire volume of the opal. Trailing down the sides of the white inclusion were numerous smoke-like dark brown to black steamers, as shown in figure 8. The central white inclusion could possibly be cristobalite, another form of silica, but no tests could be carried out to prove its nature. The smoky veiling could possibly be explained as remaining traces of the original flowing in the once-fluid silica.

Oolitic Opal

The Santa Monica laboratory recently tested a semitranslucent-to-
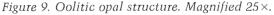
Figure 7. Apatite crystals in kornerupine. Magnified 40×.

Figure 8. Dark streamers in opal. Transmitted light, magnified 50×.

opaque polished slab that showed a play of color and proved to be a rare variety of natural opal called oolitic opal. This type of opal shows an unusual circular structural appearance under magnification, as illustrated in figure 9. Some people have put forth the hypothesis that it might be the result of opalization of a calcar-

Figure 9. Oolitic opal structure. Magnified 25×.

eous ooze or an oolitic limestone. At first glance, oolitic opal can easily be mistaken for sugar-treated opal, but under magnification the distinctive circular structure will serve to identify it. Also observed in this gem were what appeared to be a number of opaque, white to brownish white, rhombohedral-shaped included crystals that appeared to have the external morphology of calcite or some similar carbonate.

Opal Doublet

A 6.12-ct baroque-shaped opal cabochon was submitted to the Los Angeles laboratory for identification. When the stone was viewed with the unaided eye, a very attractive play of color was seen on the top of the stone and the typical ironstone matrix was observed on the back, leading one to believe that it might be a boulder opal.

Closer examination with the microscope revealed an assembled stone that had a thin brown layer with several very small patches showing play of color in the layer between the opal top and the matrix back. This layer was very soft and had several hemispherical cavities, probably formed by air bubbles (see figure 10). To minimize damage to the area, we scraped off a very small amount with a razor blade for testing with the thermal reaction tester. The substance melted easily when the hot point was applied, thus proving it to be some type of ce-

Figure 10. Hemispherical cavities in the cement layer of an opal doublet. Magnified 12×.
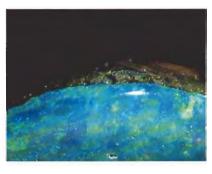
Figure 11. Shells approximately 38 to 52 mm long that contain blister pearls.

ment, formulated to resemble the ironstone backing.

Although somewhat infrequently, we have seen this type of assembled opal before. One interesting feature of this imitation ironstone cement is that it usually contains small patches showing play of color. This is apparently accomplished by adding very small pieces of crushed opal to the cement.

PEARLS

Mysterious Pearls in Shells

The New York laboratory received for testing several small (38 to 52 mm long) nacreous shells, of an unknown species, in which a pearl or blister pearl appeared near the adductor muscle scar (figure 11). The lab was unable to determine whether the "pearls" occurred naturally or were induced by man. X-ray photographs indicated natural pearls. Many of the "pearls" in the shells were not completely attached to the shell, and one appeared to be cemented to the shell. The client could not provide any information about these mysterious objects.

Unusual Natural Pearl

A large (26 mm), undrilled, baroque-shaped pearl was brought into the Santa Monica laboratory for X-ray identification. For its size, the pearl was extremely light in weight and had a distinct, rather strong, disagreeable odor. X-radiography revealed that the pearl was natural and completely hollow, with only a very thin surface shell, approximately 1–3 mm thick. The pearl appeared extremely delicate and would probably be difficult to set. The odor suggests that the irritant that caused the pearl was perhaps an organic fleshy material that did not appear on the X-ray but was in the process of decaying.

RUBY, Synthetic Star

GIA's faceting instructor, Bill Kerr, had in his possession a boule of German-produced synthetic corundum. After rounding the larger end and polishing same, he noticed how the three rays crossed each other to form the expected 6-ray star and then extended down the sides of the rough boule still attached. This inspired

the attempt to cut a cat's-eye stone oriented 90° to the c-axis of the boule that created the 6.23-ct synthetic cat's-eye ruby shown on the left in figure 12. On the right of this double-exposure photograph is the same stone viewed on the end and parallel to the c-axis. One-half of the star is now visible.

Another section of the same boule (toward the bottom) that was later worked into a stone contained part of the transparent seed crystal with a shallow overgrowth of the asteriated material. This material when cut produced a weak star with an open center caused by the non-asteriated seed-crystal section, a very unusual stone indeed (see figure 13).

Figure 12. Unusual cat's-eye synthetic ruby, 6.23 ct. View on left shows the sharp eye on the top of the stone; view on right shows the end of this cabochon and half of the would-be star.

SAPPHIRE

Dangers of Heating Sapphires during Jewelry Repair

Several months ago a client sent to the Los Angeles laboratory a man's ring set with an 11.20 × 9.10 × 7.08 mm light yellow, oval, mixed-cut center stone and numerous diamond side stones. The client explained that during the resizing process the stone had changed color from a beautiful intense yellow to a light greenish yellow (see figure 14). The client was very puzzled by this change of color due to heating and questioned whether the stone was in fact a natural yellow sapphire. Testing, however, did prove it to be a natural sapphire.

Unfortunately, we hear of cases like this quite often (see "Jadeite" above for another example). The fact that sapphires and many other gemstones may lose or change color if heated, or even worse may fracture or break, is not fully understood by some jewelers and repairpeople.

Occasionally, we see rubies or sapphires that have etched surfaces. These damaged surfaces occur when repair work is done on an article of jewelry without removing the corundum from the setting. Damage results from the stone coming into contact with the usual fluxes con-

Figure 13. Synthetic star ruby (4.22 ct) cut from a piece near the bottom of the boule from which the stone in figure 12 was cut. Note that the rays of the star do not meet in the center of the stone.

taining boron, in which corundum is soluble. Under high temperatures these fluxes, whether they are used as protective coatings or in pickling acids, become more active and may seriously attack and partly dissolve the surface of the stone. To prevent etched surfaces, the safest precaution is to remove the corundum before the mounting is repaired or pickled.

Figure 14. Heat alteration to greenish yellow in a natural yellow sapphire, 11.20 × 9.10 × 7.08 mm.

Natural Sapphire with Heat-Induced Star

Figure 15 shows the first induced-star sapphire submitted to the New York lab since the Linde Air Products Co. last submitted stones in 1968. This stone was evidently a product of the Linde patent no. 2,690,630 issued in 1954. Now that this patent and others are owned by a Hong Kong consortium, the induced-star sapphires are evidently going to become commercially available once again. In May of 1981, three such heat-induced star sap-
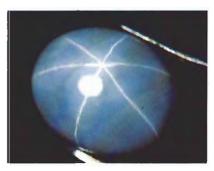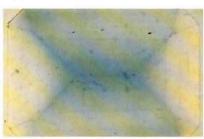
Figure 15. Heat-induced star in a 4-ct natural sapphire.

phires were submitted to the Los Angeles lab. In addition to the induced star, these three stones had evidence of surface-induced color as well.

Treated Synthetic Sapphire

Recently encountered in the Santa Monica laboratory was a very well cut 14+-ct flame-fusion synthetic sapphire that had been heat treated by the diffusion process. The gem had the refractive index and optic character of corundum and showed a chalky yellowish-white short-wave ultraviolet fluorescence typical of synthetic sapphire. Under magnification, a few tiny gas bubbles could be resolved, and only by very careful manipulation of the stone could any of the curved color zoning typical of flame-fusion blue synthetic sapphires be observed. Because the color zoning was so difficult to detect, the decision was made to immerse the stone in methylene iodide. Immersion showed that the stone had obviously been diffusion treated, in-

Figure 16. Color zoning in a diffusion-treated synthetic sapphire. Magnified 6×.

asmuch as the two sides of the pavilion were blue and the two ends were essentially colorless by comparison (figure 16). The entire crown of the stone appeared near colorless as well. Why someone would take the time to diffusion treat a synthetic sapphire is difficult to understand. Perhaps it was in with a group of stones that were being routinely treated and its synthetic nature was not known. Possibly, it was knowingly treated to hide its very elusive curved color zoning in an attempt to represent it as a treated natural sapphire.

SPINEL, Inclusions

Pink spinels and red spinels have become much better known to the consumer and are being seen much more frequently in the trade both here and in the Orient. The New York lab has had the opportunity to examine several lots of stones totaling hundreds of carats. Among the collections were two stones that had unique inclusions. Figure 17 illustrates some root-like inclusions resembling those we have seen in another cubic mineral—diamond (see *Gems & Gemology*, Fall 1974, p. 332, and Fall 1979, p. 199). Figure 18 shows a series of frosted-appearing "tennis balls," which in reality are negative "crystals" that resemble the gas bubbles seen in slag glass. Figure 19 illustrates some of the more normal spinel inclusions, including octahedrons, seen in a handsome red spinel.

TOURMALINE, Cat's-Eye

Among the many gemstones sent to the Los Angeles laboratory for identification, cat's-eye tourmalines are sometimes seen. The most common colors are various shades of pink, red, green, and blue. In the majority of these stones, tubes or needle-like inclusions throughout the entire stone give rise to chatoyancy when the stone is cut en cabochon. Figure

Figure 17. Unusual root-like inclusions in natural spinel. Dark-field illumination, magnified 20×.
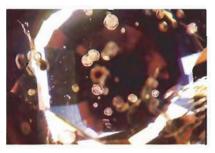
Figure 18. Negative "crystals" in natural spinel. Dark-field illumination, magnified 30×.

Figure 19. Common inclusions in natural spinel. Dark-field illumination, magnified 30×.

20 shows an exceptional 258.08-ct green tourmaline with a sharp eye.

Occasionally, we see cat's-eye tourmalines in which the inclusions are concentrated at the bottom of the cabochon, thus imparting a greater clarity and transparency to the stone than is seen in stones with inclusions throughout.

Figure 20. Exceptional green cat's-eye tourmaline, 258.08 ct.

Figure 21. Band of inclusions that does not completely cross the width of this 17.45-ct cat's-eye tourmaline.

examined with the unaided eye under a single light source and moved slightly, a strong chatoyant band was observed to move within the restricted width of its zone of inclusions. The areas on both sides of the band of needle-like inclusions were relatively free of inclusions. One of these stones, weighing 17.45 ct, is shown in figure 21.

Recently submitted to the Los Angeles laboratory were two cat's-eye tourmalines that were slightly different from those that we usually encounter. Each of these stones had a band of needle-like inclusions that was positioned down the center of the stone. When these stones were

Editorial Forum

MORE ON JADE NOMENCLATURE

I think that Jill Hobbs's article on "The Jade Enigma" is perhaps the best of its kind yet written. Unfortunately, a common misconception was perpetuated in the piece on jade nomenclature on page 5. I quote: "The color of the material, however, indicates the amount of iron present." This is simply not true. The color indicates that some iron is present, but the depth of color is more a function of the oxidation state of the iron than the total amount. There are tremolites with a deep green, but they contain only small amounts of iron.

John Sampson White
Smithsonian Institution
Washington, DC '

Actually both you and Hobbs have valid stances. From a strictly academic viewpoint, Hobbs is correct in stating that the amount of ferrous iron present is most responsible for the green color of nephrite. As you know, tremolite and actinolite are amphiboles belonging to the tremolite-ferroactinolite series, with the general formula $Ca_2(Mg,Fe^{+2})_5 [Si_8O_{22}] [OH,F]_2$. This series varies in color from colorless-to-grey tremolite, to pale-to-dark green actinolite, to dark green to black ferroactinolite with increasing ferrous iron replacing magnesium. However, other factors may also influence the green color of nephrite, but are generally considered of less importance than the total ferrous iron content. The iron-poor tremolite that you noted is one such example. It could be pigmented by an interaction between trace amounts of ferric iron with the ferrous iron present. Another alternative is that trace amounts of chromium are responsible for the green color. According to George Rossman of Cal Tech, this is fairly common in nephrite. —Editor

COMMENT ON "HEAT TREATING CORUNDUM" LETTER BY G. A. TOMBS

Mr. Tombs is indeed justified in complaining about my misquoting him. In the original manuscript, I had written "the 4000°C reported *to* Tombs" (the citation also appeared in this form in a related article by R. Crowningshield and myself in *Journal of Gemmology*, Vol. 17,
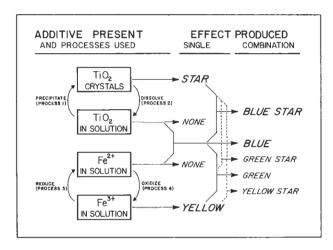
1981, pp. 528–541). Unfortunately, by the time it appeared in print (*Gems & Gemology*, Vol. 17, 1981, pp. 121–131), it had been inadvertently changed to "reported *by* Tombs," erroneously implying that I thought that Tombs had accepted this statement. I regret this error and apologize to Mr. Tombs.

Other matters raised by Tombs deserve brief comment. The reversal of his α and β alumina now makes much more sense, although it would be desirable for him to publish this evidence; if the needles are indeed β-corundum, then the very small quantities present would probably be impossible to detect by conventional X-ray powder diffraction, and the much more complex electron microscope results deserve public scrutiny.

The differences in impurity content shown by Tombs are indeed interesting and probably significant. As stated in my *Gems & Gemology* article, considerable variability in the heat-treatment behavior of sapphire must be expected "depending on the exact composition of the stone as well as on its previous treatment history, both in nature and by man."

I have prepared an additional drawing to compliment my *Gems & Gemology* article which summarizes the various results produced by titanium and/or iron in sapphire, including clear material and stars.

K. Nassau
Bernardsville, NJ 07924

GEMOLOGICAL ABSTRACTS

Dona M. Dirlam, Editor

COLORED STONES AND ORGANIC MATERIALS

African star coral, a new precious stylasterine coral from the Agulhas Bank, South Africa. H. S. Pienaar, *Journal of Gemmology*, Vol. 17, No. 8, 1981, pp. 589–601.

"Akori" coral was the local name given to the red, blue,

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.

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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.

and violet stylasterine coral, *Allopara subviolacea*, that was highly prized in Cameroon before the 18th century. In 1978 another stylasterine coral, *Allopora nobilis*, appeared on the world market as African Star Coral. It is found on the Agulhas Bank, along the coastline of South Africa, in red, pink, violet, and yellow-orange hues. The author focuses on the zoological description, taxonomic classification, methods of recovery and treatment, and chemical and physical properties of this material. He also discusses a gemological classification of corals.

After harvesting, the coral trees are cleaned, dried, and sawed before they are "stabilized"; that is, a mixture of methyl and butyl methacrylate monomers is infused into the open pores of the coral under vacuum impregnation and polymerized by benzoyl peroxide into a tough co-polymer plastic. The pink coral is sometimes bleached with peroxide to a whitish-pink product that resembles "angel's skin." In some cases, red dye is incorporated into the plastic monomer of the yellow-orange coral during the stabilizing process, which results in a deep red product that duplicates "moro" coral.

Allopara nobilis is a calcium carbonate that crystallizes as platelets of orthorhombic aragonite with a small percentage of organic material. It ranges in hardness from 3 to 4 on the Mohs scale with an excellent toughness. Its natural fragility is eliminated by the methacrylate impregnation. There is no fluorescence to long-wave or short-wave ultraviolet radiation unless the material has been dyed to imitate "moro," or "oxblood," coral, in which case the long-wave fluorescence is a brilliant scarlet. The refractive index is difficult to determine, with at best a vague spot reading at 1.65. A twinkling effect seen through a rotating polarizing filter confirms the strong double refraction expected from aragonite. After impregnation, the specific gravity is 2.41 ± 0.08. The material reacts to acids. Thermal tests do not produce "sweating" on the surface, but a fruity aroma characteristic of plastic is apparent. Continued heat chars the surface. Microscopic examination of the surface reveals three diagnostic features: (a) parallel concentric growth banding; (b) white, star-like spots; and (c) white "comet-tails" that usually cut across the concentric growth banding. Pienaar concludes with a summary of the taxonomy of coral in an effort to eliminate some of the existing confusion.   *ERL*

The Biwa pearl. G. Brown, *Australian Gemmologist*, Vol. 14, No. 7, 1981, pp. 153–157.

This article presents a succinct history of the Biwa pearl, emphasizing the Japanese contribution to its development. The author reminds us that although these freshwater cultured pearls of differing shapes and colors were named for their first commercial production at Lake Biwa, Japan, Biwa pearl is a trade name used "to describe all fresh-water cultured pearls—irrespective of their country of origin."

In the 1930s, Fugita and Yoshida discovered the mantle-tissue implantation method of initiating pearl growth in mussels, which proved to be more efficient and less dangerous than the then-popular bead-nuclei method. Seiichiro Uda, the "father" of the Biwa pearl industry, subsequently capitalized on their discovery and made freshwater pearl cultivation commercially viable. However, success in marketing the Biwa pearl did not occur until 1961, when an American market established the "respectability" of the freshwater cultured pearl after the true nature of the Biwa pearl had been disclosed.

Brown then describes current production in a step-by-step format that is a composite of how the Biwas are actually produced, since these facts are not readily revealed by Japanese sources. In addition to the author's speculation as to the exact process of Biwa pearl production, the reader is told how to judge the ultimate quality of any Biwa pearl. Size, shape, color, and orient—the important factors—are explained and illustrated.   *JCL*

Domestic cultured pearls on the way. H. Huffer, *Jewelers' Circular Keystone*, Vol. 152, No. 10, 1981, pp. 100–103.

Japan may soon be faced with some competition from the U.S. in the freshwater cultured pearl market. John Latendresse is cultivating pearls in Tennessee, where the climate is much the same as the Lake Biwa area in Japan. Latendresse has gained experience in the field by supplying the Japanese with raw materials for the saltwater pearl-growing business for 27 years. He believes that he can compete with Japan because of the rising labor costs there versus relatively cheap labor in Tennessee. Also, Tennessee has an abundance of clean water while Japan is troubled by water pollution. His first harvest will be a "token" one to assess how these pearls, which have been growing now for two years, are doing. He anticipates a broad range of colors, some round cultured pearls up to 20 mm, and some baroques that are even larger.   *RSS*

Geochimie et typomorphisme des aigues-marines zonées (Geochemistry and typomorphism of zoned aquamarines). V. F. Barbanov, *Bulletin de Minéralogie*, Vol. 103, 1980, pp. 79–87.

Zoned aquamarine and other beryl crystals from Cherlovaya Gora, an area in the mountains north of Mongolia, were studied using different physical and chemical techniques. Zoning is shown to be related to tectonic variations (that is, geological structural features, especially folding and faulting) during crystal growth; it is also useful as a typomorphic criterion for geochemical conditions of rare-metal vein formation.

The resulting evidence reveals that vein crystals that formed under deep, more-or-less calm tectonic conditions have a brilliant yellow color and a homogeneous structure. Vein crystals that formed under shallow, intense tectonic conditions were seen to have zonal properties and to vary in the quantity of impurities—such as iron, magnesium, calcium, lithium, sodium, potassium, cesium, water, and scandium—they contained.

There was evidence that the presence of iron oxide increased the refractive index of the aquamarine as well as caused the blue color. The presence of water, on the other hand, decreased both the R.I. and the intensity of the blue color. The author did not discuss the effect of water on the composition of the other colors of beryl.

Barbanov further states that all the variations in properties and structure of the microimpurities in zoned beryl crystals are due to changes in the tectonic environment, crystallization conditions, and the alkalinity of the solution and its oxidizing properties. A bibliography containing 19 references is included, as well as numerous charts and graphs.

Michel Roussel-Dupré

A mineralogical study of the Fengtien nephrite deposits of Hualien, Taiwan. L. P. Tan, C. W. Lee, C. C. Chen, P. L. Tien, P. C. Tsui, T. F. Yui, *National Science Council Special Publication 1,* Parts 1–4, 1978.

During a 1973 prospecting project in the Central Range of Taiwan, geologists located deposits of nephrite. Sponsored by the National Science Council of Taiwan, the authors wrote this special publication, which consists of four parts: (1) mineralogy of the nephrite, (2) trace elements and color, (3) minerals associated with the nephrite, and (4) related carbonate minerals.

Part 1 (by L. P. Tan, C. W. Lee, and P. L. Tien) begins with a brief historical note and then follows with a description of the geology of the region. Nephrite occurs along the hanging walls and footwalls of serpentinite sills, which are intercalcated in black schists or graphitic muscovite-quartz schists of the greenschist facies. Two geologic maps locate the deposits.

The authors emphasize the economic importance of the nephrite and associated minerals such as asbestos, bowenite, serpentinite, and talc. Approximately 1000 metric tons of nephrite were produced annually from 1973 to 1977. Useful information about the lapidary costs of nephrite and its role as a gem material are presented in this section. It is refreshing to have geologists include such information.

The authors then differentiate three varieties of Taiwan nephrite into common, cat's-eye, and waxy before beginning an extensive section on the chemistry and physical properties of each. While common nephrite is the most abundant, cat's-eye nephrite—which occurs in greenish yellow, brown, or black—is the most interesting. The information on chemical composition, hardness, density, unit-cell constants, cleavage, fracture, and optical properties is presented in seven charts and graphs in this section. One interesting fact is that although nephrite is generally reported to have a hardness of 5 to 6.5 on the Mohs scale, the cat's-eye nephrite of Taiwan may produce a Vicker's hardness of 1166, which is approximately 7+ on the Mohs scale.

Tan et al. then report on the inclusions observed. Chromite is the most abundant, but grossular, serpentine, picotite, and chalcopyrite are also seen. The authors conclude this section with a discussion of the occurrence and possible genesis of the three varieties, stating that Taiwan nephrite formed after the ultramafic rock had been metasomatized into serpentinite. The 20 plates at the end of Part 1 include four photographs of nephrite carvings and 16 photomicrographs of specimens referred to in the text.

Part 2 (by L. P. Tan and P. C. Tsui) focuses on the trace elements and their role as coloring agents in nephrite. After analyzing the eight transition elements with a spectrograph, the authors measured 53 samples of nephrite with a spectrophotometer. Seven elements were present in amounts less than 0.2% of the total composition (listed here in decreasing order): Co, Cr, Cu, Mn, Ni, Ti, and V; Fe averaged 3.0%.

The authors then attempted to describe the color in numerical terms, first using the rock color chart of the Geological Society of America, and then presenting a green-yellow index developed by Tan based on the transmission peaks of nephrite in the spectrophotometer. These figures are accompanied by charts of the transmission spectra of the common nephrite and cat's-eye nephrite from this locality. The author also investigated the effect of heat on color.

The authors conclude that the color of tremolitic nephrite may be related to Fe^{2+}, Ni^{2+}, Cr^{3+}, Ti, and structural water, and to oxidation of Fe^{2+} to Fe^{3+}. The brilliant green color is due mainly to Cr and partly to Ni in Taiwan nephrite. Ni may cause a bluish-green tint, and Ti a brownish tint.

Part 3 (by C. W. Lee, P. L. Tien, and T. F. Yui) reports on the microscopic, X-ray, thermogravimetric, cathodo-luminescent, and chemical investigation into the associated mineralogy of the Fengtien area. This study gives the occurrence and chemical composition for serpentine, pycnochlorite, and magnetite as found in serpentinite; diopside, garnet, vesuvianite, zoisite, and epidote as found in diopsidefels; and clinozoisite, sanidine, vein quartz, and tremolite as they occur in metasediments. X-ray diffraction data are provided in 10 charts. Sixteen photographs and photomicrographs illustrate the specimens discussed.

Last, in order to further our understanding of the emplacement conditions of the Fengtien area, part 4 (by C. C. Chen) examines the occurrences of calcite, dolomite, aragonite, and magnesite in relation to nephrite. Chen proposes that the sources for the calcium carbonate were liquids existing in a cognate relation with preserpentinite ultrabasic magma, and further that stress played an important role in the formation and localization of the nephrite bodies. This is based on the fact that calcite veinlets are often associated with asbestos, crystallizing in fractures (tension caused), and that at least some calcites were found to be contemporaneous with tremolite development. Part 4 concludes with an extensive bibliography of 56 citations and an index to the four parts and the illustrations included. *JPG*

Origine hydrothermale des olivines gemmes de l'île de Zabargad (St. John's) Mer Rouge, par l'étude de leurs inclusions (Hydrothermal origin of gem-quality olivine from Zabargad (St. John's) Island, Red Sea, by the study of its inclusions). R. Clocchiatti, D. Massare, and C. Jehanno, *Bulletin de Minéralogie,* Vol. 104, 1981, pp. 354–360.

On the basis of their examination of inclusions in gem-quality olivine from this locality, the authors state that these inclusions are characteristic of olivines that formed in peridotites and indicate the conditions of

their growth. From the chemical analysis of olivine from Assab, Eritrea, the authors hypothesize that they formed by processes other than hydrothermal because of the presence of carbonic fluids with high filling density. These fluids, while present in the Zabargad olivines, had a much lower partial pressure of carbon dioxide; thus, the olivines are interpreted as being of hydrothermal origin. Hydrothermal processes are said to be associated with the tectonic and magmatic events that occurred in the first stages of the opening of the Red Sea. In addition to a detailed chemical analysis, Clocchiatti et al. include photographs of inclusions and an extensive bibliography.

Michel Roussel-Dupré

Turquoise crystals at Narooma, N.S.W. C. Price, *Australian Gem & Treasure Hunter*, No. 59, 1981, p. 43.

Turquoise veins located on the southern coast of New South Wales have yielded something of a rarity in the mineral world: turquoise crystals. For the most part, the 10-mm- to 40-mm-thick veins, which resulted from the mobilization of sedimentary phosphates, contain an inferior blue-green turquoise closely associated with wavelite. When Price examined some of the material closely, however, he discovered the triclinic crystals, ranging from pale blue to pale green. The crystal groups, along with crystalline druses, stalagtite-like groups, and small bundles of parallel-growth crystals, are found in small cavities within the vein material and are best seen with magnification. *RSS*

What's the most spectacular gold and jewelled devotional crown on earth? N. Letson, *Connoisseur*, Vol. 209, No. 839, 1982, pp. 17–21.

What happened to the Crown of the Andes? Last seen publicly in 1963, this gold diadem weighing almost 13 pounds (about 6 kg) and containing 1521 ct of emeralds, was reported to have been melted down and the emeralds sold. After reviewing the history of this remarkable crown, Letson brings the story up to date. The crown was made in Popayan, a town high in the Colombian Andes that was settled in 1536 by Francisco Pizarro. There was a violent epidemic of smallpox in 1590 in Colombia; the townspeople prepared to leave, but the priest convinced them to stay and pray to the Virgin Mary. When the pox missed this isolated mountain village, the people produced this magnificent crown in thanks. Work began in 1593 and the crown was completed in 1599. In 1723 the crown was spared from an earthquake by being in the only church that was not destroyed.

In 1933, after many legal problems, the crown was sold to Warren J. Piper, a Chicago gem dealer. Sotheby's attempted to sell it in 1963, but the reserve price was not reached. The crown is now owned by a private collector in New York City who recognizes his responsi-

bility of ownership and is committed to keeping the crown intact. *JOG*

DIAMONDS

Big stones offset low grade at Lesotho's diamond mine. J. R. Chadwick, *Indiaqua*, Vol. 29, No. 2, 1981, pp. 27–33.

Although the recovery rate at Letseng-la-Terai is the lowest of all DeBeers's mines (3.09 ct per 100 tons of ore in 1979), this mine has remained profitable because of the high ratio of large gem-quality stones it has produced. The eleventh largest diamond ever found, the Lesotho Brown, was discovered at Letseng-la-Terai in 1967. In 1971, over 90% of the value of the production came from less than 10% of the material recovered.

Located in the northeast part of Lesotho, a small mountainous country surrounded by the Republic of South Africa, this mine has had an unusual history of development. The Basotho people of Lesotho, certain that diamonds would be found, began active prospecting in the 1950s, but the Letseng pipe was not discovered until 1957. It has produced diamonds sporadically ever since. The harsh weather, with all four seasons possible in one day, and extreme isolation (the mine is located at 10,500 ft.) make this operation unique. Chadwick describes in detail the history of the mine and the mining operation. *RSS*

Diamond beauty: the cutter's magic. M. Ross, *Jeweler's Circular Keystone*, Vol. 152, No. 9 (part II), 1981, pp. 76–83.

Michael Ross traces the evolution of diamond cutting and its effect on the attractiveness of diamond in this article. Using a historical approach, Ross summarizes the predominant cutting philosophies, including the crude techniques employed in the Middle Ages, the more sophisticated theories of diamond cutting that appeared in the 18th century, and the "rapid sight" technique to evaluate cutting developed by GIA in the 20th century. Ross then explains how two stones that are cut from the same quality rough can differ markedly in price and beauty. The article provides a succinct, well-researched account of how a diamond's proportions influence its beauty and salability. *JMH*

Famous diamonds of the world (X): the Lesotho Brown. I. Balfour, *Indiaqua*, Vol. 29, No. 2, 1981, pp. 123–125.

The Lesotho Brown, at 601.25 ct, is the 11th largest gem-quality diamond in the world. It was discovered in 1967 in the country of Lesotho, in southern Africa, by independent miner Ernestine Ramaboa, who quietly slipped the gem into her pocket and departed shortly thereafter on a journey that eventually took her and her husband to New York for the ceremonious cleaving of the stone. They were paid the equivalent of US$216,360

for the gem by a Belgian stone dealer who subsequently sold it to Harry Winston for more than twice that amount.

In addition to being a remarkable stone, the Lesotho Brown has had a major impact on mining in Lesotho. When the Basotho people returned to Lesotho after working in the Kimberley mines of South Africa, they began prospecting. This eventually led to the discovery of a huge kimberlite pipe in the Kao Valley. More pipes were located to the east at a point called Letseng-la-Terai. Mrs. Ramaboa's discovery prompted the government to request that DeBeers do a systematic evaluation of this mountainous and isolated region. After years of intermittent mining because of the variable quality of the material, in 1977 DeBeers opened a modern mine employing 900 people. Diamond mining in Lesotho, though still erratic, continues to be spurred by the occasional discovery of large, fine-quality stones, epitomized by the Lesotho Brown. *RSS*

The platelet story. R. J. Caveney, *Indiaqua*, Vol. 30, No. 3, 1981, pp. 115–117.

Following a review of early work on diamond types and classification, Caveney reports on current research into platelet defects in diamonds. Platelets, which are thought to be large aggregates of nitrogen atoms, occur only in type 1_A diamonds. In the early studies, unusual reflections (called spikes) were observed in the X-ray patterns of some diamonds, and an absorption at 7.8 microns in the infrared region led researchers to believe that there was some correlation between nitrogen and the platelets. As a result, Lang proposed a structural model for these platelets in 1964. Further study (by Sobolev et al.) found no direct correlation between X-ray spike intensity caused by the platelets and the 7.8-micron absorption caused by total nitrogen impurities.

Recent developments, possible only with today's advanced technology, have permitted further refinements of Lang's model. Trevar Evans and coworkers were able to produce nitrogen platelets in synthetic diamonds. Using electron microscopy, Les Bursill and coworkers obtained images of platelet defects. As a result of these two developments, Bursill has proposed a modification of the model. Caveney concludes with a drawing of the refined model in which there is a double layer of nitrogen atoms arranged in a zig-zag configuration. *SCH*

Soviet assistance for Panna diamond mines. M. P. Saxena, *Gem World*, Vol. 9, No. 9, 1981, pp. 23–24.

Unfortunately, only one short paragraph mentions the subject indicated in the title of this article. The article actually discusses a thermochemical method of processing diamond that was developed by Soviet scientists. This interesting phenomenon involves placing a transition metal—such as iron, cobalt, or nickel—in contact with diamond and heating the combination to 1000°C in a hydrogen atmosphere. The metal then interacts with the diamond in an unexplained way, and "sinks" into the stone.

Experiments have included etching a drawing on a diamond and producing a square hole. One fanciful project produced a cogwheel-shaped hole in 29 hours, through an undisclosed thickness. This may prove an inexpensive means of shaping diamond, as it involves little more than the cost of the chemicals and heating.

This incongruous article would have been of greater help if it had explored in detail the important news of Soviet assistance in the ancient Panna mines. Apparently Mr. Saxena felt differently. *FLG*

What the Siberian diamonds tell us. N. V. Sobolev, *Indiaqua*, Vol. 30, No. 3, 1981, pp. 11–13.

In an article containing 18 photographs, of which eight are in color, Sobolev focuses on the information gained from studying mineral inclusions in Siberian diamonds. Noting that the Siberian diamond pipes are much older than their South African counterparts, he begins with the commonly accepted assumption that the diamonds did not crystallize in the kimberlite but rather migrated into it. However, sometimes diamonds can be found in eclogite, the rock in which they did crystallize. Two color photographs illustrate this.

Sobolev then turns to specific examples of minerals that are included in diamonds. He emphasizes that these minerals, from olivine to coesite, take on the morphology of the host diamond and often occur in some form of the cubic crystal class. He concludes by mentioning the 1981 find in the Mir pipe of a 342.5-ct diamond, now part of the collection of the U.S.S.R. Diamond Fund, which is "a lemon-yellow colour, the size of a hen's egg and of irregular shape." *DMD*

GEM INSTRUMENTS AND TECHNIQUES

The Culti Color Stone Checker, a test report. P. Read, *Canadian Jeweller*, Vol. 102, No. 7, 1981, pp. 26–27.

The Culti Color Stone Checker, made by the Culti Company of Japan, uses three separate tests to identify alexandrites, emeralds, rubies, and sapphires. The first is a reflectivity test, the second uses long- and short-wave ultraviolet (U.V.) radiation to test for distinctive fluorescence, and the third uses the U.V. to test for the transmission of ultraviolet light. Read considers this last test the most interesting feature of the instrument. In the past, the practical application of U.V. transmission has been restricted to either the time-consuming method of immersion contact photography or the use of a piece of expensive research equipment, the spectrophotometer, to examine the absorption spectrum.

The author then reports on his experience with the instrument in the separation of natural from synthetic alexandrites, emeralds, rubies, and sapphires. He con-

cludes that although the instrument was not 100% accurate, "it can provide valuable, corroborative evidence particularly with its U-V transmission feature."

<div align="right">RSS</div>

GEM LOCALITIES

The gems and minerals of Mexico, parts I and II. K. M. and D. Castro, *Gems and Minerals*, No. 529, 1981, pp. 86–90; and No. 530, 1981, pp. 26–33.

The authors present this two-part review as part of their effort to update the invaluable, but now out of print, book by the late Paul Willard Johnson, *A Field Guide to the Gems and Minerals of Mexico.* For those who have any interest in Mexican minerals, both the book and this update are essential reading.

The first article discusses the famous Mexican "agate belt," which runs for 70 miles south of Villa Ahumada in Chihuahua. This belt includes such important deposits as Laguna, Coyamito, Gallego, and Moctezuma. Agate deposits in Durango and Sonora are also mentioned. The remainder of the article gives the reader a sampling of what the authors will publish in book form. They discuss localities, mostly in Baja, for tourmaline, turquoise, sphene, topaz, and many other important minerals.

The second article, in the December issue, includes more information on the minerals, but also expands into archaeology. Of greatest interest to the gemologist, however, is a fairly detailed account of the Mexican opal localities in the state of Queretaro. The authors describe the various mines, their history, ownership, and production. In addition to the opal discussion, the authors provide a very informative summary of Mexico's amber deposits in the state of Chiapas. These include the major mine at Simojovel, which is now exhausted.

<div align="right">Peter C. Keller</div>

Pink octahedral fluorite from Peru. D. O. Belsher, *Mineralogical Record*, Vol. 13, No. 1, 1982, pp. 29–30, 38.

Prior to the beginning of this decade, the best source for high-quality pink fluorite octahedrons was in the Swiss Alps. In November of 1980, however, extremely fine pink fluorite crystals were found at the Huanzala mine in Huanuco Province, Peru. The mine's commercial production consists of copper, lead, and zinc ore. Although fluorite is a very common mineral at the mine, it usually appears in the form of crude light green crystals. The pink fluorite crystals occur in randomly distributed vugs in the sulphide ore body, and range from almost colorless to what the author describes as "hot pink," with ill-defined grass-green zones commonly found in the center. The crystals range in size from 1 cm to 3 cm, with the largest reaching 5 cm.

Recent laboratory analysis has shown that the Peruvian pink fluorite owes its color to traces of yttrium.

Earlier tests found the same impurity to be the cause of color in the Swiss material. Most reports claim the color to be stable, and all experimental efforts to fade the material have failed.

<div align="right">SFM</div>

JEWELRY ARTS

A carver and a collector of jade. J. C. Zeitner, *Lapidary Journal*, Vol. 35, No. 8, 1981, pp. 1602–1636.

Mr. Hing Wa Lee of Whittier, California, is one of the few professional gem carvers in the United States. This article features his work and his personal collection of jade carvings, also touching on jade carving and the motifs used in Chinese art.

Although Mr. Lee prefers jade to any other material, he uses a wide variety of gem materials in his work. Chinese carvers today, as in the past, use limestone, marble, amethyst, agate, rock crystal, coral, turquoise, carnelian, lapis-lazuli, amber, hematite, soapstone, serpentine, albite, ivory, bone, shell, and tortoise shell. In recent years, carvers in Hong Kong and China have begun using chrysoprase, aventurine, chrysocolla, malachite, azurite, sodalite, tourmaline, and opal.

Although Mr. Lee was trained in the traditional methods of jade carving, he now uses modern equipment and methods. In the past, jade carvers used primitive but inventive methods that required years of challenging work to finish a piece. Now Mr. Lee can complete several pieces a year.

Most of this article is devoted to a description of Mr. Lee's personal collection of carvings. Unfortunately, while the pieces are carefully described, the photographs are much too small to do them justice.

<div align="right">ET</div>

Chinese lacquer from Yüan, Ming, and Ch'ing. J. Wirgin, *Arts of Asia*, Vol. 11, No. 6, 1981, pp. 106–112.

Jan Wirgin describes and dates important pieces of Chinese lacquer in the Museum of Far Eastern Antiquities in Sweden. The collection was fairly limited until 1973, when the museum received a bequest from King Gustaf VI Adolf.

The pieces discussed span the Yüan (1280–1368), Ming (1368–1644), and Ch'ing (1644–1912) dynasties. Particular emphasis is given to the Ming dynasty, which is considered the golden age of lacquer.

Yüan dynasty specimens all show considerable age; the relief carvings are cracked and have a tendency to detach from the background. Guri style lacquer, in which designs are carved in alternating layers of red and black onto a yellow base, is mentioned as characteristic of the 13th century.

Dragons and phoenixes are typical motifs in Ming dynasty carvings. Also common are small boxes completely covered with carved fruit or lychees. Carved landscapes that show figures and architecture in fine detail are frequently seen as well. These afford a good opportunity to study the costumes, hairstyles, and at-

titudes of the era, as well as the construction and interior design of the houses. In addition to the carved red cinnabar lacquer, a style of carving through lacquer layers of different colors was introduced and popularized in the mid to late 16th century.

Unless inscribed, Chinese lacquer is usually difficult to date precisely. There is disagreement among scholars about the origins of carved lacquer as well as when various techniques, such as inlaying mother-of-pearl shell, first appeared. On the basis of those pieces that have been inscribed, however, the author argues that the best examples are from the Ming and Ch'ing dynasties, with progressively more sophisticated designs developing with time. In the mid 16th century, a new technique of inlaying other materials along with mother-of-pearl was invented. Coral, jade, ivory, and other stones were used, sometimes combined with gold and silver foil.

This article is well illustrated; each described piece is accompanied by a photo. The color photographs are especially effective in portraying the subtlety of colors in the inlaid pieces.   *EBM*

Etonnante orfèvrerie Étrusque à propose de la collection du Louvre nouvellement exposée (Amazing Etruscan goldwork in connection with a newly displayed collection at the Louvre). I. Faudet, *Revue Française des Bijoutiers Horologers*, No. 473, 1981, pp. 58–61.

This article, an interesting and detailed account of the works of the Etruscan goldsmiths, discusses the recent opening of a room in the Louvre dedicated to Etruscan art. It describes specific pieces in this collection as well as items in other collections documenting the art of goldsmithing in the ancient Italian country of Etruria. Several well-captioned black-and-white photographs add to the appreciation of the text.

The collection contains pieces excavated from the necropoli of Palestrina, Cerveteri, and Vetulonia (Italy), as well as some from the Campana collection, which was acquired by Napoleon III in 1861 and deposited in the Louvre.

The most remarkable items in the collection are probably those local creations that appear to be influenced by the Greeks. The technique of the Etruscan artisans is not well understood in spite of many attempted imitations during the 19th century. Although their tools were simple, the workmanship is unbelievably fine. There are examples in which geometric patterns of art are formed with wires and the designs are held together by diffusion welding. Granulation, the technique whereby tiny regular spheres are soldered onto plates, is accomplished with no visible trace of solder. The lightness of many of these pieces is impressive.

Etruscan goldwork is usually divided into two phases. The first, dating from the seventh to the fifth centuries B.C., is very rich in decorative and technical innovation and is characterized by the heavy use of granulation, filigree work, and the introduction of enameling under the influence of the Greeks. Subsequent works, from the fourth to third centuries B.C., consist primarily of large gold leaves most often worked in repoussé, the technique of producing relief decoration on metal by punching and hammering from the reverse side.

Among typical pieces are large clasps that were worn on the shoulder. These rectangular plaques were adorned with animals or sirens in linear arrangement. They were mounted on transverse rods and fashioned from two stamped pieces soldered in the middle.

Bracelets of diverse styles were common during the seventh century B.C. Some were simple rings terminating in animal heads, but the most striking were made from bands of filigree openwork decorated with raised bumps, heads, or crescents.

Necklaces with multiple pendants reflect the originality and imagination of the artisans. The earliest were made of long rectangular plaques decorated with medallions. From the end of the seventh century B.C., collars were made with half-spherical pendants representing rams' or women's heads. Later, hollow spheres alternated in patterns with oval beads, leaves, or masks. Collars with repoussé pendants of subjects such as deities, mythological creatures and events, and vegetables alternated with glass or amber beads. The bubble was one of the common Etruscan ornaments. This capsule-shaped hollow pendant was originally fashioned in bronze and probably contained some substance.

Stick pins, some very elaborate, were common up to the fifth century B.C. The development of the brooch, usually elongated, with an ornate "face" was noteworthy. Etruscan artists created very luxurious brooches in gold and occasionally in silver.

Rings did not share the same popularity. During the seventh and sixth centuries B.C., gold or gilded bronze rings with scroll-shaped surfaces appeared adorned with hunting or combat scenes and occasionally with intaglios inspired by the Greeks. The fourth century B.C. brought some rare scarab rings, and during this period the "face of the ring" became larger and decorative floral motifs began to appear.

The wearing of earrings began in the sixth century B.C. In sharp contrast to the simple wire loop earrings worn by some, there were the more characteristic earrings in which the main part was a cylinder that was attached to the ear by a wire. The sixth century B.C. saw the tubular ring bearing the head of a woman, ram, or lion as popular motifs. Later earrings got larger and often had small rings or various-shaped ornaments hanging from them. Again, these items often showed the influence of Greek art. Later still, the cluster earring emerged, composed of a center sphere augmented by an oval part decorated with bumps or with more complex arrangements of stamped heads or faces.

This article is written in narrative style and provides no bibliography or references. *CKG*

The gold treasures of the Western church. C. Oman, *Optima*, Vol. 30, No. 1, 1981, pp. 56–68.

Oman reports on the interesting history of church treasures. He emphasizes that the number of pieces remaining in museums, churches, or private collections does not accurately reflect their earlier popularity. These early examples of gold craftsmanship, often the finest works of a period, were highly vulnerable to thievery as well as to the destruction wrought by war and religious intolerance. Another reason so few exist today is that because they were regarded as the capital of a church, in times of financial crisis many pieces were melted down.

Brief histories are given for a number of the remaining examples of gem-encrusted chalices, book covers, crosses, and other reliquaries as they are traced to their present locations. As the 10 impressive photographs indicate, colored stones, pearls, and enamels were used frequently. Unfortunately, Oman has included little gemological information in his descriptions. *RSS*

Good as gold. E. Lauré, *American Craft*, Vol. 14, No. 6, 1981–82, pp. 8–11.

Unconventionality is a major theme in the "Good as Gold: Alternative Materials in American Jewelry" exhibition, organized by the Smithsonian Institution Travelling Exhibition Service. The author argues that the restrictive price of gold and other traditional jewelry materials has necessitated the trend toward using metals such as titanium, tantalum, and niobium. Other alternative materials used include textiles—from cotton and silk to acetate, rayon, and nylon—as well as bone, wire, and Plexiglass.

Further elaboration of the main theme is demonstrated in the departure of jewelry from mere accessory to jewelry as "wearable art." The jeweler-artists combine not only alternative materials, but also alternative approaches to what is wearable and how different techniques such as metalworking, crocheting, and enameling can function together in the creation of a piece of jewelry. *JCL*

A short history of the art of granulation. I. J. Wolters, *Aurum*, No. 6, 1981, pp. 8–14.

Granulation, the process of bonding small granules of metal to a larger metal surface in an ornamental or figured design, is an art form that reaches back into early antiquity. Since the concept that most people have of the technical and artistic aspects of granulation has been influenced almost exclusively by Greek and Etruscan jewelry, there is a tendency to overlook the fact that these are late expressions of a craft that was nearly 2000 years old when the first Etruscan pieces were produced.

With this in mind, Wolters takes us back those 2000 years and, through the use of maps, gives us an expanding view of the art form as it spreads from its origins in ancient Mesopotamia throughout the Middle East, the greater Mediterranean area, and ultimately to the major centers of Europe and Asia. At the same time, with pertinent dates and locations, he carries us from early antiquity through classical antiquity, prehistoric Europe, and the various periods of the Middle Ages to modern times, concluding with a brief look at the present-day revival of the art form.

The account is straightforward and interesting, with good illustrations (five photos and two maps). In the following issue of *Aurum*, the author discusses the various styles and techniques used in the past and then presents a select bibliography. *Archie V. Curtis*

Touching precious metals. W. Wälchli, *Gold Bulletin*, Vol. 14, No. 4, 1981, pp. 154–158.

In this informative, well-organized article on testing metals, Wälchli discusses the history, procedure, and accuracy of the touchstone test, one of the oldest methods for determining metal content.

The assayer can perform the touchstone test to: (1) identify precious metals used in alloy, (2) identify base metals used in alloy, (3) assay finished articles, (4) test samples before using finer analytical methods, or (5) obtain an indication of the thickness of a precious metal coating.

This procedure is basically a comparative test: the object to be tested is rubbed evenly on a lightly oiled touchstone, and then a metal touch needle of known fineness and matching color is rubbed next to it. When an appropriate test acid solution is applied to both, the tester observes the rate and degree of the acid attack on the rubbings. If the acid does not behave the same—or virtually the same—on both rubbings, testing is continued with other touch needles.

Difficult gold alloys, as well as other metals such as platinum and silver, can be checked by this method. Wälchli describes aspects of each. He concludes that this simple process will continue to be popular: it is reasonably accurate, fast, and requires a very tiny amount of test metal or alloy. *Marcia Hucker*

SYNTHETICS AND SIMULANTS

Japanese manmades. F. H. Pough, *Lapidary Journal*, Vol. 35, No. 10, 1982, pp. 2004, 2006, 2008.

Pough reports on the research of Dr. Akira Kose, of the Japanese Institute for Applied Optics, and Dr. Sei Hachisu, of Kyoiku University. Using spheres of polystyrene latex, they have produced an opal simulant. With the addition of sodium polyacrylate, the spheres flocculate into opalescent patches that can be stabilized by filling the voids between the spheres with polymethyl methacrylate, which has a refractive index close to that of the

latex. Pough includes a chart comparing the properties of this simulant with those of Gilson synthetic opal and natural opal, as well as five color photographs of the opal simulant and one of synthetic quartz made in Japan.

Pough then briefly describes this synthetic quartz, noting that the red-violet "amethyst" is superior in color to the material made in the U.S.S.R. He concludes by mentioning a number of other synthetics manufactured in Japan: emeralds, alexandrites, star corundum, and padparadscha sapphires. *RSS*

MISCELLANEOUS

Contact metamorphics, part II. B. Jones, *Rock & Gem*, Vol. 11, No. 12, 1981, pp. 56–76.

Because of different temperature, pressure, or chemical environments, each contact metamorphic deposit is unique in the minerals it contains. However, certain minerals, such as grossularite and vesuvianite, that are common to many deposits almost always occur together when a limestone body is altered to a marble. Thus, the presence of such minerals can aid in identifying the type of deposit.

Many of the gem gravels of the Far East were produced in part from metamorphosed limestone. Gems such as ruby, sapphire, and spinel have been recovered from these deposits for centuries. Another contact-metamorphosed limestone in Afghanistan produces the world's finest lapis-lazuli. Jones focuses first on spinel, lapis-lazuli, and diopside, reviewing some of their more notable occurrences. He then turns to garnets.

The garnets usually found in this type of deposit are grossularite and andradite. Since each contains calcium in its chemical make-up, a limestone environment is ideal for their formation. Other minerals the author describes are staurolite, scapolite, and tremolite. *GSH*

Crystals, cornerstones of tomorrow's technology. J. Walker, *Museum*, Vol. 2, No. 5, 1981, pp. 53–57.

Electronic technology has increased tremendously since the advent of synthetically grown crystals. They are an essential part of transistors, one of the most important tools of the field. Integrated circuits are printed on thin wafers of synthetic silicon crystals. The size of the circuits has decreased to the point that thousands of them can be printed on a single wafer. These wafers can then be cut in sections, called chips, that contain a single circuit. Chips of this kind have made possible complex electronic instruments that are a fraction of the size of their predecessors.

Through the use of microelectronics, it has become possible to put laboratories in orbit around the earth. The author describes a number of advantages of manufacturing crystals in orbit. Several major problems involved with growing crystals on earth, such as the pull of gravity or the minute vibrations that are always present in a terrestrial laboratory, would be eliminated. These factors cause imperfections in the growing crystals and make the growth of crystals of particularly sensitive compounds impossible. Orbiting laboratories not only will be able to grow more nearly perfect crystals, but they also will undoubtedly be able to grow crystals that have never been grown before. With the advent of new crystal materials, electronic technology may yet make even larger advances than it has in the past. It will be interesting to see what overlap these developments will have on the production of synthetic gem materials. *SFM*

The largest crystals. P. C. Rickwood, *American Mineralogist*, Vol. 66, No. 9 and 10, 1981, pp. 885–907.

The greater part of this article consists of a listing with accompanying explanations of the largest authenticated crystals in nine classes of minerals with 24 separate categories. These crystals, for the most part, are not attractive or aesthetically pleasing, but they are interesting because of their size. There is theoretically no limit to the size that crystals can grow, so the list represents the largest that have been found to date.

Crystals mentioned include a 37.5-ton garnet; a 13-m-long, 65-ton spodumene; and a transparent perfect crystal of topaz from Minas Gerais, Brazil, that weighs 300 kg and measures 80 × 60 × 60 cm. The topaz crystal is not the largest ever found, but it is unique because of its clarity and crystal form. The largest crystal of any variety ever recorded is a beryl from Malagasy Republic that is 18 m long and 3.5 m in diameter, with an estimated weight of 379,480 kg. The largest crystal of which there is photographic evidence is a spodumene from South Dakota that is 14.3 m (47 feet) long. The extensive bibliography included underscores the amount of research involved in compiling the list, which required verifying previous reports in the literature as well as locating specimens in public and private collections. *SFM*

BOOK REVIEWS

AN ILLUSTRATED DICTIONARY OF JEWELRY

By Harold Newman, 334 pp., illus., Thames & Hudson, New York, New York, 1981. US$29.95*

Gem scholars and those with only an embryonic interest in jewelry will enjoy this beautifully executed book. Containing over 2,500 "pearls of wisdom" with 685 illustrations, it would be a welcome addition to any library, and would collect neither dust nor cobwebs.

Compiling any dictionary is obviously a monumental undertaking. Here, however, the author succeeds in creating enjoyable, informative, and succinct definitions. Mr. Newman has written two other illustrated dictionaries (one on glass and the other on ceramics); he certainly has the magic touch with this format.

The dictionary includes data concerning famous gems, cutting techniques, trade grades, jewelry-making materials and processes, designers, styles, methods of decoration, and the major gemstones used in jewelry. Also included are brief biographical notes on some outstanding firms and individuals, past and present. The author has employed cross-referencing extensively both to avoid repetition and to provide ideas for locating related subjects.

The author also provides a superb display of illustrations that are by no means ordinary. Of the 685 illustrations, 16 are in color and 37 are line drawings. In addition, the craftsmanship is excellent, with well-printed glossy pages. *An Illustrated Dictionary of Jewelry* is full of information and is perfect for reference or just browsing. Mr. Newman has put together a *quality* book.

JAVEN STEIN MORELL
Colored Stones Instructor, GIA

PHOTOGRAPHICAL ATLAS OF DETRITAL MINERALS

By Pierre Devismes, 203 pp., illus., Bureau de Recherches, B.P. 818, 45 Orleans, France, 1978. US$89.00.

This book is a marvelous pictorial essay, with 641 excellent color plates that vividly illustrate over 18 different microscopic alluvial minerals from localities all over the world. The minerals illustrated represent a nearly complete listing of the various species that are likely to be encountered when examining micro-alluvium from virtually any locality.

The book is written in both French and English, which will surely broaden its audience.

After a short forward and introduction, the author briefly describes the basic methodology of sample preparation and concentrate separation and illustrates the apparatus used to take the photographs contained in the book. The major part of the book, presenting the color mineral photographs, immediately follows.

At first glance, there seems to be no obvious order to the minerals described. Neither a chemical nor an alphabetical system of classification was used. The author chose instead to classify and group the minerals according to the particular rock type with which they are commonly associated. This classification system sometimes falls short, though; for example, chrysoberyl, which is known to occur in pegmatites, is found nowhere near the other pegmatite minerals such as tourmaline or topaz. Since certain minerals can grow in a variety of environments, it might have been better to use either the well-known Dana System of classification or a standard alphabetical method, and to add a paragraph at the beginning of each mineral section stating the various rock types and environments in which that particular mineral can crystallize. However, this minor drawback is adequately handled by the inclusion of an alphabetical index of minerals in the back of the volume.

Also included in the back of the book is a geographic index of the various localities represented by photographs of mineral detritus in the main section.

This book is somewhat limited in its gemological applications because localities of major importance to the gemologist, like Sri Lanka, are not covered. However, all of the major and many of the minor gem species are represented, so the gemologist, who is accustomed to working with faceted gems, can get a good education on how these materials look in their natural state. As stated by the author, this book is intended primarily for mineralogists and prospectors. But this reviewer recommends it for research and prospecting gemologists as well. Anyone who appreciates the beauty of nature's mineral treasures will surely enjoy this volume.

JOHN I. KOIVULA
Senior Staff Gemologist
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**This book is available for purchase at the GIA Bookstore, 1735 Stewart Street, Santa Monica, CA 90404.*

GEM NEWS

Stephanie Dillon, *Editor*

DIAMONDS

Australia. Subject to the final approval of Ashton Mining, Northern Mining, and the governments of Australia and the state of Western Australia, the Central Selling Organisation of DeBeers will market all of the gems and most of the industrial-quality diamonds of the Ashton Joint Venture. Gem-quality stones will probably comprise about 10% of the total production. DeBeers will handle 75% of the near-gem and industrial material, with the remaining 25% to be sold on the open market.

Botswana. With the depressed market for diamonds, Botswana's dependence on diamond sales (over 50% of export earnings and 30% to 35% of government revenues come from diamonds) has resulted in severe economic problems for the country. Even as the government increases the emphasis on coal export and discusses oil exploration, diamond production continues at the two pipes in Orapa. A high proportion of the output from this area is industrial quality. Starting this year, Jwaneng, near Gabarone, will produce diamonds that for the most part are gem quality. Projected output for Botswana's three mines exceeds South Africa's entire production. Because of the drop in the diamond market, however, DeBeers has asked that Botswana stockpile its stones. DeBeers has a 50% share in the state mining company (Debswana) and markets the diamonds through the Central Selling Organisation.

Ghana. Akwatia, the only producing mine in Ghana, continues operation through a US$15 million loan underwritten by the government. The mine has been operating since 1924, and its reserves are expected to be depleted in 1983. The government is currently studying a potentially substantial deposit in the Birim River Valley. A diamond cutting and polishing industry is also under consideration; Ghanaians are to be trained by Indian craftsmen.

India. Diamond-bearing areas in Madhua Pradesh and Andhra Pradesh will be explored as part of a three-year government plan to increase domestic diamond supplies. New diamond deposits have been discovered in the Trivandrum district, according to the Geological Survey of India.

Israel. The Israeli government, in an effort to strengthen the diamond industry, has removed customs duty on polished diamonds of 0.02 to 1.00 ct and has lifted the import license requirement.

Lesotho. The Letseng-la-Terai mine, operated by the Lesotho government and DeBeers Consolidated Mines, Ltd., is being closed because of the recession in the diamond market. The mine, which opened in the 1970s, was a major contributor to Lesotho's economy, employing nearly 800 people. Last year's production totaled 52,900 ct.

Namibia. Production for 1982 at Consolidated Diamond Mines was reduced by 20%, owing to the closure of one of four treatment plants.

South Africa. As it copes with a depressed market, DeBeers Consolidated Mines is closing the Koffiefontein mine and putting emphasis on Namaqualand, where smaller diamonds are produced. Koffiefontein produced 323,000 ct last year; DeBeers's total output was 15.4 million ct. In March, DeBeers laid off 498 workers (12% of its total labor force) at the Premier mine. Last year, the Premier's output was 2 million ct.

New mining activity initiated by the Octha Diamond Company is estimated to increase the company's present production of 100,000 ct per year to approximately 1 million ct by 1986. Company acquisitions include mines in the Kimberley area, the Barkly West district, and the Free State. Prospecting has revealed substantial reserves, with industrial-quality diamonds comprising about 55% to 60% of the total.

U.S.A. The Diamond Club West Coast, Inc., was officially opened May 17. The previous week, the club had been invited, by unanimous vote, to join the World Federation of Bourses. There are 125 members in the West Coast Club, which is located at 606 South Olive St., Los Angeles, California 90014.

"Diamond and Jewelry Way" is the new name for New York City's erstwhile 47th Street. Mayor Ed Koch presided at the renaming May 14 in sidewalk ceremonies that launched a six-day celebration, New York's third salute to the fashion and beauty industries.

Zaire. Declining production at the mines, combined with the effects of illegal mining and trading, has caused a substantial drop in the national production reported from Zaire—to 5.7 million ct in 1981 from 13.5 ct in 1974. For 1982, a total of only 6 million ct is anticipated. With alluvial deposits running out, an underground mining operation will be needed to tap the estimated 150 million ct contained in kimberlite. The government, aided by three independent companies, intends to establish a cutting industry that will eventually employ 700 workers. Cost of the plant is estimated at US$2 million.

EMERALD

Australia. Emeralds from the Aga Khan mine, in Western Australia, are currently being stockpiled. Approximately 11% of the production is gem quality; the largest crystal found to date is 9.6 ct.

Brazil. In the state of Goiás, an emerald deposit discovered within the last year yields stones with a color that is reported to be superior to that of other Brazilian emeralds. These new emeralds tend to have high refractive indices. A steady supply is anticipated.

PEARL

Japan. Members of the Japanese pearl industry are very concerned about the possibility that the Chinese may take over processing of their own freshwater product and become rivals on the world market. To date, Chinese freshwater pearls are imported into Japan and processed there for export.

TOPAZ AND PERIDOT JEWELRY SUITE

Currently on display at GIA is the suite pictured in figure 1. It contains approximately 88 ct of Brazilian topaz and 148 ct of almost perfectly matched peridots from the island of Zabargad in the Red Sea (see article, *Gems & Gemology*, Spring 1981). The largest cushion-cut stone in the necklace weighs approximately 26 ct. The topazes were originally orange to yellow-orange, but were rendered pink through heat treatment. They are set with 164 fully drilled natural seed pearls in 18-ct pink gold that has been plated over with high-karat yellow gold.

Figure 1. Jewelry suite containing pink topazes, peridots, and seed pearls in gold. Below are two stamps that may provide clues to the origin of these pieces. Suite photo by Tino Hammid. Stamp photos by Michael Waitzman.

An owl hallmark indicates French import in the year 1893. Another stamp (impressed twice) is a ram's head; there is also the symbol of a swan, above which is an impression containing an umbrella shape surrounded by letters (again, see figure 1). Anyone who might be able to furnish further information about the suite on the basis of these stamps is invited to write to the address given at the end of this section.

Winner of the 1982 George A. Schuetz Memorial Fund Jewelry Design Contest is Judith M. Evans, of J.B. Hudson Jewelers, Minneapolis, Minnesota. The scholarship of $500 was awarded for her original rendering of a man's ring featuring 18 diamond baguettes in a setting of 18-karat gold and platinum.

The Schuetz scholarship is offered annually for a distinguished design in men's jewelry and may be used for training in a jewelry-related subject at any institute of the winner's choosing. The 1983 Schuetz Memorial Design Contest will be open in October of this year. Contest rules and applications will be available at that time from the Scholarship Office, Gemological Institute of America, 1660 Stewart St., Santa Monica, California 90404.

The Association of Women Gemologists, newly organized by Anna M. Miller of Pearland, Texas, and Elaine Baker of La Jolla, California, is con-

Figure 2. Schuetz Contest winner.

ducting a membership drive. The association is open to women who are gemologists, graduate gemologists, certified gemologists, F.G.A.'s or the equivalent. The association plans to publish a membership directory and monthly newsletter. At present, no dues are being collected. For further information, please contact: Anna M. Miller, P.O. Box 1179, Pearland, Texas 77581.

Deutsches Edelstein und Mineralienmuseum Museum—6580 Idar-Oberstein 2, Mainzer Strasse 34. Telephone: (0681) 4821-4822. Reopened in April 1982, the newly enlarged museum exhibits cut gemstones and gem mineral specimens from all over the world. A recent addition is the unique collection of more than 200 carved pieces that demonstrate the evolution of the carving art over 6,000 years. A pegmatite gem pocket from Madagascar is also on display, with beryl and quartz crystals. Other exhibits feature gem phenomena, pleochroism, inclusions, and discoveries of the 20th century. The museum is open year round, except for Christmas.

Gems & Gemology welcomes news of exhibits and events of a gemological nature. Please contact Stephanie Dillon, Gemological Institute of America, 1660 Stewart St., Santa Monica, CA 90404. Telephone: (213) 829-2991.