

Gems & Gemology

VOLUME XX

FALL 1984



The quarterly journal of the Gemological Institute of America

Gems & Gemology

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ABOUT THE COVER: All of these pearls were fished from the Tennessee River (U.S.A.). The graduated necklace contains 90 natural pearls, all white rosé, which range from 11.5 to 3.0 mm (128.24 ct total weight); it represents over 25 years of collecting in this region. The 14K ring is set with a distinctive turtleback pearl, also white rosé in color, which weighs 21.67 ct. The history, formation, and distinctive colors and shapes of natural freshwater pearls from North America are discussed in the article by James Sweaney and John Latendresse in this issue. Pearls courtesy of American Pearl Creations, Camden, Tennessee. Photo by Tino Hammid.

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

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Subscriptions in the U.S.A. are priced as follows: \$24.50 for one year (4 issues), \$65.00 for three years (12 issues). Subscriptions sent elsewhere are \$34.00 for one year, \$95.00 for three years.

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

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

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

FRESHWATER PEARLS OF NORTH AMERICA

By James L. Sweaney and John R. Latendresse

*Natural pearls are among the rarest and most valued of fine gems. American freshwater pearls have a history thousands of years old and played a particularly prominent role in the jewelry of the late 19th and early 20th centuries. Today, though a fraction of its original size, the American freshwater pearl industry continues to produce fine material for the jeweler worldwide. The source of this pearl is the *Unio mussel*, "fished" by brailing boats and intrepid divers from the rivers and lakes of America. From the *Unio* in which it grows, the American freshwater pearl derives its distinctive shapes and colors. A new entry to the American pearl industry is the freshwater cultured pearl, illustrated in this article for the first time ever.*

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Acknowledgments: The authors would like to thank the following people for their assistance and contributions to this article: Ed Noble and Jo Ferguson, of the Tennessee River Folk Life Center, Eva, Tennessee; Dr. D. H. Stansbery, Ohio State University, Columbus; Dr. Henry van der Schaille, University of Michigan, Ann Arbor; Dr. Bruce Smith, Smithsonian Institution, Washington, DC; and Elise Misiorowski and Dona Dirlam, GIA Library, Santa Monica, California.

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Pearls are undoubtedly one of man's oldest treasures. As he sought food, primitive man would have found certain mollusks easy game. Inevitably, in time, he would have encountered pearls within these mollusks. Only the simplest of tools were needed to pierce these lustrous objects and fashion them into enchanting, enduring ornaments. As civilization developed, the pearl was often associated with purity, innocence, hope, and femininity. In contemporary times, the pearl has come to be known as the "Queen of Gems."

Historically, pearls have been enormously popular. During the Renaissance, when exploration opened the Orient and the New World to the traders of Europe, pearls were sought with such passion that the period has been called "the Pearl Age" (Kunz and Stephenson, 1908). No opportunity was ignored, and so pearls were fished wherever they could be found, from both freshwater and saltwater sources.

The next great pearl boom occurred in the late 19th and early 20th centuries, when pearl prices soared to fabled heights not seen before or since. In fact, natural pearls were so important during this period that many fine jewelers derived most of their income, reportedly as much as 80%, from the sale of pearls (Shire, 1982). Freshwater pearls played an important role in this market, because new discoveries of freshwater pearly mussels in the lakes and rivers of the United States contributed significantly to the supply of fine natural pearls. Although freshwater and other natural pearls have been overshadowed in recent years by the sheer volume of their cultured counterparts, they continue to be one of the classic gems, distinctive and highly prized for their beauty, wearability, uniqueness, and rarity.

In this article, we will discuss the freshwater pearls of North America, in particular those from the United States (figure 1). We will review how the freshwater mussel and its pearls have been harvested and used, describe

the natural history of these mussels and the pearls they produce, and look at the future of the freshwater pearl industry—both natural and cultured—in the United States.

A HISTORICAL PERSPECTIVE

There is good reason to believe that freshwater pearls were found very early in man's history. Indigenous to the lakes and rivers of North America, Europe, and Asia, the freshwater pearly mussel was an easily accessible food source. Opportunistic aborigines had only to wade into the shallows to be able to gather protein-rich food from often enormous beds of *Unio* mussels. Even in modern times, mussel beds have been found stretching several miles along a river, harboring hundreds of thousands of these creatures. Given the tendency of these mussels to form pearls, it is likely that men who lived off the mussels encountered freshwater pearls very early on.

In their monumental work, *The Book of the Pearl* (1908), Kunz and Stephenson describe early written references to pearls, the earliest of which appears to be the Chinese *Shu King*, in which freshwater pearls are described as having been fished from rivers in China and strung into necklaces around 2300 B.C. In America, some of the ancient mounds and shell middens of the Tennessee River Valley show evidence that the Indians used the mussel as food and the shell for utilitarian and decorative purposes as early as 4500 B.C. During the Woodland period, approximately 1000 B.C. to 800 A.D., the use of pearls appears to have been extensive, especially in culturally advanced tribes. The Hopewell mounds of Ohio, which contained large caches of freshwater pearls, date from about 200 B.C. to 200 A.D. (Dr. Bruce Smith, pers. comm.).

When the Spaniards began their exploration of the New World, they found and exploited good saltwater pearl fisheries in the Caribbean, especially around Venezuela, and along the Pacific coast of Panama and Mexico. Hernando de Soto's expedition into the southeastern portion of continental North America (1539–1542) was the first to report the discovery of American freshwater pearls. De Soto and his men encountered Indian tribes with what were described as "strings" and "festoons" of pearls. They were able to come away with some treasure, but on the whole the expedition was disappointing. Although some of what they brought back were actually fine pearls,

much of what they saw were probably beads and other ornaments that the Indians had made out of the mother shell (Kunz and Stephenson, 1908). Other early finds occurred along the Atlantic seaboard and the lower portions of the Mississippi River, but these were generally minor in scope. Perhaps because their expectations were too high, or because the freshwater pearls were less accessible to the great sailing ships of the time, or because many of these pearls were different from the saltwater pearls the Spaniards were familiar with, these early explorers did not make much of their discoveries, and the North American freshwater pearls lapsed into obscurity for several centuries.

With the "rediscovery" of the freshwater pearl at Notch Brook in New Jersey in 1857, however, the heyday of the American pearl fisheries began. Significant pearl finds—on the Little Miami River of Ohio in 1878, the Pecatonica and other rivers of Wisconsin in 1889, the White River of Arkansas in 1895, the Clinch River of Tennessee in 1901, and others—made headlines that brought frenzied "pearl rushes" to these areas. During this period, many of the waterways of the eastern portion of the country were explored and developed for pearl or mussel fishing, but most of the pearl seekers wanted quick riches and so concentrated their efforts on the major finds (Kunz and Stephenson, 1908).

Freshwater pearls were very popular during this period, especially in the local areas where they were fished and in Europe. Jewelry of the Victorian period was sometimes set with numerous small "seed" pearls encircling a center gem or with rosettes of freshwater pearls arranged like the petals of a flower (see, for example, the pendant in the center of figure 1, a reproduction of a Victorian design). Jewelers of the Art Nouveau movement used American freshwater pearls extensively because the baroque, often grotesque natural shapes and unusual colors of these pearls worked well with the themes and sentiments of the period.

The mussel shells soon became an important resource themselves. J. F. Boepple, a button maker who immigrated to the United States from Germany in 1887, is credited with having fathered a new industry when he established a mother-of-pearl button factory in Muscatine, Iowa, in 1891. This new industry quickly expanded and became very important to the economy of the Midwest.



Figure 1. A sample of contemporary jewelry fashioned using American natural freshwater pearls. The pendant in the center is a reproduction of a piece from the Victorian era. Photo © 1984 Tino Hammid.

Besides buttons, numerous other mother-of-pearl products, such as handles for knives and razors, inlaid shell boxes, and other decorative objects, were turned out by these factories. By the turn of the century, Muscatine was the pearl-shell capital of the world. Button making brought prosperity to many areas, and steady employment to large numbers of factory hands as well as to the river folk and fishermen who gathered the mussel. The pearls were a valuable and important by-product, so pearl buyers from all over the world came to the button-making centers (Musgrove, 1962).

The mussel-shell and pearl industry ran at a strong pace until the 1920s, when a series of factors combined to topple it. The introduction of

plastic buttons, which could be made more cheaply and to the precise dimensions required by modern sewing machines, began to erode the market for mother-of-pearl buttons. Many major natural pearl suppliers left the business at this time as increasing sales of cultured saltwater pearls from Japan, and decreasing production of natural pearls of all types, worked with negative publicity about the difficulty of separating cultured from natural pearls to undermine the market for natural pearls. Finally, the stock market crash of 1929 triggered the collapse of already weak natural pearl prices, and the Depression brought the shell-button industry to a virtual halt. To date, natural pearl prices have never re-



Figure 2. On "Decoration Day," the people who live and work along the Tennessee River gather at their family cemeteries and decorate the graves of their loved ones with freshwater mussel shells and other objects. The custom is said to have come to the U.S. from Ireland. Photo courtesy of the Tennessee River Folk Life Center, Nathan Bedford Forrest State Park, Eva, Tennessee.

gained the heights they reached in the early part of the 20th century. The shell-button industry remained marginally active until the last major factory, located at Savannah, Tennessee, closed in the 1950s.

The collapse of the button industry was offset in the late 1940s and early 1950s by the development of a new market for the shell: the saltwater pearl culturing industry of Japan. These growers, through trial and error, had found that the shells that produced American freshwater pearls were the ideal raw material for the shell bead they needed to nucleate their cultured pearls. After World War II, Japanese buyers came into the market heavily and a new boom for the mussel shell business began. Today, four or five suppliers export about 3,500 to 6,000 tons of freshwater mussel shell to Japan each year. In the midwest and southeast portions of the United States, mussel fishing is still a tradition for the people who live along the rivers and lakes. Indeed, it has become the custom in some areas to decorate the graves of loved ones with the mussel shell (figure 2).

In the 1950s and early 1960s, a number of important pearls were found as a result of the shell harvest, since many areas had not been worked seriously for 20 or 30 years. As recently as the early 1960s, annual raw production of freshwater pearls in the U.S. was about 20,000 troy ounces, (only 15% of which was useful for jewelry). The current yield is paltry—only 500 to 600 troy ounces annually—because water pollution and other types of habitat destruction have shortened

the lifespan of the mussels and as a consequence diminished the size and quality of these natural freshwater pearls. Although the current market for American natural freshwater pearls, as for all pearls, is strong, the outlook for new production of all types of natural pearls, both in the U.S. and worldwide, is bleak, because the environmental problems that led to the current state of these fisheries are not likely to be reversed.

METHODS OF HARVEST

The pearly *Unio* mussels are easy prey to muskrats, otters, and other animals. The Indians of North America gathered them by simply wading into the river or lake, locating the mussels with their feet or hands, and pulling them out of the mud. This method is still used occasionally in areas where the mussel can be found in shallow water, and is referred to by local people as "toe digging." The Indians also developed a method of harvesting that was a precursor to one of the principal methods of commercial harvesting used in the 20th century, known as "brailing." Their method was to drag cedar branches behind their dugouts and canoes. The branches passing over a mussel bed would disturb those mussels that were open to feed, so that they would quickly close their shells, as often as not clamping onto the branches.

During the pearl rushes of the 19th and early 20th centuries, "toe digging" and long-handled rakes were the most common methods of harvest. As the button industry developed and the demand for large quantities of shell grew, the harvest be-

came more sophisticated, and "brailing" became the favored technique. The brail is a long bar or board, 6 to 15 feet (3–5 m) long, to which numerous "crowfeet" are attached via short ropes or cords. The "crowfoot" is a steel-wire device with several hooklike prongs that splay out like the toes on a bird's foot. Several "crowfeet" are fastened to each rope, and these ropes are attached every six inches or so along the brail. The brail is dragged behind a boat over the mussel bed, and the mussels clamp onto the "crowfoot" as it passes over them (figure 3). Brailing is mainly suited to working level areas with high concentrations of mussels, and since the brail can also disturb the habitat and damage the mussels not captured, it is now only in limited use.

Much of today's harvesting is done with conventional diving techniques. The diver dons a wetsuit, weight belt, and mask, and breathes with a regulator that is connected by an air hose to a compressor situated in his boat. Submerged in murky water from 20 to 60 feet (6–20 m) deep, the diver works in total darkness, finding his catch by touch. Since most of the shells produced today are used to make the nucleus for saltwater pearl culturing, the diver seeks only certain types and sizes of mussels. Those he leaves behind suffer minimal disturbance. Diving also allows production from areas that would not normally be accessible by other methods.

Experienced divers can make good money, but the work is risky and dangerous. First, the diver must often operate in total darkness, a condition that many people cannot tolerate. Also, any diving done in water over 20 feet deep is dangerous. Without controlled and accurate decompression, the diver runs the risk of getting the "bends," which can be crippling or even fatal. Many divers work alone, so accidents or equipment malfunction can also be a real problem. Since they breathe air pumped down from the surface and are not limited in the time they can spend on the bottom, the divers can easily work to the point of exhaustion, becoming too weak to help themselves when a problem arises. The diver must often work his way around commercial fishing lines, tree stumps, and other underwater hazards, and often dives near commercial shipping lanes or in areas open to recreational boating. It takes a special kind of person to cope with working in such a difficult and hostile environment.

Yet some of the areas where mussels are still found are economically depressed and the opportunity to earn some money can be a very strong incentive. Many who try diving have little or no training; some do not even know how to swim! Some earn a good living fishing the mussels, but most simply get by or supplement other earnings. The risks are too great, the work is too hard for most. Those who succeed earn every penny.



Figure 3. A modern-day brail, with a few captured freshwater pearly mussels. Photo courtesy of the Tennessee River Folk Life Center, Nathan Bedford Forrest State Park, Eva, Tennessee.

NATURAL HISTORY OF THE UNIO MUSSEL

Freshwater pearly mussels are a diverse and widespread group of bivalve mollusks classed under the family Unionidae. The name is derived from the Latin word *unio*, which means a large, fine pearl. Fossil records and other data indicate that this group of animals appears to have developed about 350 million years ago, during the late Devonian or early Mississippian period. The Unios probably evolved from marine animals, although exactly when and where is the subject of some dispute among scientists (Dr. D. H. Stansbery, pers. comm.).

Technically, Unios are neither mussels nor clams, but are a distinct and unique family of freshwater mollusks, characterized mainly by nacreous shells and a life cycle that has an intermediate larval form which parasitizes vertebrate animals, usually fish. The scientifically correct term is *naiad*, after the nymph of Greek mythology who presided over rivers and lakes. However, those who make their living from the Unios, and even scientists, usually call them "mussels" or "freshwater pearly mussels." In this article, we will use the traditional name *mussel*.

At one time, scientists estimated that the Unio family contained more than 500 species, which were spread throughout the lakes and rivers of Asia, Europe, and North America. Currently, the number of species is estimated to be around 250 to 300. Although much of this reduction is due to reclassification and clarification of the nomenclature, many Unio species have become scarce or extinct in recent times because of habitat reduction and alteration, water pollution and, to some extent, overharvesting. At least 20 species have vanished from North America during the 20th century, and a similar number are listed as endangered (Dr. H. van der Schaile, pers. comm.).

North America, especially within the Mississippi River drainage area, provides the perfect habitat for these animals because of the large areas of watershed with limestone substrata. This abundance of limestone creates the "sweet" (alkaline) water and the concentration of calcium that is most conducive to the growth of Unios, enabling North America to support a diverse and abundant population of these mussels. The distribution of these mussels is mainly in the eastern

two-thirds of the United States (figure 4).

As mentioned, Unios have been found worldwide. The populations of the British Isles, mainly in Scotland and Ireland, are much reduced, although some very marginal pearl fishing still takes place. In Europe, the mussels have almost totally vanished. India and Pakistan have some Unio species, and some are probably found in Russia, especially Siberia, but the information on these occurrences is limited. China and Japan probably harbor the largest population of Unios outside North America. All the cultured freshwater pearls produced in these countries are grown in the three Unio species they have found suitable for culturing. Africa and South America are also known to support some of these mollusks.

Unios are generally hardy animals. Some species live in clear, fast-running mountain streams; others inhabit larger, slower moving rivers; still others prefer the even quieter waters of lakes and ponds. Their basic pattern of life is quite simple. Most live half-buried in the mud, sand, or gravel bottom of the body of water that they inhabit, feeding on waterborne bacteria, algae, and other plankton, and breathing waterborne oxygen by means of gills. Some types, especially those that live in mud or sand, can move about by means of a muscular foot. And several species, commonly called "floaters," are even able to inflate their bodies with gas so they can float and be carried along by current and wind! For the most part, though, Unios are sedentary, staying in one spot their entire life.

Unios normally populate a habitat rapidly, because one female can produce hundreds of thousands of larvae each year. These offspring are a valuable contribution to the food chain: where mussels are numerous, fish and other aquatic life forms are usually abundant. The larvae usually disperse by attaching themselves to fish. They may be further transported by birds and other animals that eat the host, so it is not unusual to find them in landlocked lakes and ponds.

While most Unios range from 3 to 6 inches (7.5–15 cm) across, some species are much smaller, with a maximum size of one inch or less. Others, like *Megalonaias gigantea* (the "washboard"), span a foot (30 cm) or more at maturity (figure 5). All species continue to grow as long as they live, but growth is most rapid the first few years. Most species live 15 to 50 years; in a

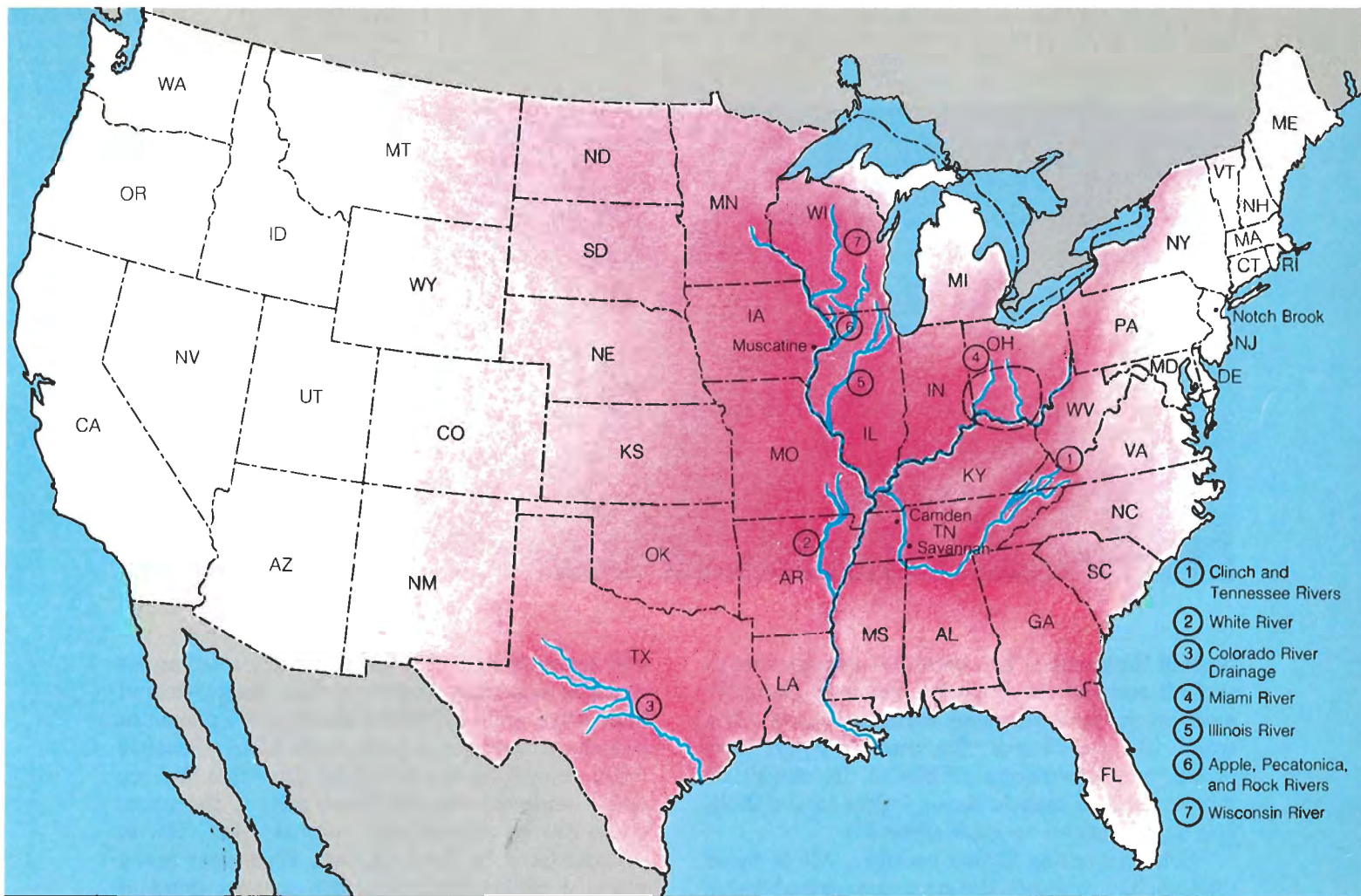


Figure 4. General range of *Unios* in the United States, approximate maximum distribution. Rivers of note are shown in blue; the Hopewell mound area is indicated by a dotted line.

nonpolluted habitat, some live as long as 100 years.

Because of their diversity, *Unios* can occupy many niches in the ecosystem, their main requirement being suitable water quality. Most importantly for man, *Unios* convert dissolved calcium into the lustrous aggregate materials that make up their shell and, under certain conditions, form pearls. All *Unios* produce shells with nacreous inner surfaces, and all continue to secrete nacre as long as they live, although the nacre flow slows with age. Some species, such as those used for freshwater pearl culturing in Japan and China, grow very thin shells, no more than 1 or 2 mm thick. Other species, such as those that provide the raw material for the mother-of-pearl beads used in saltwater pearl cultivation, form rather heavy shells, some portions of which are 15 to 30 mm thick. Generally, the thicker-shelled *Unios* are found in waters that contain a high concen-

tration of dissolved calcium.

While most species produce white nacre, many other colors also occur, including pink, orange, lavender, and purple. The color of the shell and the pearl is a complex result of genetic and/or environmental factors, and is not totally understood. Some species that normally produce white nacre may also produce pink or orange nacre in certain bodies of water. Other species always produce one basic color of nacre, but the tone and general appearance of that color may vary considerably, depending on numerous factors.

Because most *Unios* are sedentary and live in habitats that tend to be quite rich in animal life, they are exposed to many natural circumstances that can cause pearls to form. For example, *Unios* are often hosts to various parasites, usually snails, other small mollusks, and various types of worms. In their search for food, these creatures get inside the protective shell and burrow into the



Figure 5. The *Unio*, or pearly mussel, in which natural freshwater pearls form. The species illustrated here, *Megaloniaias gigantea* (the "washboard"), may grow to more than a foot; this shell measures approximately 5 in. (13 cm). Photo © 1984 Tino Hammid.

flesh of the mussel. The mussel is usually able to seal off and kill the intruder, and then gradually envelop the body in nacre, forming a pearl. Or a small fish can attack the mussel when it is opened to feed, tearing off bits of the mantle. A stray crumb of mantle tissue lodges in the shell, and a pearl begins to grow around it.

Self-nucleation is also possible. All of these mussels have a tooth-like structure on each valve near the hinge which allows them to grind their food. Because of the tremendous leverage involved, bits of this structure frequently break off and pearls form around them, between the "teeth." These pearls have a distinctive shape and texture that matches the "teeth" perfectly.

Unio pearls are often nucleated by debris, primarily bits of shell and possibly fish scales, carried into the mussel bed by water currents. In the early days, pearl seekers looked for mussel beds located just downstream from Indian mounds and shell heaps, where an abundance of minute shell particles weathered out, causing pearls to form much more frequently.

A common belief is that pearls are started or nucleated by a grain of sand. In the authors' opinion, based on years of personal observation and experimentation, the usual process of nucleation of natural pearls, at the very least in freshwater mussels, is the accidental introduction of natural *organic* substances, especially those of calcareous shell, into the body of the mollusk. While it is true that mineral substances can be used to culture blister pearls, and that pebbles can be encapsulated within a natural blister, these objects become heavily coated with conchiolin before the nacre

will cover them. There is little if any attachment of nacre to such an object. In fact, the growers of Mabe-type cultured blister pearls use a plastic or soapstone hemisphere to start the blister, because these objects do not attach to the nacre and are easily removed, so that the inside of the nacre dome can be cleaned and colored. This view is substantiated by the fact that, even after many years of experimentation with various types of nuclei, including several types of manmade calcareous substances, the Japanese saltwater pearl growers still use the freshwater shell bead.

Once a pearl has been started, it grows as the mussel and its shell grow. As the years go by and the pearl becomes larger, it increasingly affects the mussel. Pearls that start out in the main body of the mussel tend to migrate downward as they gain weight, eventually settling against the lowest portion of the shell. As the mussel continues to grow, the nacre produced in that area accumulates on the pearl rather than the shell, so that the shell gradually becomes deformed. Historically, mussel fishermen have sought these "crippled" shells because they often contain a large pearl.

Pearls that form in areas around the hinge may become so large that the mussel can no longer close its shell. Once this occurs, the mussel has little chance of survival. It is not unusual for a single *Unio* to produce many small pearls—some have been found to contain more than 100. In general, the larger the pearl or the greater the number of pearls, the harder it is on the mollusk.

Why do some mollusks produce that magical stuff, nacre, and others simply calcareous substances? A simple question, yet the authors have

found no answer, even among malachologists. The pearly mussels, biologically not much more than a worm with a hard shell, have long been sought for their glowing pearls. The wonder is that such a lowly creature should create such a beautiful object.

AMERICAN NATURAL FRESHWATER PEARLS

The freshwater pearls of the Unios are often beautiful, distinctive, and unusual. If one is simply interested in smoothness and roundness in pearls, then look to the cultured pearl, because the truly round natural pearl is the exception rather than the rule. The freshwater pearls of North America exhibit an exceptionally broad range of colors, shapes, qualities, and sizes.

The physical and structural properties of these pearls are essentially the same as those of saltwater pearls. Natural pearls are composed mainly of nacre, which is primarily calcium carbonate, in the form of aragonite (82%–86%), conchiolin (10%–14%), and water (2%–4%), as described in Webster (1975). The presence of manganese as a trace element is evidenced by the X-ray fluorescence exhibited by natural freshwater pearls and shells. Other trace elements are present in the pigmentation seen in freshwater pearls and shells, but the role of these substances needs more scientific study.

Identification of natural freshwater pearls is most reliably accomplished in the laboratory using a combination of X-radiography, which discloses the internal structural characteristics that show natural or cultured origin, and X-ray fluorescence, which usually establishes freshwater or saltwater origin. In the field, distinctive characteristics of appearance are in many cases adequate to identify freshwater natural pearls. Important identifications should be confirmed by laboratory tests or by persons experienced in handling these goods. We will describe some of these distinctive characteristics below.

Color. Peach, apricot, and tangerine . . . rose, orchid, and lavender . . . bronze, silver, and gold . . . these and other names have long been used to describe the delicate colors and shadings of freshwater and other pearls. Lacking a scientific system for the communication of pearl colors, and well aware that the description of pearl color is complicated by the optical phenomena of luster, over-

tone, and orient, pearl dealers usually manage to communicate to one another through consistent use of these color names. Still, actual matching of colors must be done with the pearls themselves. The development of a reliable and repeatable system of color communication for pearls is an area that the authors are currently investigating, but the problem has no simple solution. Pearl colors can be so subtle that they challenge not only our language skills but our visual skills as well.

The phenomenon of rosé (or traditionally, rosea) is a good example of why the color description of pearls can be so difficult. In natural pearls, and to some extent, cultured pearls, rosé is both an overtone color and an optical phenomenon associated with a generally high level of luster. One could say that rosé describes a certain quality of nacre that is very lustrous and translucent and that has a typical color appearance. The color appearance of rosé is usually pinkish, but it can also appear reddish, violetish, or purplish.

The degree or intensity of rosé can vary greatly also. On some pearls, rosé appears as a slight to noticeable overtone on a light body color, and would be called white rosé or creme rosé, etc. Occasionally, one sees superior pearls of light body color, where the luster is so bright and the rosé tint so strong that the underlying body color is not really noticed. The color of such a pearl might be described as a *true* rosé.

On natural pearls, rosé is almost always natural. On cultured pearls, rosé is commonly accomplished with various types of dye. It is not unusual to enhance or develop rosé in both natural and cultured pearls by simple surface treatments that remove cloudy or opaque material or smooth the surface of the pearl. As a general rule, such treatments do not work well on pearls of inferior quality.

The color description of pearls is also complicated by the presence of conchiolin in the nacre. Although conchiolin is always present in nacre, it usually occurs in minor amounts which are colorless. Often, however, conchiolin picks up impurities that turn it dark brown or black. When this dark form occurs deep within the pearl around the nucleus, it may darken the overall color; when it concentrates in patches closer to the surface, it may appear as dark blotches of various colors. It also may be deposited as a layer or layers thick enough to affect the overall color of the pearl, but not heavy enough to appear dark, thereby adding a

golden, greenish, brownish, or grayish component to the body color. Many natural freshwater pearls called bronze, golden, and the like are conchiolin-rich, and many pink and lavender colors are modified by thin layers of conchiolin, often with a pleasing effect.

Lastly, certain colors are typical of pearls from particular locales and species. White is the most prevalent body color of freshwater pearls in America; it is usually a pure snowy white, touched with varying degrees of rosé and/or orient. At least two-thirds of the natural freshwater pearls produced in North America are white. Creme colors are not particularly common in American freshwater pearls, although they are typical of pearls of the Ohio River, especially those from the upper reaches of the system. In contrast, creme colors are frequently seen in the freshwater cultured and natural pearls of Japan and China.

The "black" colors occur in freshwater pearls, but the look we associate with South Sea pearls (both natural and cultured), of a deep pure black with attractive overtones, is rare in freshwater pearls. The "black" colors normally present on freshwater pearls are very dark pinks, lavenders, bronzes, grays, and the like.

Fancy colors in pearls are considered to be any desirable body colors not found in the light group or the black group. Although freshwater pearls of the Unios are noted for fancy pink, orange, purple, or golden hues, there are so many modifications and variations of these basic colors that the range seems almost endless. Even blue and green occur rarely. The colors usually have a soft, subdued pastel look, but some can be quite vivid. Figure 6 shows excellent examples of some of the various colors, including white and rosé, of American natural freshwater pearls.

Freshwater mussels and other mollusks sometimes produce pearls with more than one color. These may be bicolored, where the two sides of the pearl are two totally different colors, or multicolored—like an opal—where a number of totally different colors are seen on a single pearl.

In the heyday of the natural freshwater pearl, specific mussels and certain locales were noted for their production of beautiful fancy colors. The Tennessee River and its tributaries were good producers of fancy colored pearls, because the habitat supported many different *Unio* species. In Texas, the Colorado River drainage, including the Concho River, the San Saba, and others, were

noted for pink, purple, and lavender pearls. And several rivers in Wisconsin, including the Apple, the Pecatonica, the Rock, and the Wisconsin, produced pearls of various fancy colors, especially delicate and pure greens (again, see figure 6). Natural fancy colors are one indication (though not proof) that the pearls are of freshwater origin.

Shapes. Most natural pearls are and always have been baroque, and a good percentage of cultured pearls are baroque. In nature, the perfectly round pearl is very rare, accounting for less than 0.01% of American natural freshwater pearls, and a very small portion of other types of naturals. Even expensive strands of natural Oriental pearls usually contain many pearls that are off-round or slightly baroque. Other symmetrical shapes, such as the bouton, pear, and barrel, are also rare and unusual in natural pearls, because specific and limited factors must be present for a natural pearl to form symmetrically. The authors estimate that fewer than 5% of natural pearls are truly symmetrical.

In contrast, the shape of today's cultured pearls is usually a result of the grower's skill. Modern techniques of pearl culturing allow varying degrees of control over the form of the final product. For example, the shape of the myriad round salt-water cultured pearls produced in Japan is controlled mainly by three factors. First and most important, the round mother-of-pearl bead that is implanted as the nucleus accounts for about 70% to 90% of the volume of these cultured pearls, and thus largely determines the final shape. Next, the quality of that shell bead is carefully controlled so that no flaw in the nucleus will cause baroque in the cultured pearl produced. Lastly, the length of the growing period for the bulk of these cultured pearls has been reduced from several years to six to 10 months, thereby greatly reducing the chances that the cultured pearls will become baroque (Cohen, 1984).

The freshwater pearly mussels do form all the classic symmetrical shapes associated with natu-

Figure 6. Some of the many colors in which American freshwater pearls occur. Counter-clockwise, from top right: rosebud, rosé, 25.4 × 20.8 mm (52.89 ct); round, light peach-pink, 17.2 mm (33.55 ct); pear, white rosé, 17.9 × 11.0 mm (15.54 ct); group of boutons 7.5 to 10 mm in diameter, showing various natural fancy colors. Photo © 1984 Tino Hammid.



ral pearls. Usually, these pearls are formed in areas near the adductor muscles and at the periphery of the shell, where the pearl can be turned or spun by the normal activity of the mussel, thus causing the nacre to be deposited smoothly and evenly. As evidence of this phenomenon, some symmetrical pearls show deposits of coarser nacre or chalky substances, and also grooves, that have been laid down concentrically onto the surface of the pearl, as if with a draftsman's compass. Symmetrical freshwater pearls are quite rare and desirable, with the round and the pear shape being the rarest, and the bouton and the barrel shape the most common. The pearls in the graduated necklace shown on the cover of this issue are all natural round freshwater pearls from the Tennessee River, and represent over 25 years of diligent collecting and sorting.

The Unios also produce pearls in an amazing array of baroque shapes and forms, often delightful, sometimes grotesque, but never boring. Some of these shapes are similar to the baroque pearls formed by other mollusk groups, but many are unique and typical of the freshwater pearly mussels. Certain of these shapes occur repeatedly, reflecting a set of conditions that is prevalent within the environment of the mussel.

Figure 7 shows several groupings of natural freshwater pearls which represent the most common baroque shapes found in American waters. Note that within each group, each pearl is unique but the overall shapes are similar. These groupings by shape are part of the system traditionally used

by natural pearl dealers in America to sort and grade small natural freshwater pearls. Larger goods are usually graded and evaluated on an individual basis. Of these basic groups, "wings" and "petals" are the most common, and shapes no. 2 and no. 6 are the least common.

Other baroque shapes have been found with enough frequency to merit special names. Because of beauty, rarity, and demand, these classic baroque pearls may carry the same value as some of the symmetrical pearls of equivalent size and quality. One of these, the "turtleback," is roughly oval in outline with a domed cabochon-like top. Turtlebacks generally have a smooth surface with good luster and orient, so they are ideally suited for making important pieces of jewelry (the ring on the cover of this issue contains a fine turtleback pearl). Turtlebacks sometimes show a curious texture within the nacre that resembles stretch marks in human flesh. This texture reflects the fact that they usually grow near the outermost edge of the mussel shell, where the mantle has to stretch to cover the pearl. Mabes and other blister pearls which grow near the periphery of a mollusk shell sometimes show a similar texture. Turtlebacks normally start out as a free pearl within the mantle, but they may break through the mantle as they gain weight, settle against the shell, and become encapsulated as a blister pearl.

Another special shape is the "rosebud." This characteristically American freshwater pearl is typically high domed, with a flat back and roughly

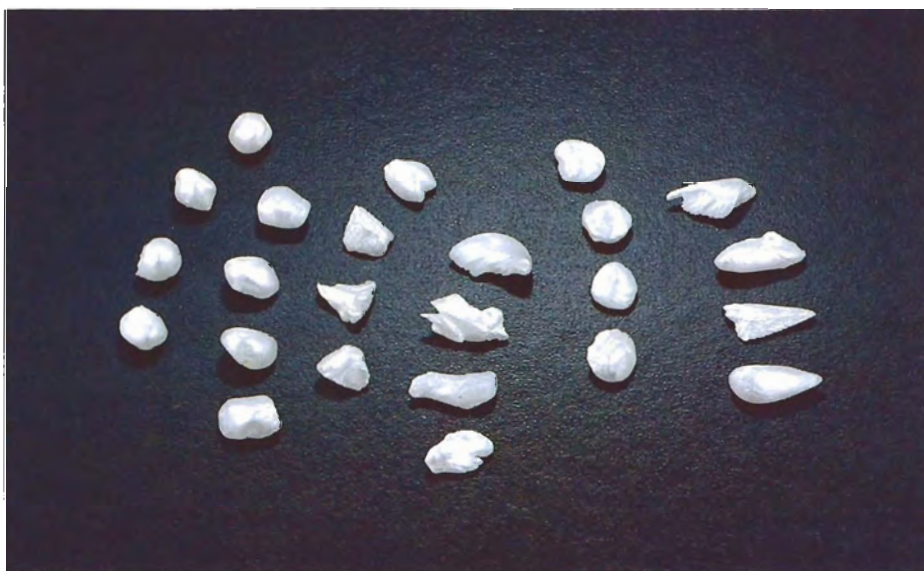


Figure 7. Typical small baroque American natural freshwater pearls, of average to better quality, grouped in traditional shape categories. Left to right: shape no. 2, semi-round, sometimes referred to as "nuggets"; shape no. 3, oval but thick; shape no. 4, roughly triangular, known as "petals"; shape no. 5, longish but flat; shape no. 6, roundish or oval, but flat; and one size of "wing" pearls. Photo © 1984 Tino Hammid.

Figure 8. American natural freshwater pearls, nucleated by snails and periwinkles. Counter-clockwise, from top right: snail, white rosé, 39.0 × 30.0 mm (89.93 ct); snail, fancy bronze-lavender, 31.0 × 25.2 mm, (80.43 ct); pair of periwinkle pearls, matched, fancy pink and gold. Photo © 1984 Tino Hammid.



roundish outline. The top is always covered with bumps or ridges and, to be a true "rosebud," must be of very high luster and quality. Again, this type of pearl lends itself to fine jewelry. The bumpy or ridged surface is thought by the authors to be caused by multiple nucleation or by minute life forms or debris attaching to the surface of an otherwise smooth pearl. The face-up view of an exquisite and very large rosebud pearl is shown in figure 6, upper right.

The "snail" shape is also considered a classic. Pearls that are nucleated by snails or other shelled creatures usually take on the orientation of the calcium carbonate platelets of the shell at the nucleus, and can maintain the basic shape of the nucleus for many years. The large snail-shaped pearl in figure 8, upper right, was X-rayed and found to have a nucleus about 4 mm across. This pearl probably grew for at least 30 years before it was taken from the host mussel, and yet it retained the orientation of that tiny snail for the entire

time. Figure 8 also shows an extremely fine and large lavender-colored snail pearl and a pair of wing-shaped pearls, which were probably nucleated by periwinkles.

Baroque pearls with totally unique shapes may be referred to as "exotics" or, if grotesque, as "monsters." Often, the form brings to mind a picture or image, and that pearl will be formally described according to that image, for example, "acorn," "bird's head," "strawberry," and the like. When such a pearl is large and of fine color and luster, the unique shape may add significantly to its beauty and value.

The nucleation of natural freshwater pearls by snails and other small mollusks also generates distinctive surface features. Many natural freshwater pearls show swirling, spiraling grooves or raised lines on the surface, which may be either deep and prominent or quite fine. These grooves or lines usually follow the overall shape of the pearl, more or less paralleling one another, rarely if ever



Figure 9. Size and age progression of natural "wing" pearls. Left to right; 6-7 x 2-3 mm, two to three years; 8-9 x 2-3 mm, three to four years; 10-11 x 3-4 mm, four to five years; 12-13 x 4-5 mm, five to seven years; 14-15 x 4-5 mm, six to seven years; 16-17 x 5-6 mm, seven to eight years. Ages are authors' best estimates. Photo © 1984 Tino Hammid.

crossing. A finely grooved surface can give the pearl a silky luster and, if the nacre is clear and translucent, can create light interference and dispersion, that is, orient. Because of these and other surface features, because of their baroque and irregular shapes, and because the nacre is often very pure and clear, American freshwater natural pearls show a lot of orient, often significantly more than pearls from other localities.

The rosebud, turtleback, snail, wing, and petal shapes can all be considered typical of American freshwater natural pearls. While it is possible for saltwater and other freshwater pearls to occur in similar shapes, it is unlikely because the same conditions and circumstances do not prevail in these environments.

Other Characteristics. The size of some freshwater pearls can be quite breathtaking. Many of the Unios are long-lived and large, inhabiting warm calcium-rich waters that promote the growth of very large pearls. Figure 9 shows a progression of wing pearls, small to large, with the authors' estimation of age. Unfortunately, most of the best habitats have been destroyed, disturbed, or contaminated, so the mussels growing today have relatively short lifespans and, consequently, produce very few large pearls.

American natural freshwater pearls, like other natural pearls, exhibit the full range of luster quality. The best of these pearls will compare favorably with the finest from any locality.

PEARL CULTURING IN AMERICA

Pearl culturing is both an art and a science. The pearl farmer needs the intuition to understand and

work with nature and the pragmatic ability to apply new techniques and methods that will enhance his production. Pearl culturing is essentially farming in water, where the objective is high production at low cost. The risks are enormous. To set up a new pearl farm, large outlays of cash are needed for equipment, water leases, and the training of people to nucleate the shells. More capital is needed to obtain the livestock of the pearl farmer, the mollusks. Then the farm must be able to operate without income until the first crop can be harvested, which may be several years after it was "planted." Add to these problems the unpredictability of nature, which can wipe out a substantial investment overnight.

The success of the freshwater pearl growers in Japan and China led to the author's (Latendresse) endeavors to cultivate freshwater pearls in America. After years of research and experimentation in the 1960s and 1970s, the first pilot pearl farm was established in 1981 (Sweaney and Latendresse, 1982).

At the pilot project, a good-sized pearl farm located at Cedar Lake in western Tennessee, over 20,000 mussels were nucleated. At first, these shells showed good pearl growth, but several months into the project, a water-quality condition developed that had never before been encountered, even in the experience of the growers at Lake Biwa. This condition caused the mussels to stop producing nacre. The crop of nucleated mussels was moved to a site that had excellent water quality and a good population of wild mussels. Again, production proceeded very well until a drought in the summer of 1983 caused the water level to recede and the water quality to degenerate, with the re-

sult that the mother shells began to die off. Although the shells were quickly moved to another site that had proved itself in earlier experiments, a significant portion of this first large crop was lost.

The new site is well suited for culturing, since it already produces good natural pearls, and is accessible and workable. A good section of water has been leased and is being developed into a full-scale pearl farm. The shells from Cedar Lake have recovered and are doing reasonably well, considering their experience, and new mother shells are being nucleated at a laboratory nearby. Several other sites in Tennessee and other states are currently being tested with small groups of nucleated mother shells, and will be developed as farms if they prove feasible.

There is a cloud on the horizon that may dampen the future of these pearl-culturing efforts in some areas: acid rain. Through constant monitoring of water quality, our technicians have found that some of the local rains already have the chemical equivalent of weak sulphuric acid. Acid is very bad for the mussel, which needs "sweet" water that is neutral to alkaline in pH in order to be able to form its shell and pearls. At this point, acid rain is not recognized as a problem in the South, but indications are that it may soon become one, since many power-generating plants and industries in the area burn high-sulphur coal and oil.

The pearl-culturing enterprise has had its share of ups and downs, but the prospects are still quite good. We expect a harvest within the next year or two, but given our previous setbacks, we know that it is too early to name a specific time. Culturing has been accomplished in the American mussel, and the pearls promise to be exquisite, well worth the time and effort. As evidence, refer to figure 10, the first published photograph of American cultured freshwater pearls (GIA Gem Trade Laboratory report no. 2416970, 1984).

CONCLUSION

The natural freshwater pearls of America present a paradox. Although some are, without a doubt, the most beautiful pearls of all, many people, including many jewelers, do not realize that such fine gems have come from the lakes and rivers of the United States. In part, this is probably due to the fact that natural pearls of all types are not as available as they once were, primarily because of environmental factors. Current production of freshwater natural pearls in America is 5%, or less, of what

it was as recently as the 1950s and early 1960s; worldwide, production of natural pearls, from freshwater and saltwater, is also dramatically reduced.

And, while many people understand the difference in price between a fine natural ruby and its synthetic counterpart, the cost of a fine natural freshwater pearl is difficult for some to accept, especially when compared with the inexpensive cultured products on the market today. Yet the price ratio between natural freshwater pearls and

Figure 10. A sampling of freshwater pearls cultured in America by John Latendresse. The group includes one baroque, white rosé, 12 × 10 mm (2.2 ct); one baroque, white rosé, 9 × 8 mm (1.5 ct); one smooth baroque, white rosé, 10 × 9 mm (4.9 ct); one smooth baroque, white rosé, 8 × 7.5 mm (2.7 ct); one round, white, 7 mm (2.8 ct); one round, bronze-lavender, 5 mm (0.79 ct); and five semi-round pearls, white rosé, about 4 mm each (2.65 ct total weight). None of these pearls was treated or enhanced in any way. Photo © 1984 Tino Hammid.



cultured pearls is no greater than that between natural and synthetic rubies.

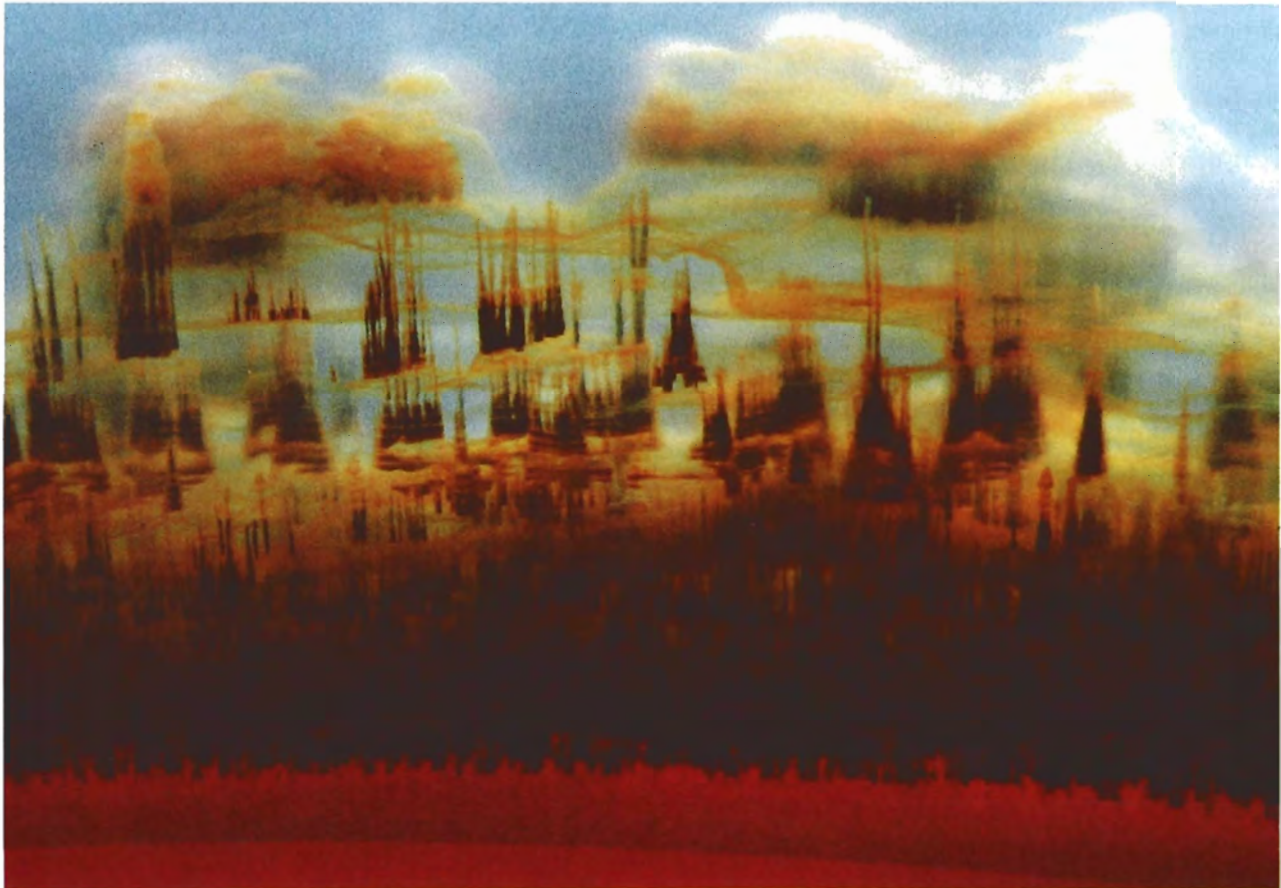
Tastes have changed. Whereas 60 years ago, when natural pearls dominated the market, pearls of all colors and shapes were accepted as the norm, and round white pearls were the exception; today, with cultured pearls in the forefront, almost the opposite is true. While the beauty and variety of American natural freshwater pearls can never be duplicated, some of that can be recaptured. The consumer will have many new choices and the jeweler, a new product, with the American freshwater cultured pearl.

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Gems & Gemology Editor John Koivula Wins Nikon Photomicrography Contest

Noted gem photomicrographer John Koivula was recently awarded first prize in the 1984 Small World International Annual Photography competition sponsored by Nikon International. Mr. Koivula, who is editor of the Gem News section of Gems & Gemology and a frequent contributor to the journal, won the contest with his photomicrograph of inclusions of goethite and hematite in a slab of Brazilian agate that was sectioned and polished perpendicular to the formational layering. In addition to a cash award, John and his wife Kristie will be flown to New York for the award ceremony. All of the entries that placed in the contest will be on display throughout November at "Nikon House," Rockefeller Center, New York. The winning photomicrograph is reproduced here courtesy of Nikon Inc. Instrument Group, Garden City, New York. Magnified 30x.



THE CHEMICAL DISTINCTION OF NATURAL FROM SYNTHETIC EMERALDS

By Carol M. Stockton

The chemical characteristics of natural and synthetic emeralds were studied in order to identify differences that could be used to separate them from one another. Thirty-eight natural emeralds from 20 localities and 11 synthetic stones from six manufacturers (flux and hydrothermal growth processes) were analyzed by microprobe and X-ray fluorescence. The results revealed a complex collection of chemical constituents that reflect the different environments in which natural and synthetic emeralds form. The present study agrees with the limited number of analyses previously reported for both materials. Thus, a new method of distinguishing natural from synthetic emeralds is now available for use in gemology when more conventional methods prove inadequate.

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Acknowledgments: The author wishes to thank the California Institute of Technology for the use of their microprobe and X-ray fluorescence equipment, as well as Arthur Chodos and Randy Heuser for their assistance with the instrumentation. Grateful appreciation is also extended to the National Museum of Natural History (Smithsonian Institution) for providing samples from some of the more unusual localities. All other materials came from the permanent reference collection at the Gemological Institute of America; we thank the many donors who have supported our efforts over the years.

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The gemological techniques now used to separate natural from synthetic emeralds—primarily refractive index, fluorescence, and inclusions—do not provide solutions for all current situations, especially in the case of stones that lack inclusions. Moreover, the rapid advances being made in the manufacture of synthetics are almost certain to reduce the usefulness of these gemological tests even further. Consequently, a detailed analysis of major and minor-element chemistry of natural and synthetic emeralds was conducted to determine the possible existence of essential differences in the chemical compositions of these materials in order to provide gemology with additional means of distinction.

The theory that one can distinguish chemically between synthetic and natural gem materials is based on the premise that natural gems incorporate a variety of nonessential chemical components from the natural environments in which they are formed that are not present in the manufacture of their synthetic counterparts. Conversely, elements that are not associated with the natural environment for minerals are frequently incorporated into the artificial environments created for the growth of synthetic crystals.

The results of a small preliminary sampling of natural and synthetic emeralds indicated that there was support for the idea of chemical distinction and that more extensive work was justified. In addition, a recent article by Schrader (1983) provided further evidence that natural and synthetic emeralds have significant chemical differences. Although Schrader's paper is a summary of a more thorough study, it is not conclusive and demonstrates the need for additional work, especially since his study included natural emeralds from only seven localities and omitted hydrothermally grown synthetics.

Another recent article (Hänni, 1982) presented chemical data on a number of natural and synthetic emeralds, but

TABLE 1. Localities of the natural emeralds and manufacturers of the synthetic emeralds discussed in this article (from this and two previous studies).

Country/method of synthesis	Specific locality/ manufacturer	Stockton (49 stones)	Schrader (1983) (58 stones)	Hänni (1982) (43 stones)
Natural Emeralds				
Austria	Salzburg		+	+
Brazil	Santa Terezinha	+	+	
	Goiás	+		
	Bahia		+	
	Salininha		+	
	Minas Gerais		+	
Colombia	unknown	+	+	+
	Chivor	+	+	
	Muzo	+		
	unknown	+		+
Ecuador				+
Egypt (3rd century B.C.)		+		
Tanzania	Lake Manyara	+		
Norway	Eidsvoll	+		
Pakistan			+	+
Peru		+		
South Africa	Cobra Mine, Transvaal		+	
	Transvaal	+	+	+
U.S.A.	North Carolina	+		
USSR	Ural Mountains	+	+	
Zambia		+		+
Zimbabwe	Sandawana	+	+	+
Unknown		+		
Synthetic Emeralds				
Hydrothermal	Linde	+		+
	Regency	+		
	Biron	+		
Flux	Chatham	+	+	+
	Gilson	+	+	+
	Inamori	+	+	+
	Lens Lens		+	+
	Zerfass			+

there are some important disparities between Hänni's data and the information obtained from this study. A discussion of both Schrader's and Hänni's data as well as those of other researchers is included with the presentation of results obtained in the current study.

Chemical data on emeralds are relatively scarce, and the wide ranges of sources, colors, and qualities of this gem also suggest that extensive analysis is advisable before any general conclusions can be reached. The work presented here both confirms Schrader's findings and introduces data for additional localities and synthetics manufacturers. The sum of these works thus establishes that natural emeralds can be chemically distinguished from their synthetic counterparts.

MATERIALS AND METHODS

The collection compiled for this study includes 38 natural emeralds from 20 different localities

and 11 synthetic emeralds that represent six different manufacturers. All are either cut gems or gem-quality rough specimens. An attempt was made to sample as many localities and manufacturers as possible; a list of these specific sources is provided in table 1. In addition, the collection represents as broad a variety of colors as could be found that still lie within the range generally accepted as emerald (figure 1).

The emerald specimens were analyzed for Na₂O, K₂O, MgO, CaO, MnO, FeO, Al₂O₃, V₂O₃, Cr₂O₃, SiO₂, and Cl by a MAC electron microprobe at an operating voltage of 15 KeV and beam current of 0.05 μ A. This provides only partial analyses (less than 100% total), because the light elements, most importantly Be and Li, cannot be detected by the microprobe. The raw data were corrected by the Ultimate program (Chodos et al., 1973). Microprobe results were checked and additional trace elements identified by qualitative energy-



Figure 1. A representative sample of natural and synthetic emeralds from the study collection. The stones pictured range from 0.50 to 1.91 ct and originate from the following sources (left to right): Santa Terezinha de Goiás (Brazil), Lake Manyara (Tanzania), Biron (hydrothermally grown synthetic), Chatham (flux-grown synthetic), natural (country unknown), and two stones from Colombia (specific localities unknown). Photo by Michael Havstad.

dispersive X-ray fluorescence spectrometry (EDXRF) with a Kevex 0700 system.

DISCUSSION OF RESULTS

The results of the chemical analyses of the study collection are summarized in table 2. Major elements include Al_2O_3 and SiO_2 . Minor elements, for the purposes of this study, are those present in oxides below 10.0 wt.% but above microprobe detection limits (≤ 0.1 wt.%): Na_2O , MgO , FeO , V_2O_3 , Cr_2O_3 , and Cl . Trace elements then, are those present in quantities below the microprobe detection limits (i.e., determined by EDXRF).

The oxides measured by microprobe fall into two categories: (1) those that provide no information useful for distinguishing natural from synthetic emeralds; and (2) those that, at certain levels of concentration or in conjunction with other elements present or absent, provide means of separation. Among the oxides measured, V_2O_3 and Cr_2O_3 fit the first category and thus can be disregarded.

Chemical components that fall into the second category mentioned above provide us with reliable means of identification in most cases. In the samples analyzed here, chlorine (Cl) was found

in all the hydrothermal synthetics, but in no other emeralds examined. It was detected at trace to minor levels and reportedly comes from the chloride hydrate ($\text{CrCl}_3 \cdot 6\text{H}_2\text{O}$) that is used to supply chromium as a coloring agent (Nassau, 1980, p. 151).

The remaining major and minor chemical components are present in ranges that partially overlap for natural and synthetic emeralds. Na_2O , MgO , and FeO are all present in greater quantities in natural emeralds than in the synthetics. Na_2O was found in amounts not exceeding 0.1 wt.% in synthetics but up to 2.3 wt.% in natural emeralds, therefore suggesting that quantities appreciably greater than 0.1 wt.% indicate natural origin. Likewise, the presence of MgO and FeO in amounts that notably exceed 0.1 wt.% is characteristic of natural emerald. Smaller quantities of Na_2O , MgO , and FeO , however, provide no diagnostic information.

Al_2O_3 and SiO_2 supply additional information about origin. In natural emeralds, Al_2O_3 ranges from about 11.7 wt.% to 18.2 wt.%, while in both types of synthetics it invariably exceeds 18.0 wt.%. Similarly, SiO_2 ranges from approximately 63.3 wt.% to 66.5 wt.% in the natural specimens,

but exceeds 65.6 wt.% in all the synthetics. Thus, amounts of Al₂O₃ and SiO₂ below those found in synthetics (18.0 wt.% and 65.7 wt.%, respectively) are indicative of natural origin and probably reflect the greater amounts of minor and trace elements usually included in the composition of natural emeralds.

Qualitative analysis by EDXRF revealed the presence of a number of elements at the trace level that provide additional evidence of natural or synthetic origin. From the data listed in table 2, one can see that several elements identified at trace and minor levels in many of the natural emeralds were not found at corresponding levels in any of the synthetic emeralds examined here. On the other hand, only one element (rhodium) found in synthetics at the trace level did not appear at all in the natural specimens. In conjunction with the

data on minor-element composition, these data enable us to distinguish between natural and synthetic emeralds of the localities and types analyzed, since every natural specimen in the study collection contains at least one trace element not found in any of the synthetics and/or at least one minor element found at levels appreciably greater than in the synthetic samples.

Table 3 summarizes the earlier data published by Schrader (1983) and Hänni (1982). Schrader's data were originally presented in atomic-percent units, but have been converted to weight-percent oxides for comparison with the other data presented here. A comparison with table 2 shows that the data reported by Schrader generally agree with the results obtained in the present study. The only notable exception among his data are two synthetic emeralds that have appreciably more iron than has otherwise been found: a Gilson with about 0.25 wt.% FeO and an Inamori with approximately 0.52 wt.% FeO. The greater range of vanadium (V₂O₃) reported in table 2 is largely due to the new Biron hydrothermal synthetics that are included in the present study but are not yet available on the gem market (and, in all probability, were not available to Schrader at the time of his study). Other minor but nonsignificant differences between the two sets of data probably reflect differences in test samples: The present study includes stones from six localities and three manufacturers not sampled by Schrader, whereas he reported on samples from two localities and one manufacturer not analyzed here (see table 1).

The data published by Hänni (1982) agree for the most part with those obtained here and by Schrader, except that the figures reported for TiO₂ and MnO appear to be considerably higher than otherwise found. Of greater concern, however, Hänni reported the presence of MgO in amounts greater than 0.1 wt.% in synthetic emeralds. This is a significant departure, given the almost total agreement between the latest data (table 2) and Schrader's findings. However, about half of the elements reported by Hänni, including MgO, MnO, and TiO₂, were measured by means of an energy-dispersive X-ray (EDX) detector (Hänni, pers. comm.), which is considerably less sensitive and less accurate than the wavelength-dispersive spectrometers usually used for quantitative microprobe analyses (as in the present study). The inconsistencies reported by Hänni fall below the detection limits of the EDX detector (around

TABLE 2. Chemical data (in wt.%) for the study collection of natural and synthetic (hydrothermally grown and flux-grown) emeralds.^a

Components	Natural (38 stones)	Hydrothermal (6 stones)	Flux (5 stones)
Oxides			
Na ₂ O	≤ 2.3	nd	< 0.1
MgO	≤ 3.1	nd	nd
FeO	tr - 2.0	nd	≤ 0.1
Al ₂ O ₃	11.7-18.2	18.1-18.8	18.1-20.1
V ₂ O ₃	tr- 2.0	≤ 0.7	≤ 0.1
Cr ₂ O ₃	tr- 1.2	0.3- 0.8	0.2- 0.9
SiO ₂	63.3-66.5	65.8-66.6	65.7-67.4
Cl	nd	tr- 0.3	nd
Trace Elements			
K	*	-	-
Ca	**	-	-
Sc	**	-	-
Ti	*	-	-
Mn	*	-	-
Ni	**	*	-
Zn	**	*	-
Ga	*	*	*
Rb	**	-	-
Zr	*	-	-
Mo	*	-	**
Rh	-	**	**
Cs	**	*	-
Ba	**	-	*
La	**	*	-

^aSymbols:

nd = not detected

tr = traces detected by EDXRF

** = traces detected in 50% or more of the specimens examined

* = traces detected in fewer than 50% of the specimens examined

- = not detected at trace levels

TABLE 3. Chemical data for natural and synthetic (flux-grown and hydrothermally grown) emeralds from the Schrader (1983) and Hänni (1982) studies.^a

Components	Schrader		Hänni		
	Natural (44 stones)	Flux (13 stones)	Natural	Hydrothermal (43 stones total)	Flux
Oxides					
Na ₂ O	~0.04–2.29	0.002–0.04	0.6– 2.3	nd	≤ 0.1
MgO	tr–0.83	nd	1.0– 3.1	≤ 0.2	≤ 0.4
FeO	0.06–0.64	*≤0.52	≤ 1.3	nd	nd
Al ₂ O ₃	nr	nr	13.4–17.7	18.6–18.8	18.1–19.9
V ₂ O ₃	tr–0.22	≤0.19	≤ 0.9	nd	≤ 0.1
Cr ₂ O ₃	≤2.06	0.57–2.19	≤ 1.4	0.5– 0.8	0.3– 1.9
SiO ₂	nr	nr	63.0–65.9	66.1–66.2	66.0–67.6
Cl	nr	nr	nd	0.3– 0.4	nd
Also Reported					
K ₂ O	0.02–0.04	tr–0.013	nr	nr	nr
MnO	tr–0.005	≤0.0003	≤ 0.1	nd	≤ 0.2
TiO ₂	tr	tr	≤ 0.1	nd	nd
Also Detected					
	Sc, Ni, Rb, Ga, Y, Cu, Zr, Cs	Ga, Mo, Rh, Ni, Y, Cu, Zr, Cs, Rb, W, Pt			

^aSymbols:

nr = not reported

nd = not detected

tr = traces detected

* = usually 0.04 wt. %

0.5–1.0 wt.%) and can thus be accountably superseded by the more recent data reported here and by Schrader.

Additional chemical data on natural emeralds from a number of researchers (Gübelin, 1958; Bank, 1974; Metson and Taylor, 1977; Graziani and Lucchesi, 1979; Hänni and Kerez, 1983; see also Sinkankas, 1981, pages 376, 400, 419, 535, and 607) show no significant differences from the analyses of the natural emeralds in the current study collection, although only the most recent reports include information on vanadium content.

CONCLUSIONS

The information provided by this study verifies and supplements the existing body of chemical data on natural and synthetic emeralds so that clear distinctions can now be made. Natural emeralds invariably include at least one and usually more chemical components that are not found in any of the synthetic emeralds currently being manufactured. Moreover, the ability to determine these characteristic components by nondestructive analytical techniques renders such chemical distinction a viable gemological test, although the expense and limited availability of good microprobe and XRF analyses, as well as the expertise required, essentially restrict use of these methods

to important cases in which all other gemological tests have been exhausted.

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IDENTIFYING GEM-QUALITY SYNTHETIC DIAMONDS: AN UPDATE

By John Ilmarii Koivula and Charles W. Fryer

The existence of gem-quality synthetic diamonds and their potential impact on the marketplace has long been a source of concern to gemologists and gem dealers the world over. While we do not know whether cuttable gem-quality diamonds have been synthesized in other nations, we do know that the General Electric Company has successfully synthesized cuttable gem-quality diamonds in the United States. Eight of these diamonds were studied in an attempt to determine means of identifying them using standard gemological tests. Sophisticated chemical and X-ray diffraction analyses and spectrophotometric and ferromagnetic studies were also performed. Distinctive inclusions, absence of strain in polarized light, electrical conductivity, and absence of both an absorption spectrum and a reaction to long-wave ultraviolet radiation were found to be useful indicators. Magnetism was also found to be a positive basis for separation but is not practical for the jeweler/gemologist.

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Acknowledgments: The authors are grateful to John Sampson White, Dr. Peter C. Keller, and Dr. Kurt Nassau for arranging the loan of the synthetic diamonds. Helpful technical information was provided by Robert Crowningshield, Dr. George Rossman, Dr. Joseph Kirschvink, Dr. James Shigley, Carol Stockton, Christine Perham, and Dr. Herbert Strong, one of the original team of General Electric high-pressure research scientists.

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Rumors continue to circulate in the trade concerning the presence of gem-quality, round-brilliant-cut, synthetic* diamonds as large as one carat. In view of these rumors, and the subsequent concern about how to separate natural from actual synthetic diamonds, we decided to reexamine eight of the only *known* cuttable gem-quality synthetic diamonds, which were manufactured by General Electric Company in 1970 (figure 1) as a by-product of high-pressure/high-temperature research. Although the four largest of these stones had been studied by Robert Crowningshield in 1971, we felt that the current study would serve three purposes: (1) to bring the original work by Crowningshield (1971) back into focus, (2) to see if any new information could be discovered about these synthetics, and (3) to reveal any definitive tests that could positively separate these synthetic diamonds from their natural counterparts.

To this end, both standard gemological tests and more sophisticated research techniques were applied to the three faceted stones and five rough pieces. The results revealed that these synthetic stones can be identified even by conventional gemological techniques.

METHOD OF SYNTHESIS

Although the process used to produce gem-quality synthetic diamonds has been described elsewhere in the gemological literature (Nassau, 1978, 1980; Strong, 1982), a brief review is provided here as background for our study.

Time is perhaps the most important difference between the process used to grow the very small particles of synthetic diamond used for industrial grit and the one used by General Electric to grow the larger gem-quality syn-

**Important note: The term synthetic diamond as used in this article does not refer to cubic zirconia or any of the other common diamond simulants, but rather only to those manufactured stones that have all the chemical, physical, and optical properties that natural diamonds have.*



Figure 1. The eight gem-quality synthetic diamonds, manufactured by General Electric Company, that were examined for this study. Photo by Tino Hammid.

thetic diamond crystals that are suitable for faceting (figure 2). Whereas it takes only a matter of minutes to convert graphite into diamond grit, it takes at least a week to grow a single 5-mm gem-quality synthetic diamond crystal (i.e., which would cut an approximately $\frac{1}{2}$ -ct stone).

The diamonds were grown in a sophisticated high-pressure apparatus like the one illustrated in figure 3. The use of a metallic flux solvent (often called a catalyst) allows growth of diamond at much lower temperatures and pressures than would otherwise be required for diamond synthe-

sis. Microprobe analysis of the inclusions in the synthetic diamonds studied in this report indicates that they were probably grown using an iron solvent; traces of nickel and aluminum may have been part of the solvent, or may represent contamination in the growth apparatus. The metal melts and acts as a fluxing agent, allowing carbon atoms from the feed material to go into solution in the hot zone in the center of the growth vessel. Once in solution, the carbon atoms are then free to migrate toward the slightly cooler ends of the vessel, where a small natural or synthetic diamond seed crystal

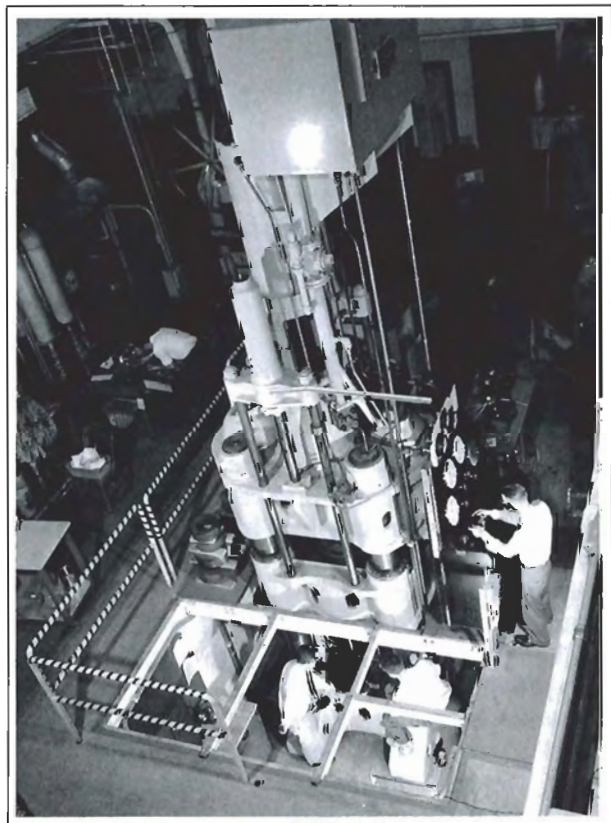


Figure 2. A selection of rough synthetic gem-quality diamond crystals grown by General Electric in 1970. Photo courtesy of General Electric.

has been implanted. The carbon atoms then deposit on the seed to produce a larger crystal (figure 4). The shape of the resulting crystal can be controlled by the orientation of the seed crystal in the cell. The addition of nitrogen will produce a yellow diamond; boron will produce a blue diamond. Figure 5 shows a blue synthetic diamond on its original growth site.

Synthetic diamond powder rather than graphite was used as the carbon source material for the large gem-quality synthetics because graphite has a lower density (2.27 grams/cm³) than diamond (3.54 grams/cm³) and thus occupies more volume per unit of weight. Therefore, when graphite is converted into diamond, there is an instantaneous loss of volume with a corresponding drop in pressure. This seriously slows the rate of diamond growth and makes control of the process much more difficult. Unless the press is specially programmed to maintain the pressure, or the temperature is increased to expand the cell contents to compensate for the volume loss, the internal pressure may decrease to the equilibrium point so that the impetus of the reaction is lost. This loss of volume and pressure in the cell can be avoided if diamond feed powder is used. Additional line drawings illustrating the interior of the pressure vessels used in synthetic gem diamond growth, together with further details, can be found in Nassau (1978, 1980) and Strong (1982).

Figure 3. An early photo of the 1000-ton hydraulic press at the G.E. Research Laboratory in Schenectady, New York. Photo courtesy of General Electric.



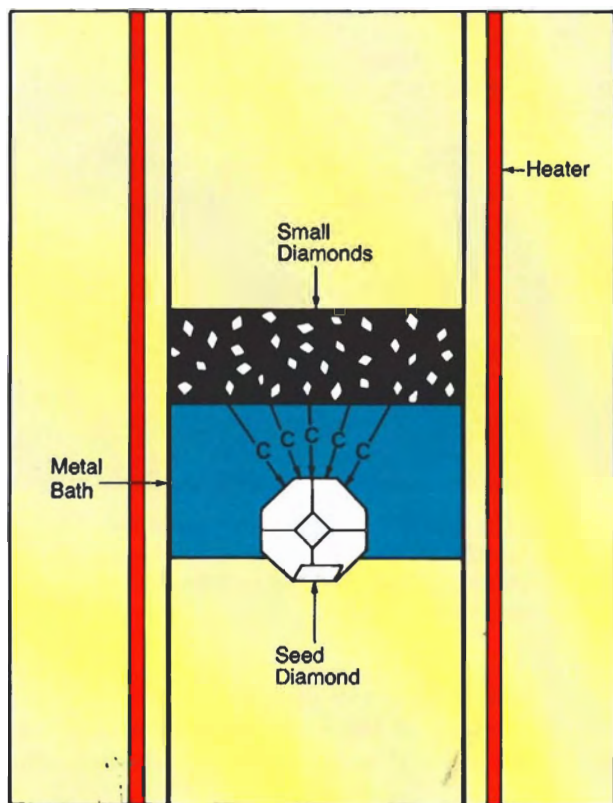


Figure 4. This diagram illustrates the method used to grow large gem-quality diamonds in a molten solvent catalyst metal. There is a temperature gradient between the hot upper portion of the cell, where the small feed diamonds are located, and the cooler lower portion, where the seed crystal is placed. The carbon atoms (c) move across this gradient and are deposited on the seed crystal.

DESCRIPTION OF THE SYNTHETIC DIAMONDS STUDIED

The eight synthetic diamonds examined in this study were among those manufactured in 1970 by the high-pressure diamond research laboratory of the General Electric Company. The three cut stones were faceted by Lazare Kaplan and Sons, Inc. of New York and donated together with a synthetic rough crystal to the National Museum of Natural History, Smithsonian Institution, in June 1971.

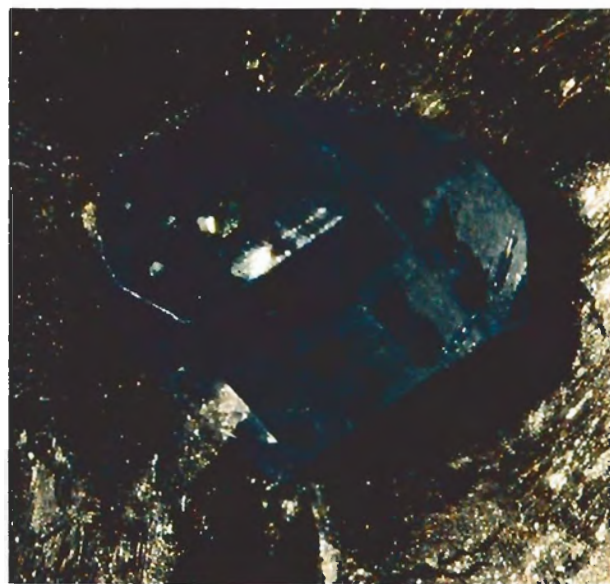
Dr. Peter Keller, of the Los Angeles County Museum of Natural History, obtained the four Smithsonian synthetic diamonds for this study through the kind offices of John Sampson White, of the Mineral Sciences Division of the Smithsonian

Institution. Dr. Kurt Nassau loaned us the four smaller rough crystals. All of the cut stones were round brilliants: one near-colorless, one a bright yellow, and one a grayish blue. The largest rough crystal was near-colorless with cube, octahedral, and dodecahedral faces; one of the cube faces had been polished. The four smaller crystals—one near-colorless, two bright yellow, and one grayish blue—were also examined. The colors and corresponding weights of these eight synthetic diamonds are provided in table 1. To the authors' knowledge, these are the only gem-quality synthetic diamonds that have ever been made available for gemological study. General Electric has never released any of the stones into the gem trade.

TESTING AND RESULTS

Ultraviolet Fluorescence and Phosphorescence. As previously reported by Crowningshield (1971) for the stones he studied, all eight of the G.E. synthetic diamonds we examined were completely inert to long-wave ultraviolet (366.0 nm) radiation. They differed, however, in their reaction to short-wave ultraviolet (253.7 nm) radiation. The near-colorless round brilliant showed a very strong yellow fluorescence with a very strong, very persistent phosphorescence of the same color. The yellow cut stone and yellow crystals were inert to the short-wave lamp. Both the grayish blue cut

Figure 5. A blue synthetic diamond crystal resting in the iron flux in which it grew. Photo courtesy of General Electric.



stone and the grayish blue crystal showed very strong fluorescence of a slightly greenish yellow color, again with a very strong, persistent phosphorescence of the same color. The near-colorless rough crystals glowed a strong whitish yellow with a strong, long-lasting phosphorescence of the same color. These results are outlined in table 1. The cruciform fluorescence patterning (figure 6) observed in short-wave ultraviolet light (first reported by Crowningshield, 1971) was readily apparent in the blue and near-colorless round brilliants, but only faintly visible in the largest uncut crystal.

Only blue type IIB natural diamonds phosphoresce after exposure to both short-wave and long-wave radiation. Therefore, the inert reaction to long-wave ultraviolet radiation, together with a strong to very strong short-wave fluorescence and phosphorescence in all but the inert yellow stone, is certainly a good indication of synthetic diamond.

X-Ray Fluorescence. Each of the eight synthetic diamonds was also checked individually with an



Figure 6. The cruciform fluorescence pattern as observed in the synthetic blue round brilliant when exposed to short-wave ultraviolet radiation. Magnified 6x.

X-ray fluorescence unit operating at 88 kV and 4 mA. The results of the X-ray fluorescence testing (again, see table 1) were identical with those ob-

TABLE 1. Gemological properties of eight cuttable gem-quality synthetic diamonds manufactured by General Electric Company.

Shape	Color ^a	Weight (in ct)	Fluorescence and phosphorescence			Electrical conductivity	Specific gravity	
			LWUV	SWUV and X-ray	Phosphorescence		Computed hydrostatic S.G.	Reaction in 3.51 liquid
Round brilliant	Near-colorless—GIA J	0.305	Inert	V. strong—yellow	V. strong—same color ^b	Conductive ^b	3.49	Floated
Round brilliant	Yellow—Fancy intense	0.390	Inert	Inert	None	Nonconductive	3.54	Sank slowly
Round brilliant	Grayish blue—Fancy	0.310	Inert	V. strong—greenish yellow	V. strong—same color	Conductive	3.52	Sank very slowly
Rough crystal	Near-colorless—GIA I	0.735	Inert	Strong—whitish yellow	Strong—same color ^b	Conductive ^b	3.50 ^c	Sank very, very slowly
Rough crystal	Near-colorless	0.200	Inert	Strong—whitish yellow	Strong—same color ^b	Conductive ^b	— ^d	Sank very slowly
Rough crystal	Yellow—Fancy intense	0.073	Inert	Inert	None	Nonconductive	— ^d	Remained suspended
Rough crystal	Yellow—Fancy intense	0.221	Inert	Inert	None	Nonconductive	— ^d	Rose very slowly
Rough crystal	Grayish blue—Fancy	0.157	Inert	V. strong—greenish yellow	V. strong—same color	Conductive	— ^d	Remained suspended

^aAccording to the GIA diamond-grading system.

^bSuggests synthetic origin.

^cIt is clear that a slight error in weighing occurred to result in a calculated S.G. of 3.50; in reality, the stone sank very, very slowly in a 3.51 liquid, indicating that the actual S.G. might be 3.515.

^dAccurate results could not be obtained because the stones were too small.

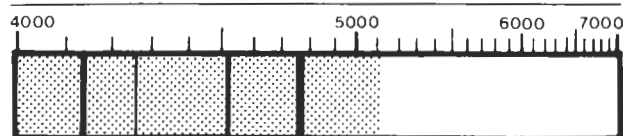
tained using short-wave ultraviolet radiation. The near-colorless and grayish blue stones all showed strong to very strong yellowish X-ray fluorescence with strong to very strong, and very persistent, phosphorescence; again, the yellow stones were inert to X-rays.

As Crowningshield (1971) mentioned, most, but not all, natural near-colorless diamonds show a whitish blue to blue fluorescence to X-rays and very limited, if any, phosphorescence. The color and strength of the X-ray fluorescence and phosphorescence exhibited by some of these near-colorless synthetics could certainly be used as a strong indication of synthetic origin.

Spectroscopic Examination. The synthetic diamonds were examined using a Beck prism spectroscope. None of the stones showed any signs of visible light absorption. The temperature of the stones was then lowered using an inverted can of the compressed gas chlorofluorocarbon (photographic duster), and the cooled stones were studied under the spectroscope. Even at the lower temperature, none of the stones examined showed any visible-light absorption spectrum. In most natural yellow stones in the cape series, including those of a near-colorless to pale yellow color, we expect to see at least a 4155 Å (415.5 nm) absorption line, with additional lines of the cape spectrum as the color deepens. The absence of these absorption lines in synthetic diamonds thus provides another test that can suggest the synthetic origin of a diamond. Because not all natural yellow diamonds are in the cape series, however, positive identification cannot be made on this basis. Still, we believe that given the known methods of gem-quality diamond synthesis, if a 4155 Å (415.5 nm) line or other lines from the cape series are visible in the hand spectroscope, then the stone being tested is most probably natural. An example of the absorption spectrum associated with natural cape series diamonds is shown in figure 7.

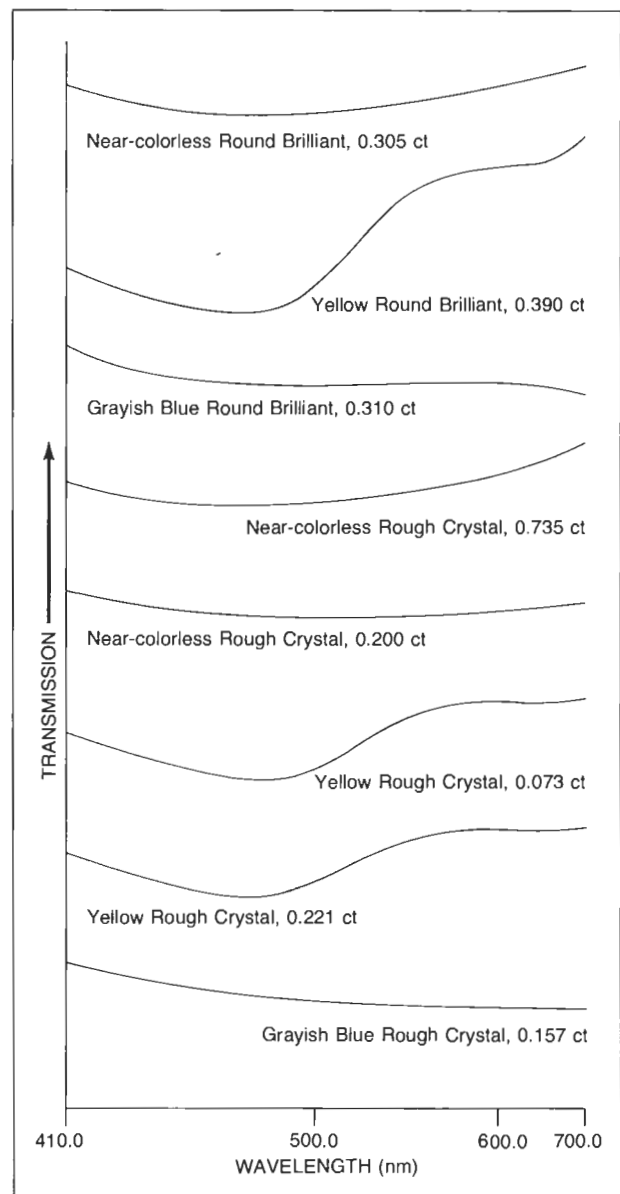
Spectrophotometry. The sample synthetics were next cryogenically cooled by means of a closed-

Figure 7. A representative absorption spectrum found in natural cape series diamonds.



cycle helium refrigerator to 60°K and then examined with a Zeiss PMQ-3 UV-VIS spectrophotometer. The transmission spectra of the synthetics were studied in the visible-light range (410.0 nm to 700.0 nm). The spectral transmission curves (figure 8) provided by Dr. James Shigley confirmed the total lack of absorption bands that had been observed through the Beck hand spectroscope. Only the general regions of absorption causing the color of the colored ones was evident. Spectropho-

Figure 8. Spectrophotometric transmission curves obtained from each of the eight synthetic diamonds studied.



tometry done in 1978 by Dr. George Rossman of the California Institute of Technology (pers. comm.) on one small yellow General Electric synthetic diamond crystal (R&D #2) revealed a "textbook-example nitrogen spectrum" with a strong 415.5-nm line. This spectrum may have originated from a natural diamond used as a seed. This particular stone was not available to the authors during this study, and no similar absorption characteristics were observed in any of the eight stones tested or in the other yellow synthetic stone (R&D #362) examined by Dr. Rossman.

Electrical Conductivity. The synthetic diamonds were tested for electrical conductivity using a conductometer. The results were the same as those reported by Crowningshield in 1971; that is, the yellow crystals and yellow cut stone did not conduct electricity but the blue and near-colorless crystals and cut stones did (again, see table 1).

Aluminum, beryllium, boron, and lithium can all readily enter a diamond's structure and any one of them will cause the diamond to become type IIB, electrically conductive (Nassau, 1980). However, only boron will produce a colored diamond (blue); the others will be near-colorless. The fact that small amounts of aluminum were found during semiquantitative analyses of the iron inclusions in the near-colorless G.E. synthetic diamonds suggests that some of this aluminum may have entered the diamonds' structure, making them conductive. A very low level of boron, not detectable by the microprobe, might also cause conductivity without color.

Natural type IIB diamonds encountered to date have been blue, grayish, or, rarely, completely colorless (GIA color grade D) or brownish. Since it is not common practice to test near-colorless diamonds for electrical conductivity, more research is needed in this area before one can state unequivocally that all natural near-colorless stones are nonconductors. However, no conductive natural near-colorless stones have thus far been reported. Consequently, on the basis of the stones tested thus far, the conductivity of a near-colorless diamond strongly suggests that the stone is synthetic.

Specific Gravity. The specific gravity for each of the largest synthetic diamonds was determined by the hydrostatic method using a Voland double-pan balance modified for specific-gravity determinations. The four smallest crystals were considered

to be too small to provide accurate results. The individual specific gravities of the four largest stones ranged from 3.49 to 3.54, with the average being 3.51. Since even these four stones were relatively small in size, a very slight error in weighing could cause a significant error in the final computed specific gravity. Therefore, a specially prepared heavy liquid was used to check the accuracy of the hydrostatically obtained specific gravities. Since a hydrostatic specific-gravity determination can be achieved with greater accuracy on a large stone, a 15.98-ct gemmy octahedron from GIA's reference collection (#11954) was selected. The specific gravity of this large diamond crystal was hydrostatically calculated to be 3.51. A liquid composed of Clerici's solution and distilled water was then mixed so that the large diamond crystal stayed suspended in it. All eight of the synthetic diamonds were then tested in this liquid. It is interesting to note that, as expected, those diamonds containing large inclusions of metallic iron (that is, the blue and yellow stones as well as the near-colorless rough crystals) all sank slowly in the liquid. Both the largest yellow crystal and the near-colorless faceted round brilliant, neither of which contained obvious iron inclusions, floated. Both the small yellow and small blue crystals remained suspended. Table 1 lists the results of this testing.

Microscopic Examination. The stones were examined with a Mark V Gemolite to determine the nature of the inclusions. The least included of the eight stones was the near-colorless round brilliant, followed in order by the three yellow ones, the grayish blue stone, and finally the two near-colorless rough crystals. All eight stones showed opaque, black, rod- to plate-shaped primary inclusions of the metallic flux (figures 9 and 10) in which the diamonds grew. Some inclusions in the blue faceted stone (figure 10) and the largest rough crystal broke the surface and so were ideally situated for chemical analysis. The primary flux inclusions observed in the rough crystals also showed a definite orientation parallel to the edges of the cube, octahedral, and dodecahedral faces. This is to be expected because primary flux inclusions are usually trapped by the formation of growth steps on the growing host.

All of the stones also contained clouds of tiny whitish pinpoint-sized inclusions (figure 11). The individual inclusions in these clouds were much

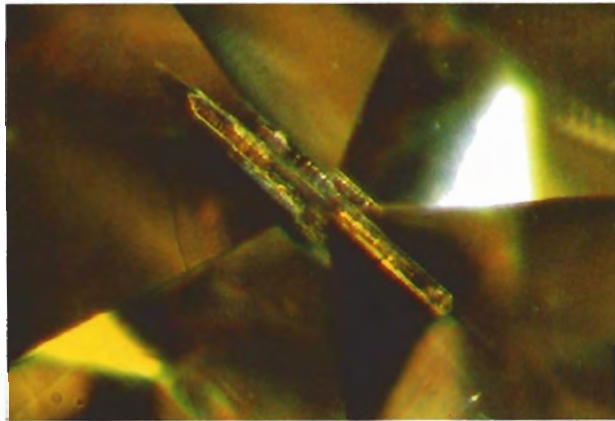


Figure 9. A rod-shaped primary flux inclusion in the faceted yellow synthetic General Electric diamond studied. Dark-field and oblique illumination, magnified 50 \times .

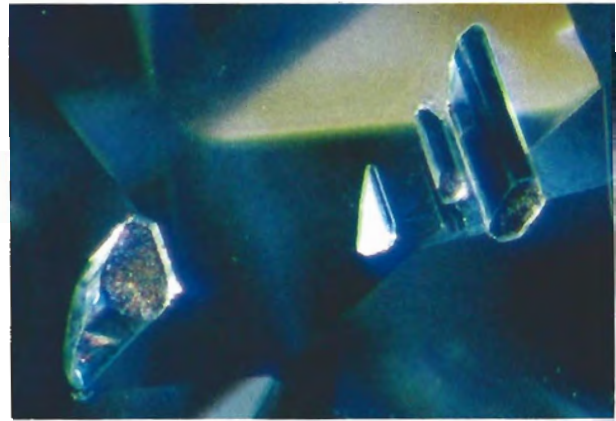


Figure 10. Large rod- and plate-shaped primary flux inclusions of metallic iron in the faceted blue synthetic diamond studied. Dark-field and oblique illumination, magnified 50 \times .

too small to be analyzed and therefore remain unidentified.

The largest of the two rough yellow crystals revealed some quite unique broom-like inclusions (figure 12) that pointed directly away from the

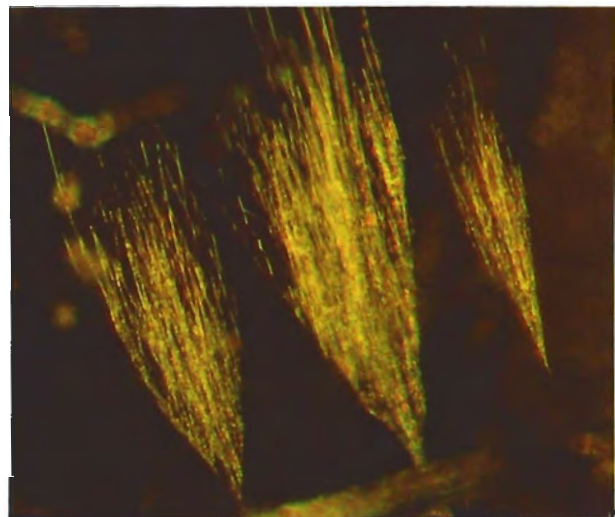
Figure 11. A cloud of tiny, whitish pinpoint inclusions in the faceted blue synthetic diamond. Dark-field and oblique illumination, magnified 50 \times .



cube face that was attached to the growth vessel where the original seed had been placed. In reflected, shadowed light, the square outline of the seed could also be seen centered on the cube face (figure 13).

Very distinct and obvious growth zoning was present in the yellow faceted stone, but none of the other seven synthetic diamonds we examined displayed this feature. However, color and growth zoning can also occur in blue synthetic stones, as shown in figure 14, which was provided by General Electric. The yellow was also the only cut stone to

Figure 12. Broom-like growth inclusions oriented perpendicular to the cube face of the seed. Dark-field and oblique illumination, magnified 50 \times .



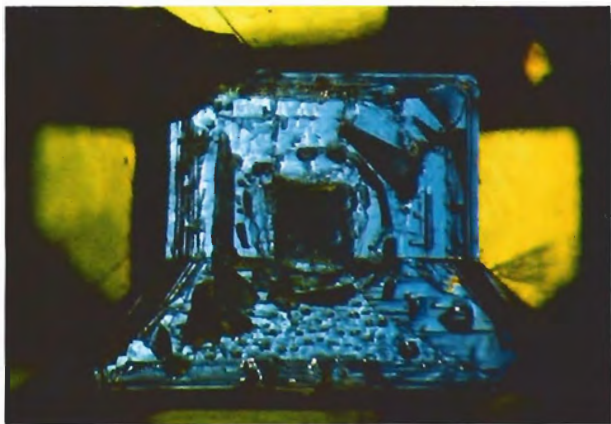


Figure 13. Surface tracing of the square-shaped seed crystal embedded in a cube face of the largest rough yellow crystal. Oblique illumination and shadowing, magnified 50x.

have a natural on its girdle, as pictured in figure 15. The surface features of the only rough crystals available to us were also quite interesting. Figure 16 illustrates the trigons found on one of the octahedral faces of the largest rough crystal. Striations were common to the dodecahedral faces, while cube faces generally displayed somewhat veined and striated geometric surfaces (figure 17).

Reaction in Polarized Light. In studying these synthetic diamonds with the polariscope, we observed no signs of internal strain, even in the yellow stone that contained obvious growth zoning. Small, faint fields of strain were visible under polarized light around some of the larger iron flux inclusions.

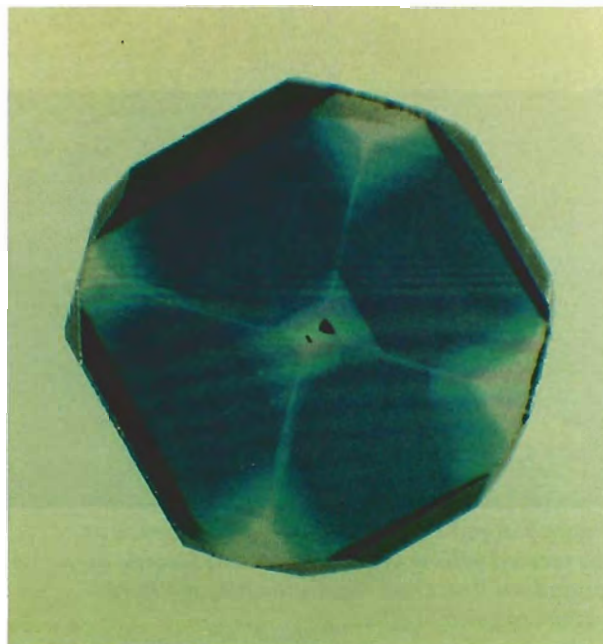


Figure 14. This sectored, blue, boron-containing synthetic diamond crystal (5 mm across), produced by General Electric, shows cruciform color and growth zoning. Photo courtesy of General Electric.

These thin strain halos, appearing as gray, ghost-like zones, were difficult to resolve and visible only in certain directions. This is in direct contrast to what the gemologist would normally expect to see when examining natural diamonds under polarized light, as in figure 18. Although most natural diamonds show strain, some may be almost

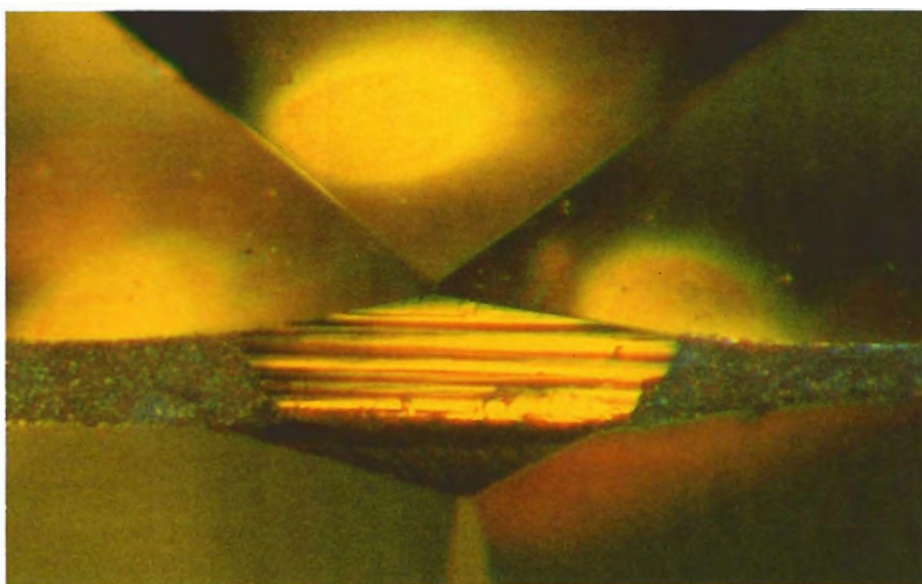


Figure 15. A striated natural on the girdle of the faceted yellow synthetic diamond. Dark-field and oblique illumination, magnified 50x.

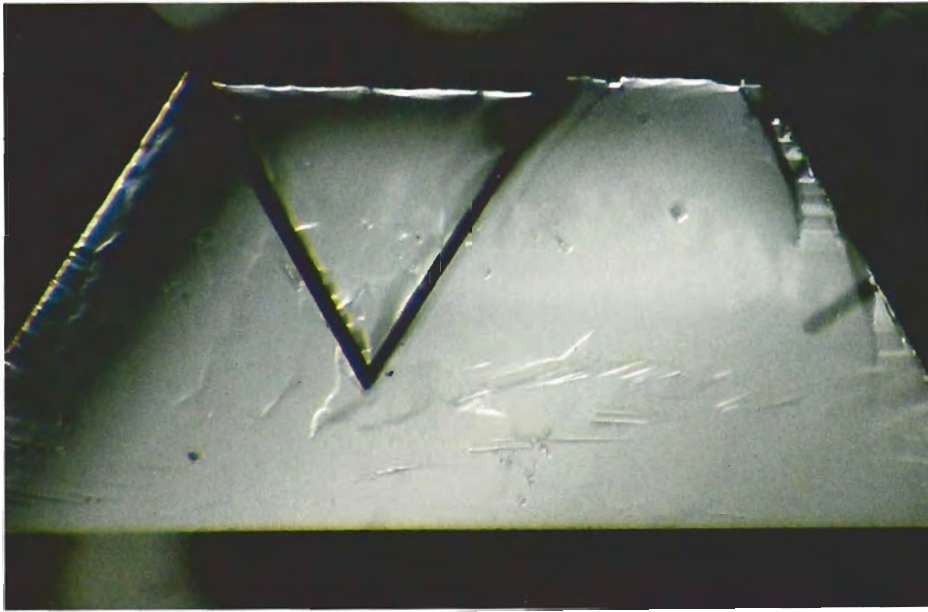


Figure 16. A single large trigon aids in the identification of this octahedral face on the largest rough synthetic diamond crystal. Oblique illumination and shadowing, magnified 50x.

strain free. Therefore, the absence of strain only suggests synthetic origin but is not conclusive proof. A great deal of strain visible in a diamond under polarized light strongly suggests that the gem is natural.

X-Ray Diffraction Analysis. Some of the inclusions reached the surface of these synthetic diamonds and so provided the perfect opportunity for X-ray diffraction studies. After the inclusions were scraped, spindles were prepared from the scrapings

Figure 17. Veined and striated cube face surface on the largest yellow rough synthetic diamond crystal. Oblique illumination and shadowing, magnified 50x.

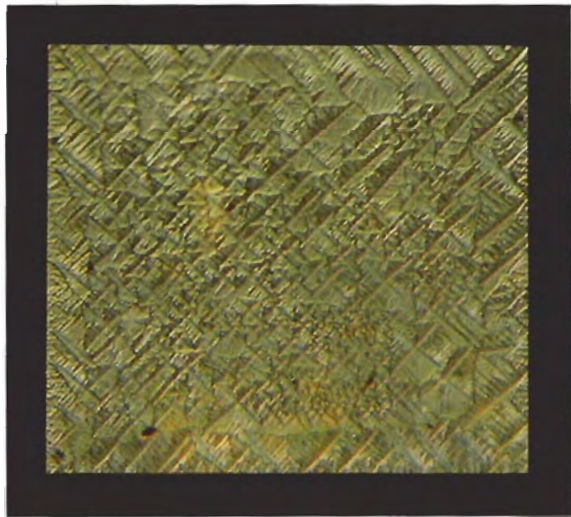


Figure 18. Strain effect in a natural diamond as observed in polarized light. No similar effect was observed in any of the synthetic diamonds. Magnified 50x.

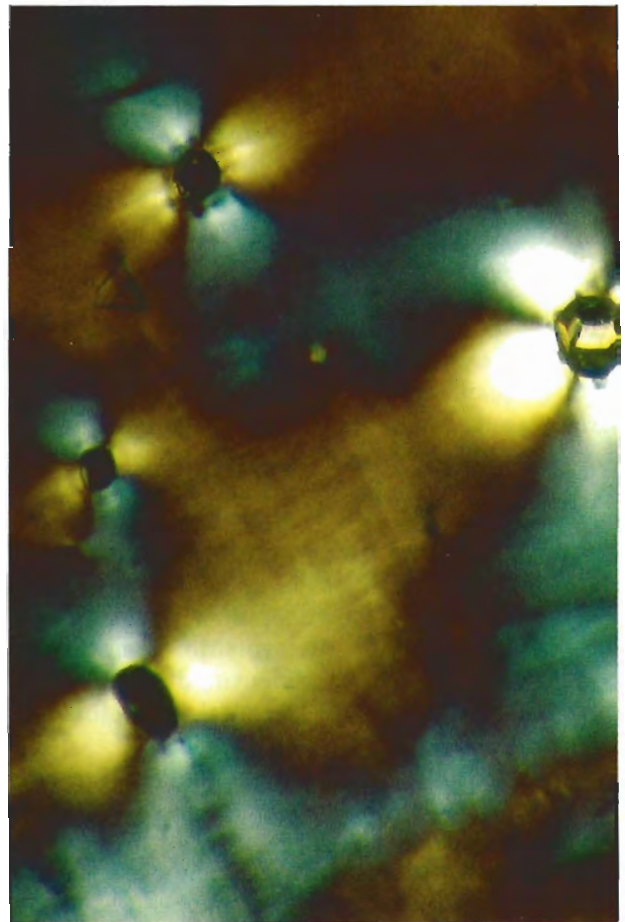
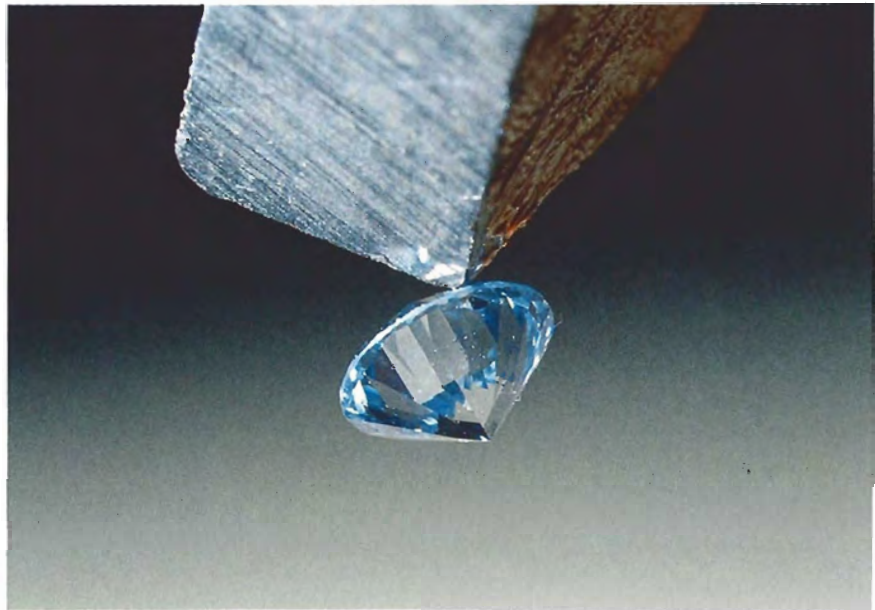


Figure 19. Synthetic blue diamond suspended from a pocket horseshoe magnet. The presence of elemental iron inclusions in the diamond causes this magnetic attraction.
Photo by Michael Havstad.



and run in a Debye-Scherrer camera on a Phillips X-ray generator unit for approximately 10 hours at 48 kV and 18 ma.

The patterns obtained were somewhat surprising because there were only two very broad, diffuse bands centered at approximately 2.03 and 1.86 Å. At first it was thought that plastic deformation had occurred in the sample as a result of the scraping, which is not an uncommon occurrence when samples are prepared from a metal. However, when other spindles were prepared and diffracted, these two diffuse bands were still the only pattern visible. A sample of meteoritic iron was then scraped and tested in the same manner, but the pattern obtained from this material showed the strong, clean, thin lines of crystalline iron. This strongly suggests that the pattern obtained on the synthetic diamond inclusions was not influenced by plastic deformation from the scraping procedure, but actually represented the pattern of the material. The band at 2.03 Å corresponds with the position of the strongest line in an iron diffraction pattern. The 1.86 Å band does not appear to line up with any identifiable pattern. More research is needed to explain the unidentified and unusual diffraction pattern obtained from these inclusions.

Semiquantitative Analysis of the Inclusions.

Those metallic inclusions that reached the surface of both the largest crystal and the grayish blue faceted stone were also prime candidates for semi-

quantitative chemical analysis. Testing with the microprobe by Carol Stockton of GIA determined that the inclusions consisted almost entirely of elemental iron (96.0%) with only small amounts of aluminum (2.8%) and nickel (1.3%) present. Since iron is a known metallic flux in General Electric's synthesis of diamond, the presence of elemental iron was not at all surprising. Independent chemical analyses by Dr. George Rossman also showed that the inclusions in these two stones were mostly iron with only a trace of nickel; he did not test for aluminum.

Magnetism. Since the dark primary inclusions were composed mainly of iron, we decided to test whether the synthetic diamonds would react to a pocket "horseshoe" type of magnet. To our knowledge, this method of testing had not been tried before. Those stones with obvious metallic inclusions were tested first. Figure 19 illustrates the reaction shown by the blue faceted synthetic stone. The largest near-colorless rough crystal and the smallest near-colorless crystal were both easily lifted by the magnet as well. This reaction has not yet been encountered in a natural diamond. Although the yellow faceted stone and the smallest yellow crystal reacted to the presence of the magnet, they could not be lifted. The near-colorless faceted stone, the largest yellow crystal, and the blue crystal showed no visible reaction to the magnet while resting on a table top. Although the

near-colorless faceted stone contained no eye-visible iron inclusions, we felt that since it was grown in the presence of the same molten iron flux it was likely that submicroscopic quantities of this flux might be dispersed inside it. If a more sensitive magnetic test could be devised, the presence of elemental iron impurities at all levels of concentration might be detected, possibly providing another practical method of separating natural from synthetic diamonds.

The next phase of magnetic testing involved using a very fine linen thread approximately one meter long. One end of the thread was hung from a support. A small wad of beeswax was attached to the loose end of the string and a diamond was pressed to the wax. However, the wax reacted to the magnet, so another method was needed. Next, a very small lead wire basket was constructed and was suspended from the thread. The four largest synthetics were then tested. In this basket, the large near-colorless crystal and the grayish blue and yellow round brilliants all reacted very obviously to the presence of the magnet. The near-colorless round brilliant showed only a slight reaction (the apparatus had to be shielded from air currents before any reaction at all was detected). The most sensitive means of testing available to us was found to be the reaction of the stones to a magnet when they were suspended in the specially prepared 3.51 specific-gravity liquid. The four smallest stones were noticeably attracted by the magnet, and even the near-colorless round brilliant reacted to the presence of the magnet under these conditions. Eight natural stones were also tested by this last method, but no attraction was observed.

In view of the above-noted reactions of the synthetics in a magnetic field, we felt that the strength of the magnetic attraction should be measured by more sophisticated methods to determine whether magnetism could indeed provide another test to separate synthetic from natural diamonds. The synthetic diamonds, together with a number of natural faceted diamonds for comparison, were turned over to Dr. George Rossman for further testing. Using a superconducting "SQUID" magnetometer, Dr. Rossman and Dr. Joseph Kirschvink examined each of the stones and found that without exception the synthetic diamonds could be separated from the natural gems on the basis of inherent magnetic properties.

Details of this magnetometer study are reported elsewhere in this issue (Rossman and Kirschvink, 1984).

CONCLUSION

Although General Electric maintains that the fundamental technology used to produce the stones reported on here has not changed significantly since 1970, there is always the possibility that the process that has been employed in the past to produce gem-quality diamond synthetics may be changed in the future. Perhaps a fluxing agent other than elemental iron will be used, or an entirely different process—resulting in a different product—will be developed. While there has been considerable speculation in the trade that other countries have begun to produce gem-quality synthetic diamonds, many researchers in the U.S. maintain that the large-scale production of gem-quality synthetic diamonds is still not financially feasible, since the cost of synthesis (a single one-carat rough stone ties up an extremely expensive piece of equipment, such as that illustrated in figure 3, for at least one week) far exceeds the cost of mining and processing natural diamonds (Dr. Kurt Nassau, pers. comm.). To date, the only *known* cuttable gem-quality synthetic diamonds are those produced by General Electric. From our study of eight of these synthetic diamonds, we feel that any cut synthetic diamonds manufactured by a process similar to that used by General Electric can be effectively separated from natural stones.

Perhaps the most unusual property of these synthetic diamonds is their reaction in a magnetic field. All eight of the synthetic stones we tested showed a reaction even to a pocket magnet under certain conditions, while no reaction has been observed in the natural diamonds tested so far. These inherent magnetic properties provide a means of conclusively identifying synthetic gem-quality diamonds manufactured by the G.E. process using iron as the solvent. However, the positive detection in all cases and accurate measurement of this property currently requires sophisticated equipment beyond the scope of the gemological laboratory. Although magnetic tests are not feasible for the present, there are a number of other procedures that can be carried out by the jeweler/gemologist to effectively separate natural from synthetic diamonds.

Specifically, the inclusions seen in these syn-

thetics do not resemble anything seen in natural stones. The rounded, opaque, metallic rod- or plate-shaped flux inclusions, together with the diffuse clouds of minute pinpoint inclusions, are indicative of synthetic origin.

The vast majority of natural diamonds show varying degrees of strain in polarized light. The synthetic stones we examined are remarkably strain-free. The complete absence of strain in polarized light could be considered a good indication of synthetic origin.

A near-colorless stone (without a bluish or grayish cast) that is darker than E on the GIA color-grading scale should not conduct electricity. If it does conduct, it is probably a synthetic.

Natural diamonds, other than type IIB which would have a tint of blue or gray, do not react to short-wave ultraviolet radiation without also reacting strongly to long-wave U.V. radiation. Therefore, diamonds that are near-colorless (not tinted blue or gray) that fluoresce and phosphoresce strongly to short-wave, but are inert to long-wave, U.V. radiation can be considered to be synthetic. There may also be a sectored pattern to the fluorescence.

The vast majority of natural fancy yellow diamonds that do not show any absorption pattern in the spectroscope both fluoresce and phosphoresce to long-wave ultraviolet radiation. Conversely,

most natural fancy yellow diamonds that do not fluoresce will usually have a fairly strong cape spectrum, depending on the depth of color of the stone. Therefore, if a fancy yellow diamond shows neither an absorption spectrum nor a reaction to long-wave U.V. radiation, it is probably synthetic. A near-colorless stone, without a tint of blue, gray, or brown, that does not have a 415.5-nm line is also probably a synthetic.

Finally, diamonds that fluoresce strong yellow to X-radiation, with persistent strong yellow phosphorescence, are also probably synthetic. Most natural stones fluoresce blue to X-radiation. Very rarely, a natural stone might fluoresce red or orange to X-rays, but not yellow.

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NOTES • AND • NEW TECHNIQUES

INCLUSIONS IN TAAFFEITES FROM SRI LANKA

By Mahinda Gunawardene

This article reports on a gemological and mineralogical study of inclusions in taaffeites from Sri Lanka, with photomicrographs of some of the most characteristic occurrences. The presence of minerals such as apatite, phlogopite, spinel, and muscovite is noted and their significance in the genesis of taaffeite is discussed.

Taaffeites from Sri Lanka, China, the USSR, Australia, and even Burma have been the subject of considerable interest with regard to their rarity, their chemical composition, and the problems of nomenclature that have arisen (Schmetzer, 1983). However, the internal paragenesis of taaffeites has not yet been investigated in great detail.

The first gem taaffeite reported is believed to be of Ceylon (now called Sri Lanka) origin (Anderson et al., 1951; Anderson, 1968). Most of the gem-quality taaffeites encountered in the trade to date originate from this South Asian locality (figure 1). However, natural counterparts of this mineral have been found in Hunan Province, China (Peng and Wang, 1963); in Ladoga Lake, USSR (Kozhevnikov et al., 1977); in Mount Painter Province, Australia (Teale, 1980); in Casey Bay, Antarctica (Grew, 1981); and, most recently, in Burma (Spengler, 1983). In 1981, Moor et al. described a new mineral of the taaffeite group under the name "taprobanite," but this has since been proved to be the red variety of taaffeite (Schmetzer, 1983). The object of the present study was to examine gem-quality taaffeites from the locality with which they are most closely associated—Sri Lanka—to determine both what inclusions are characteristic



Figure 1. A 0.67-ct taaffeite from Sri Lanka. Stone courtesy of W. Taylor, *Finest Faceted Gems*.

of this rare gem material and what these inclusions might tell us about the genesis of their host.

SAMPLE STONES AND EXPERIMENTS

For this study, 46 gem taaffeites were carefully obtained from different gem deposits within the

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Acknowledgments: The author thanks Many Gems of Sri Lanka for their help in collecting the sample stones and for providing transportation to the various deposits. Thanks also go to Dr. G. Lenzen, who provided the laboratory facilities at the Deutsche Gemmologische Gesellschaft for this study.

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Highland region of Sri Lanka (Zwaan, 1982), as listed in table 1. Because of the costliness of the gem taaffeites, only six samples could be prepared for microprobe analysis. The stones were sliced to expose the inclusions at the surface. Qualitative analyses were performed to identify the various minerals rather than calculate their exact chemical compositions. A microscope with crossed polarizers and a magnification range of 10× to 100×

(60× was the maximum used in the investigations) was used to study the optical characteristics and crystal morphology of the inclusions; in some instances, the stones were examined while they were immersed in methylene iodide ($n_D=1.735$).

INCLUSIONS IN TAAFFEITE

Several inclusions were observed in the stones studied. The most important ones are described below.

Figure 2. Distinctly developed crystal of apatite in a taaffeite from Sri Lanka. Dark-field illumination, magnified 45×.



Apatite. Long prisms of apatite were commonly observed in most of the taaffeites studied (figure 2). The apatites varied in color from yellowish and opaque to near-colorless and transparent. The well-formed shape of the included crystals strongly suggested that they were apatite, although the crystals themselves were not analyzed with the microprobe. In larger samples (3 ct), this hexagonal inclusion could be seen with the 10× lens. Dr. Edward Gübelin also noted the presence of apatite in taaffeite (Koivula, 1980–81).

Phlogopite. Another frequently observed inclusion in taaffeite is phlogopite, a species of mica. A few of these colorless pseudo-hexagonal tablets were exposed at the surface of taaffeites from Kuruwitta. The polished surfaces analyzed with

TABLE 1. Deposits represented by the 46 Sri Lankan taaffeites studied and their most important inclusions.

Gem deposit	Number of stones	Color	Size range (in carats)	Inclusions observed
Hattota Amuna (North Central Province)	17	Mauve to violet	0.50 to 3.00	Fingerprints of negative crystals and small spinels; well-formed apatite prisms, phlogopite mica, and zircon crystals
Kuruwitta (Sabaragamuwa Province)	11	Pinkish purple and violet-brown	0.40 to 2.67	Phlogopite; fingerprints of negative crystals
Deraniyagala (Sabaragamuwa Province)	2	Mauve	0.32 and 0.72	Spinel fingerprint; garnet crystal
Balangoda (Sabaragamuwa Province)	1	Nearly colorless	0.87	Phlogopite; fingerprint of negative crystals
Horana (Western Province)	7	Mauve to violet	1.00 to 4.00	Negative crystals, apatite, and spinel; partly healed liquid fractures
Baduraliya (Western Province)	4	Purplish to light mauve	0.60 to 1.50	Phlogopite, apatite, and zircon; fingerprints of negative crystals
Okkampitiya (Uva Province)	2	Yellowish mauve	0.87 and 1.02	Partly healed fracture
Amerawewa (Uva Province)	1	Violet-brown	0.37	Muscovite mica
Deniyaya (Southern Province)	1	Purplish with a tinge of brown	1.59	Phlogopite and fingerprints

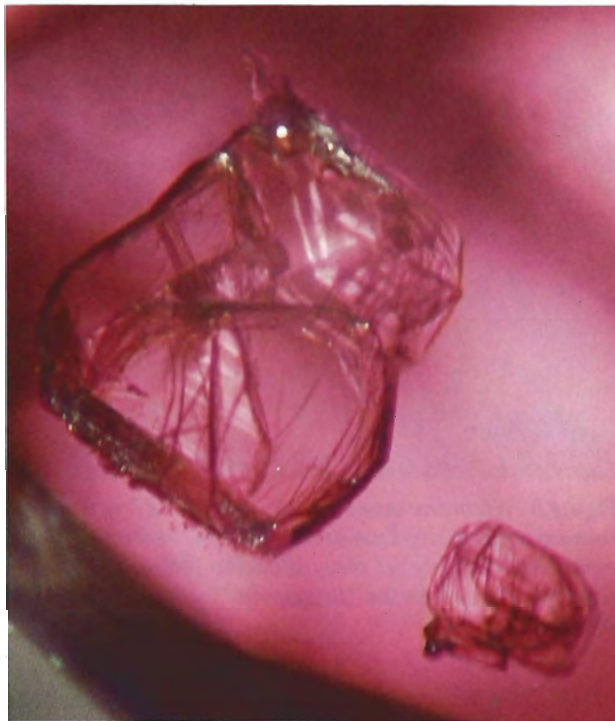


Figure 3. Tabular prisms of pseudo-hexagonal appearance identified as phlogopite in a taaffeite from Sri Lanka. Dark-field illumination, magnified 60x.

the microprobe confirmed the presence of K, Mg, Si, and Al corresponding to the formula of phlogopite (figure 3). Moreover, the polarizing microscope revealed the characteristic strain

Figure 5. Characteristically oriented fingerprint-like feather consisting of minute spinel inclusions in a taaffeite from the Hattota Amuna gem deposit, Sri Lanka. Dark-field illumination, magnified 30x.



Figure 4. Phlogopite in taaffeite from Sri Lanka as observed with crossed polarizers. Magnified 25x.

colors and structure of mica (figure 4). Only rarely was the euhedral form evident; in most instances, these inclusions were anhedral.

Spinel. The fine crystallites shown in figure 5 were quite difficult to identify even under higher magnification. However, the microprobe confirmed that they are spinel. The detection of iron in addition to the Mg and Al ratios indicated that these minute crystals formed before the host gem.

Muscovite. One flat taaffeite plate obtained at Amerawewa contained crystals of muscovite (fig-

Figure 6. Muscovite mica observed in a taaffeite found in the Amerawewa gem area of Sri Lanka. Immersion microscope, magnified 40x.



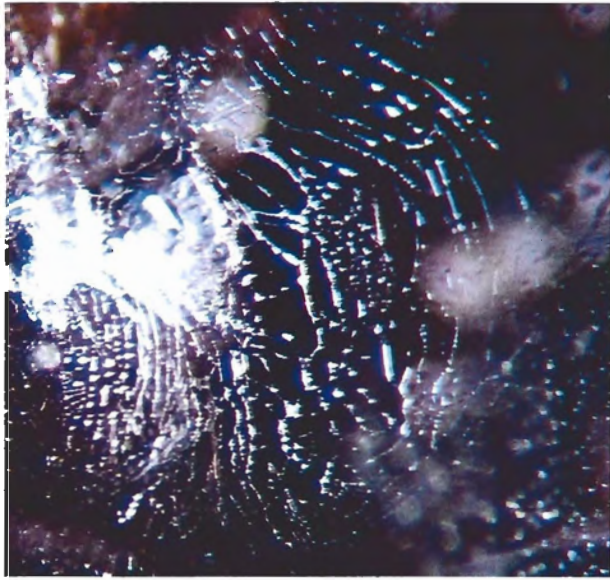


Figure 7. "Fingerprints" of negative crystals such as this are observed in a taaffeite from Kuruwitta in Sri Lanka and were commonly encountered in the stones studied. Dark-field illumination, magnified 20 \times .

ure 6), another species of mica. The inclusion became apparent when the Beck line method was used. Since the refractive index of muscovite is lower ($n_D = 1.60$) than that of the host taaffeite, the ring of light passes into the mica inclusion once the objective of the microscope is turned toward the gem. Because the microprobe revealed no Mg in the inclusion, phlogopite was ruled out in this instance.

Negative Crystals. With dark-field illumination, as in figure 7, most of the taaffeites found in Sri Lanka showed numerous small inclusions in a fingerprint-like pattern (see also, Fryer et al., 1982). At higher magnification, the minute inclusions appeared to be negative crystals (figure 8).

DISCUSSION

Although apatite is a common phosphate mineral that crystallizes early in the rock-forming phase of the igneous cycle, under various circumstances it can be widely distributed in other rock types. Specifically, in metamorphic rocks, apatite has been reported as an inclusion in spinel (Zwaan, 1965). During metamorphism, recrystallization of preexisting rock types can give rise to various schist-type deposits. Mica schists are a classic example of a new generation of mineralization; in fact, taaffeite has been reported to occur in association with spinel-phlogopite schists in Australia (Teale,

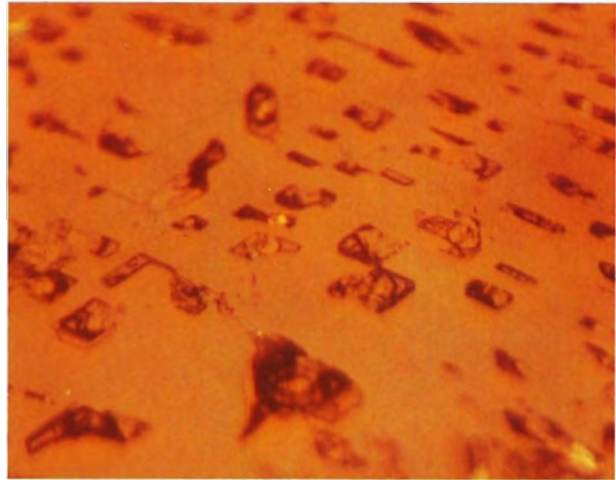


Figure 8. When the stone pictured in figure 7 was immersed in methylene iodide and the inclusion examined at a higher magnification (30 \times), the negative crystals in the "fingerprint" were clearly evident.

1980). The presence of spinel in taaffeite confirms their occurrence in a metamorphic rather than igneous environment.

In fact, the spinel inclusions provide important clues to the occurrence of taaffeite in Sri Lanka. Specifically, Sri Lanka has shown an abundance of spinel ($MgAl_2O_4$) and chrysoberyl ($BeAl_2O_4$). Gem spinel is a classic accessory mineral to corundum in zones of contact metamorphism (Dahanayake and Ranasinghe, 1981; Dahanayake et al., 1980). Be-rich fluids in pegmatites can enrich the basic zones of country rock to create environmental conditions conducive to the formation of chrysoberyl. The dominant rock type in the Highland region is a crystalline limestone; introduction of Be to such a metamorphic environment would allow for a composition intermediate between spinel and chrysoberyl, namely, $BeMgAl_4O_8$, or taaffeite, to form. We would expect other minerals such as phlogopite, apatite, graphite, and spinel to be present in this same environment, and this is supported by their occurrence as inclusions in the taaffeite.

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MAGNETIC PROPERTIES OF GEM-QUALITY SYNTHETIC DIAMONDS

By George Rossman and Joseph L. Kirschvink

Measurements of the magnetic properties of four gem-quality synthetic diamonds indicate that higher levels of permanent magnetism can be induced in the synthetics than could be induced in a number of gem-quality natural stones. As received, the colored and included synthetics showed much higher levels of magnetism than the natural stones, but one near-colorless synthetic had less magnetism than many of the natural stones. Most of the magnetism of the natural stones is due to surface contamination, which can only be removed by rigorous acid cleaning. After cleaning, the natural diamonds were not only less magnetic than all of the synthetic stones, but they were also more resistant to demagnetization. Significant levels of metallic impurities were detected in most of the synthetics. These results on a limited number of samples suggest that natural diamonds can be distinguished from synthetics on the basis of their magnetic properties, but that in the case of near-colorless, inclusion-free stones, such tests may require sophisticated instrumentation.

The existence of synthetic gem-quality diamonds and speculation about their possible introduction into the commercial market has raised the need for a test to distinguish between visually flawless

natural and synthetic diamonds. When we first considered this problem, we speculated that submicroscopic residues of the metallic catalysts used during synthesis could be included in the stones. Such residues are commonly found in non-gem-quality synthetic diamonds (Wedlake, 1979). These residues should be weakly magnetic but detectable with sensitive instruments. When we were informed that some of the synthetic diamonds studied at GIA were attracted to a hand magnet (Koivula and Fryer, 1984), we tested a variety of synthetic and natural diamonds both for their existing magnetism and for their response to induced magnetism. The results showed some relationships that might be useful in the development of reliable tests to distinguish natural from synthetic diamonds.

MATERIALS

Three groups of synthetic diamonds were examined: (1) the three faceted (near-colorless, bright yellow, and grayish blue) stones and largest unfaceted near-colorless crystal described by Koivula and Fryer (1984), (2) an 83.9-mg lot of about 200 deep yellow industrial-quality crystals also made by General Electric, and (3) a 108-mg lot of about

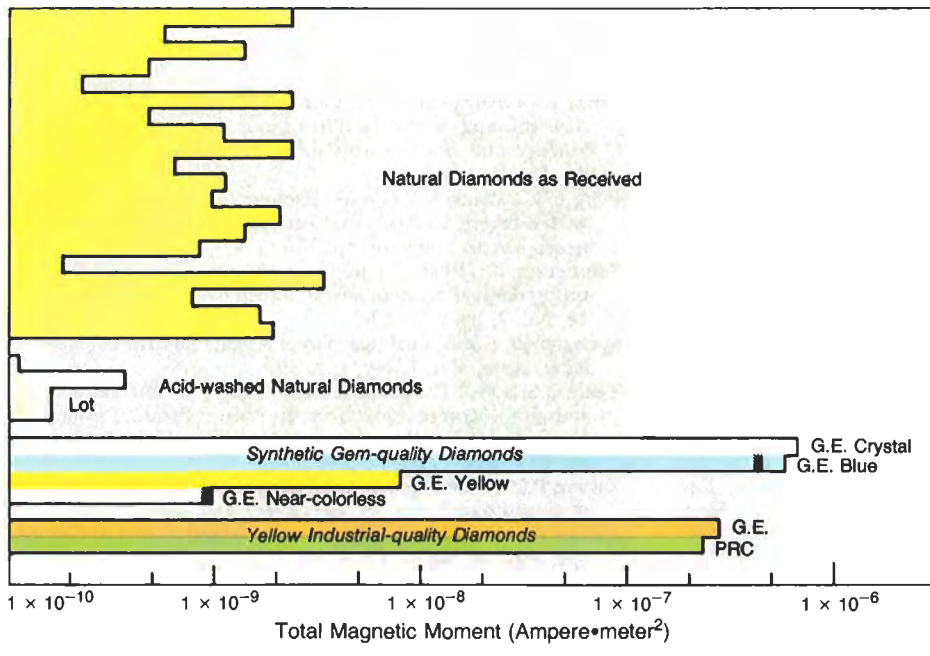


Figure 1. Intensity of magnetization of the natural and synthetic diamonds studied. Values are indicated both for the stones as received and after acid cleaning. The values for the acid-washed natural diamonds represent the minimum and maximum values observed, and the combined value for a lot of 18 stones. The values for the two synthetic gem-quality stones that were acid-washed are indicated by the shaded regions. The yellow industrial stones did not change magnetization appreciably upon acid treatment.

300 deep yellow-green industrial-quality crystals synthesized at the Academia Sinica Institute of Geochemistry, Guiyang, People's Republic of China (PRC), which were chosen to represent a different technology of synthesis.

For comparison, the following natural stones were examined: a lot of 60 colorless to pale yellow faceted stones (ranging from 0.2 to 0.4 ct), six 0.3–0.4 ct stones irradiated to various colors, nine brown to gray industrial grade crystals (about 1 ct each), and an approximately 300-mg lot of colorless melee.

TEST FOR PERMANENT MAGNETISM

Our initial tests consisted of measuring the permanent magnetism contained within the stones as received. Microscopic particles of catalysts such as iron contained within the diamonds will acquire

magnetism and will behave like miniature magnets. To detect this magnetism we used an ultrasensitive instrument that utilizes a superconducting detector operating at -269°C (called a Superconducting Quantum Interference Device, or a SQUID Magnetometer, for short) following techniques described by Kirschvink (1983). This instrument can detect the magnetism produced by as little as a few picograms (10^{-12} gram) of most ferromagnetic materials, particularly after they have been briefly exposed to a strong magnetic field.

All of the diamonds initially tested were magnetic, although most of the synthetic stones were stronger than the natural ones (figure 1). Aware, however, that the cutting and polishing processes used to prepare these stones can leave submicroscopic metallic inclusions on their surfaces, we cleaned all of the natural stones and most of the synthetic ones in hot, concentrated hydrochloric acid while in an ultrasonic water bath. The results of this treatment on the natural stones were quite dramatic: It reduced their magnetization by nearly one order of magnitude (again, see figure 1). In contrast, the acid wash produced only minor changes in the two gem-quality synthetic stones washed and in the batch of small, uncut yellow G.E. synthetic diamonds. We did not acid treat synthetic stones with visible inclusions at the surface to avoid destroying the inclusions.

As indicated in figure 1, the level of magnetism of the faceted near-colorless synthetic stone is too

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Acknowledgments: The gem-quality natural and synthetic diamonds were provided for our studies by Chuck Fryer of GIA who, along with Peter Keller of the Los Angeles County Museum of Natural History, brought this problem to our attention. The industrial-quality synthetic diamonds were provided by Dr. A. L. Boetcher of the University of California at Los Angeles. These included diamonds synthesized by the General Electric Corporation and by Dr. S. C. Shaio, Academia Sinica, Institute of Geochemistry, Guiyang, People's Republic of China.

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low to allow the stone to be distinguished from natural stones by readily available methods such as attraction to a hand magnet. Furthermore, several natural diamonds were more intensely magnetic than this synthetic stone before acid treatment. The technique of testing the attraction of the stone to a magnet while suspended in a liquid of a comparable density (Koivula and Fryer, 1984) greatly improves the sensitivity of the hand-magnet test, but such results must be interpreted with caution because the attraction of a stone to the magnet can be due to the presence of either ferromagnetic or paramagnetic impurities. Ferromagnetic materials, such as iron and its alloys, are permanently magnetic; paramagnetic components, such as some forms of nitrogen and some mineral inclusions, will cause the stone to be attracted to the magnet but do not carry any permanent magnetism themselves. The instrument we used responds only to the ferromagnetic components of the diamonds.

COERCIVITY SPECTRUM

Because there is no assurance that future batches of colorless synthetic diamonds will have levels of magnetism as high as the weakest synthetic encountered in this study, we also measured some of the other magnetic properties of the synthetic stones, including the coercivity spectrum. This is a measure of the magnetic field strength required to either magnetize or demagnetize the magnetic components of the stone. In general, this property depends in a complex fashion on the chemical and structural composition, particle size, and spatial arrangement of the magnetic inclusions within the material. All of the gem-quality synthetic stones we examined had median coercivities in the

10 to 50 millitesla (100 to 500 Gauss) range, numbers that are comparable to the magnetic field strength used to record information on magnetic recording tapes. Although there are a number of materials (including a variety of magnetic alloys), that have coercivities in this range, many other materials (including other alloys and materials such as hematite and some hardened steels), with coercivities greater than 1 tesla, can be excluded as the origin of the magnetism.

For the stones that we examined, the coercivity data indicate that the synthetic diamonds all lose their internal magnetism more readily than the natural diamonds. Whether or not this property could form the basis of a definitive test can be determined only after the magnetic properties of a larger number of natural and synthetic diamonds are tabulated. Such a test would be especially useful because it would not depend on absolute amounts of magnetic impurities in the stone.

CHEMICAL ANALYSIS

In an attempt to verify the presence of magnetic elements, several of the synthetic diamonds were subjected to X-ray fluorescence analysis. While traces of metallic elements could be detected in all cases (see table 1), the amounts detected decreased as the intensity of the color of the stones decreased (with the exception of the colorless crystal containing the large metallic inclusion). The proportions of the impurity elements also varied among the stones. Nickel was prominent in the more highly colored stones, but at low concentrations; it was not detected in the pale blue and colorless ones. Although yellow and blue in diamonds is usually associated with nitrogen and boron, respectively, these elements were not determined in

Table 1. X-Ray fluorescence analysis of various synthetic diamonds.^a

Synthetic diamonds	Cr	Mn	Fe	Co	Ni	Proportions
G.E. colorless faceted	0	0	29	0	0	Fe
G.E. grayish blue faceted	0	0	371	0	0	Fe
G.E. bright yellow faceted	0	0	85	0	63	FeNi _{0.74}
G.E. colorless crystal	0	0	2295	0	19	FeNi _{0.01}
G.E. deep yellow industrial	308	206	2044	0	683	FeNi _{0.33} Cr _{0.15} Mn _{0.10}
Chinese yellow-green industrial	0	8988	151	594	8887	MnNi _{0.99} Co _{0.07} Fe _{0.02}

^aThe proportions are given on the basis of the wt. % of the elements present, but they have not been calibrated in absolute concentrations. The numbers indicated for each element are counts per unit time multiplied times a sensitivity factor for that element.

this study. The role of the metals in causing or modifying the color, particularly in the case of the yellow stones, has also not been addressed. It is questionable whether the low concentrations of metals found in the colorless synthetic stone would be useful as a test in view of the known occurrence of low levels of iron and other metals in natural diamonds (Fesq et al., 1973).

CONCLUSIONS

This study has shown that the General Electric gem-quality synthetic diamonds contain impurities which allow the stones to carry permanent magnetism. X-ray fluorescence analyses indicate that these impurities are traces of the metallic catalysts used in their synthesis. Some natural diamonds may also contain small amounts of magnetic impurities and have a much greater amount of magnetic contamination on their surfaces. The colored synthetic diamonds, both gem quality and industrial quality, could be magnetized to a greater degree than any natural stone examined, but one near-colorless synthetic was weaker than several natural diamonds before acid washing. The synthetic diamonds were distinguished from rigorously cleaned natural diamonds by their higher level of ferromagnetic impurities and by the ease with which they lost their magnetism. For the near-colorless stones, the levels of magnetism are

low and sensitive instruments were required to measure them.

These results indicate that there are fundamental differences between the magnetic properties of natural and synthetic diamonds that can form the basis for a distinguishing test. The types of tests used in this study, while highly sensitive, use instruments that are only practical for the research laboratory. Before the results of this study can be furthered to develop a routine test, the data base needs to be expanded to include a greater number of both synthetic and natural diamonds to ensure that the range of variation in magnetic properties has been covered.

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Gem Trade LAB NOTES

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DIAMOND with Phantom Growth Plane

The Los Angeles laboratory recently received a 2.10-ct brilliant-cut marquise diamond for quality analysis. This diamond was graded imperfect because it contained a number of crystals, feathers, clouds, pinpoints, and laser drill holes. These inclusions are all typically observed in diamonds. However, this diamond also contained an unusual, large, phantom growth plane. The photomicrograph in figure 1 shows some of the particularly notable patterns within this plane.

R.K.



Figure 1. Phantom growth-plane patterns in diamond. Magnified 63x.

DIAMOND Simulant, Inclusions in Cubic Zirconia

Cubic zirconia is frequently submitted for identification to both the Los Angeles and the New York laboratories. Although cubic zirconia, grown by the skull-melt technique, can have inclusions, the faceted CZ that we have examined is generally devoid of visible inclusions and internal textural growth features. However, the Los Angeles laboratory recently examined a 0.90-ct round brilliant-cut cubic zirconia that exhibited somewhat unusual irregular "swirled" growth features (figure 2). If hastily examined, these growth features might be mistaken for the "phantom" type of graining that is

commonly observed in diamonds. However, the true identity of this man-made material is quickly ascertained by considering its many other typical visual characteristics, in addition to its excessively high specific gravity (5.80 ± 0.20) when compared to that of diamond (3.52). Although the facet junctions on a well-cut cubic zirconia may appear nearly as sharp as they do on diamond, this particular cubic zirconia exhibited very rounded facet junctions.

Several weeks after we examined the 0.90-ct stone discussed above, we received the heavily included 1.62-ct cubic zirconia shown in figure 3. The numerous, nearly spherical inclusions (oriented in subparallel lines) in this stone, although rare, are an excellent example of what can be encountered by the gemologist. When examined under the microscope, these inclu-

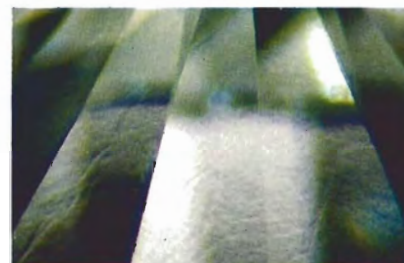


Figure 2. Swirled "graining" in cubic zirconia. Magnified 40x.

sions were determined to be negative crystals, but the voids appeared to be lined, or partially lined, with a white substance that is probably undissolved zirconium oxide (ZrO_2). Some of the negative voids were large enough to reveal well-formed, somewhat angular growth patterns.

R.K.

EMERALD Substitute

Dyed Beryl

A translucent green brilliant-cut stone (figure 4), weighing 0.23 ct, came into the New York laboratory for testing. A refractive index of 1.57–1.58 identified the material as beryl. Examination under magnification easily revealed the presence of green dye in the numerous fractures. The absorption spectrum is similar to that of dyed green jadeite except that the red end of the spectrum is transmitted slightly beyond 7000 Å (700.0 nm).

R.C.

Lechleitner Synthetic Overgrowth

In 1959, J. Lechleitner of Innsbruck, Austria, announced the production of an emerald substitute that con-

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

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Figure 3. Unusual number and variety of inclusions seen in a 0.90-ct faceted cubic zirconia.

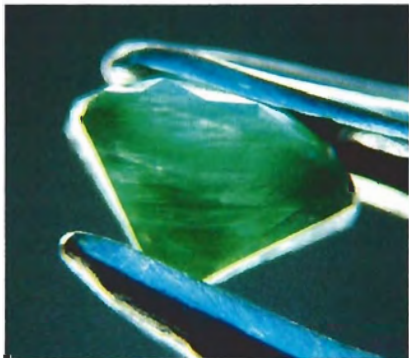


Figure 4. A translucent, dyed green brilliant-cut beryl. Magnified 20x.

sisted of a faceted colorless, or very lightly colored, natural beryl "seed" that was completely coated with a thin layer of synthetic emerald. This unique emerald substitute is frequently referred to simply as Lechleitner synthetic emerald, but is more correctly called Lechleitner synthetic emerald overgrowth.

The hydrothermal synthetic emerald coating is generally only a few tenths of a millimeter thick. To remove surface irregularities developed during the crystallization

of the synthetic coating, all, or nearly all, of the facets are repolished, which considerably reduces the thickness of the synthetic overgrowth. As a result, the polished stones often have a lighter color and a greater transparency than the un-

polished material. In some instances, repolishing may even remove all of the overgrowth on a few facets.

Occasionally some facets are not repolished, thus leaving the "rough" synthetic surface. The Los Angeles laboratory recently received such a stone for identification. Figure 5 shows this rough surface as viewed in reflected light. Figure 6 shows an adjacent facet viewed with dark-field illumination, which reveals the internal stress cracks that occur in the contact zone between the natural "seed" and the synthetic overgrowth layer. These stress cracks (which do not break the surface) are typical of the overgrowth process and immediately identify this material.

R.K.

ENSTATITE, Near Colorless

One of our clients recently purchased a 7.54-ct rough piece of what was purported to be a very rare mineral, ekanite. To conclusively identify the material, he sent the near-colorless crystal fragment (figure 7) to the Los Angeles lab. We were only able to obtain a vague refractive index spot reading of 1.66, with low

Figure 5. Surface characteristics of unpolished Lechleitner synthetic emerald overgrowth in reflected light. Magnified 35x.



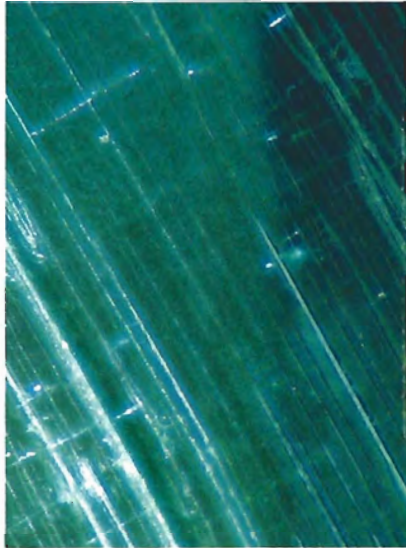


Figure 6. "Stress" cracks at the interface of the synthetic overgrowth and the natural seed of a Lechleitner "synthetic emerald." Dark-field illumination, magnified 25 \times .

birefringence, on one slightly concave polished surface. A biaxial optic figure was revealed in the polariscope with the help of immer-

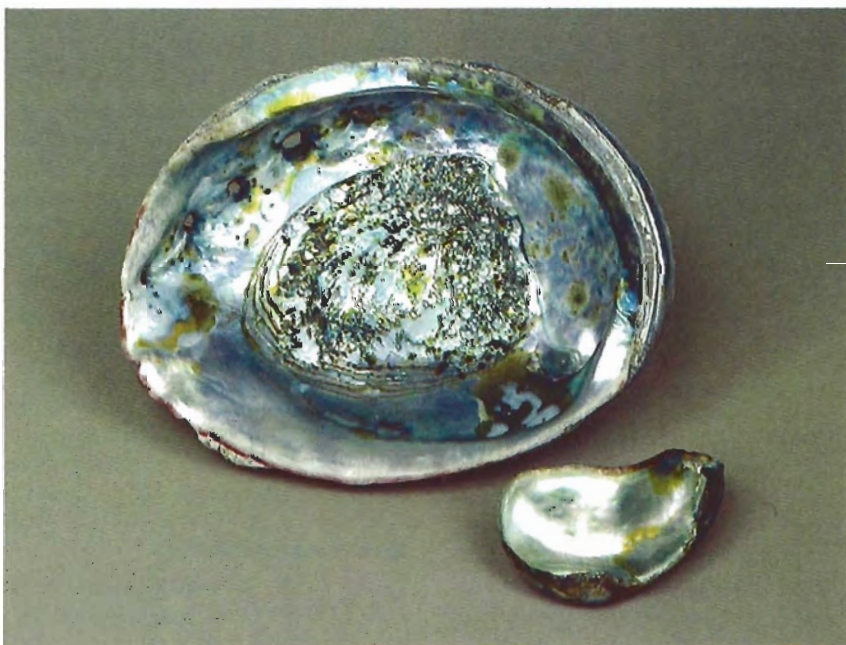


Figure 7. Near-colorless enstatite crystal fragment measuring approximately 16 \times 10 \times 8 mm.

sion. Specific gravity was determined with heavy liquids to be approximately 3.10. In the spectroscope, we noticed the very sharp absorption line at 5060 \AA (506.0 nm) that is characteristic of enstatite. Numerous inclusions were evident, but we could not identify them.

Pure enstatite is a colorless magnesium silicate. It forms a continuous series grading into hypersthene as iron replaces some of the magnesium. Increasing iron results in an increase in the properties of the

Figure 8. Abalone shell, 17.5 cm long, with the large pearl that it produced.



material, as well as a darkening of the color to yellowish green, brownish green, and brown. X-ray diffraction confirmed that the stone was enstatite. We had not previously encountered material this pure in the labs. *K.H.*

PEARLS

Abalone Pearl

We occasionally have the opportunity to examine a variety of calcareous concretions from various mollusks. The majority of them, including those from abalone, have nacre with orient and are therefore pearls. However, some have no nacreous layers or orient and so are not considered true pearls in the jewelry industry.

A few months ago, the Santa Monica and Los Angeles GTL staff were shown a *Haliotis*, or abalone, shell found off the northern Pacific coast at a depth of about 13 m (40 ft.). The shell, which measured approximately 17.5 cm in length, contained a multicolored baroque-shaped pearl (figure 8). The entire surface of the pearl (approximately 78 \times 46 \times 12 mm) was made up of nacreous layers that had an almost metallic luster, with the high orient that is very characteristic of an abalone pearl. An X-radiograph of the concretion was taken to reveal its internal structure; numerous concentric layers which closely followed the external baroque shape of the concretion confirmed its identity. *K.H.*

Accidental, or "Keshi," Pearls?

A strand of oval pearls reported to be "Keshi" came into the New York Gem Trade Lab for identification (figure 9). The pearls, which measured approximately 3.30 mm \times 2.15 mm, were determined to be of saltwater origin by their lack of X-ray fluorescence. Their uniformity suggests that they are not "accidental," but the product of mantle-tissue implantation, probably in Australia. The X-radiograph in figure 10 shows that they are tissue-nucleated cul-



Figure 9. A strand of cultured pearls, represented as "Keshi." Average size is approximately 3.3×2.15 mm.

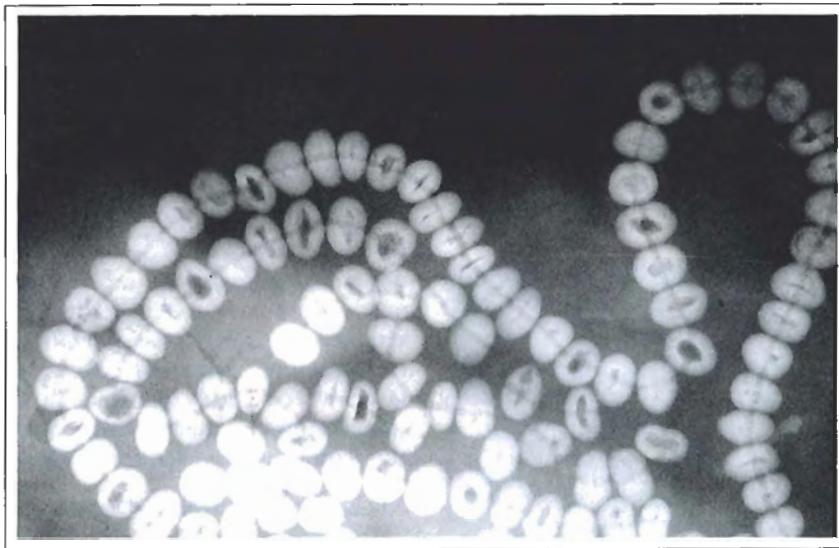


Figure 10. This X-radiograph of the necklace in figure 9 shows that they are tissue-nucleated cultured pearls.

tured pearls. Occasionally, however, a group of apparently tissue-nucleated cultured pearls will include some pearls that do not show on the X-radiograph the void that is evidence of tissue nucleation. Thus they are indistinguishable from natural pearls. Some people have re-

served the term *Keshi* for these so-called "accidental" pearls. However, the original meaning of the term *cultured* or *cultivated*, taken from the French *perle de culture*, meant product of cultivating the pearl oysters. By this definition, any product of oyster cultivation is a cultured

pearl—whether it is identifiable as cultured or not. In practice, though, if X-rays cannot separate an "accidental" from a natural pearl, the pearl is identified as natural. R.C.

Cultured Pearl Mystery

If an experienced gemologist were asked to give an opinion based on the X-radiograph shown in figure 11, he might say that the item appears to be a silver-dyed black cultured pearl necklace. His opinion would be based on the presence of white areas along the drill holes which are the result of silver from the dye having been deposited there. Since silver is opaque to X-rays, the film under it would not be exposed. However, the necklace that came into the New York lab for identification consisted entirely of normal-appearing white cultured pearls. We were at a loss to explain the white areas along the drill holes and within the conchiolin layers of some of the pearls. Perhaps a reader can suggest some explanation to us. R.C.

Imitation "Rice Grain" Biwa Cultured Pearls

If imitation is the sincerest form of flattery, then the costume jewelry trade has acknowledged the continuing interest in baroque forms of tissue-nucleated freshwater cultured pearls. Figure 12 shows a bracelet of imitation Biwa cultured pearls recently examined in our New York lab. The bracelet has been cleverly assembled to show the beads in different aspects, thus effectively imitating the variations one expects in Biwa freshwater cultured pearls. The appearance and symmetry of the beads suggested that they might be coated glass. We were surprised to learn, though, when the "essence de orient" was removed from one end of the beads (figure 13), that they were mother-of-pearl shell. R.C.

More Imitation Pearls

Figure 14 shows what appeared to be a 36-inch (90 cm) long twisted 20-strand necklace of seed pearls that

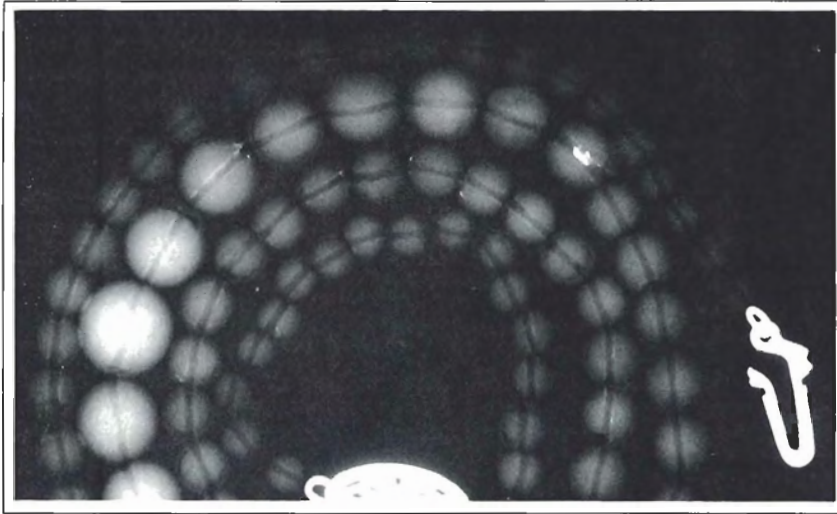
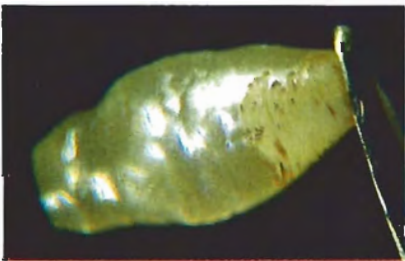


Figure 11. X-radiograph showing mysterious white areas in the drill holes of some white cultured pearls.



Figure 12. Imitation Biwa cultured pearl bracelet.

Figure 13. A single bead from the bracelet illustrated in figure 12 with the "essence de orient" partially removed to expose the mother-of-pearl center. Magnified 10x.



was sent to the New York GTL for identification. On close examination, the beads proved to be glass. An X-ray of the pearls (figure 15) shows the remarkable uniformity of size of the drill holes. Since drilling such small beads seems to be an almost superhuman task, we believe that the beads may have been made on a wire that was either later dissolved

in acid, or was simply stretched to release them. R.C.

Natural Seed Pearls and Glass Imitations

Recently sent to the Los Angeles laboratory for identification was the

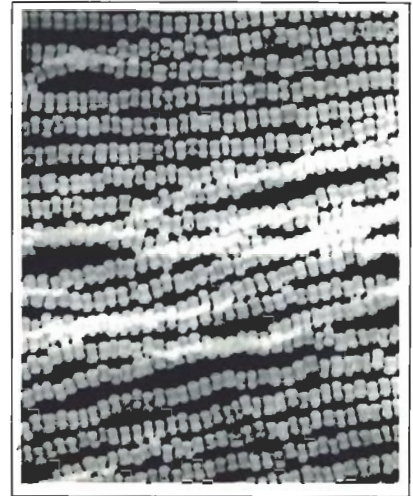


Figure 15. This X-radiograph of the imitation seed pearls shown in figure 14 reveals the similarity of drill hole size.

Figure 14. A 20-strand imitation seed pearl necklace.



necklace shown in figure 16. The necklace consisted of a natural-color, mottled green-and-white jadeite jade pierced carving suspended from a double-strand pendant composed of numerous translucent, white, round drilled beads set with one translucent white glass bead and one brownish pink tourmaline bead. The pendant was in turn suspended from a natural seed pearl necklace. Interestingly, although the double-strand white bead pendant predominantly consisted of natural seed pearls, these were interspersed with glass imitation seed pearls. The imitations were easily detected with microscopic examination. The string of the center pendant where the glass imitation seed pearls were appeared to have been damaged (again, see figure 16); perhaps this area had been broken and the glass beads added to replace some lost pearls. *R.K.*

TURQUOISE "Hidden" Treatment

Presume that as a gemologist you are testing the blue cabochons set in the necklace illustrated in figure 17. The refractive index spot reading is 1.61, an iron line of moderate intensity centered near 4320 Å is observed through the spectroscope using the external reflection technique. Microscopic examination reveals a natural-appearing structure when viewed with overhead illumination. When tested with the thermal reaction tester, no evidence of paraffin or plastic stabilization is discovered, and no evidence of dye in matrix areas is detected when the cabochons are tested with an acetone-soaked cotton swab. All of your tests indicate that the material is natural turquoise. However, would you identify and/or appraise this material as completely natural untreated turquoise? Could these turquoise cabochons have been treated in a way that your testing did not reveal? Any closed-back bezel-set mounting such as is typical of "Indian" or "South-



Figure 16. Jade and pearl pendant suspended from a natural seed-pearl necklace. Some of the "pearls" in the pendant were subsequently identified as glass imitations.

western" turquoise jewelry, as well as many other types of jewelry, can prevent complete viewing and testing of the gem material, and thus can conceal treated or assembled areas.

Since turquoise is a secondary mineral, it is often deposited as thin veins in various types of rock matrix. The view on the top left in figure 18 shows this thin formation with the

matrix partially polished away to reveal the natural beauty of the turquoise. Veins of turquoise that are too irregular, or too thin to be fashioned into cabochons, are frequently backed with a metal-loaded epoxy cement mixture (figure 18, top right), which adds thickness, strength, and weight to the shaped and polished cabochon (figure 18, center). The



Figure 17. Turquoise cabochons in a closed-back bezel-set mounting.

backed turquoise is then bezel set in a closed-back mounting, thus hiding the backing. This type of turquoise treatment is generally accepted among turquoise dealers. However, the price of backed turquoise is generally much lower than unbacked turquoise of equal quality. Therefore, this type of treatment should be disclosed.



Figure 18. Top left: a thin layer of turquoise in matrix. Top right: turquoise backed by a metal-loaded epoxy cement. Center: finished backed cabochon.

It is suggested that any identification report or appraisal of a gemstone that is bezel set in a closed-back mounting and cannot be removed from that mounting be adjusted to reflect the fact that testing was done only to the extent that the mounting permitted. This should be considered with any gemstone that may be commonly treated or assembled. For example, a bezel-set closed-back mounting can conceal the separation plane of an opal dou-

blet or hide an artificial filling in the cavity of an opal (see *Gems & Gemology*, Fall 1983, pp. 162-164).

R.K.

PHOTO CREDITS

Ricardo Cardena took the pictures in figures 4 and 9-13. Shane McClure is responsible for figures 1, 3, 7, and 16. Robert Kane is credited with figures 2, 5, 6, and 17. Figures 8 and 18 are the work of Michael Havstad. Andrew Quinlan took the photos in figures 14 and 15.

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GEM NEWS

John I. Koivula, *Editor*

DIAMONDS

Australia

Cutters report problems with Australian diamonds. Mr. S. N. Sharma, president of Hindustan Diamond (an organization owned jointly by De Beers and the government of India, which markets rough to Indian cutters), stated during a recent visit to GIA that Indian cutters dislike working with diamonds from Australia for two reasons: (1) the Australian stones are so irregular in shape that they often require more than one cleavage separation before they can be cut, and (2) they seem to act harder on the wheel and so take about 20% longer to facet.

It is interesting that the diamonds first found in 1851 at Copeton, New South Wales, were also considered to be harder than diamonds from other sources. The Copeton diamonds, which are for the most part roughly round in shape, are still being mined, but because they are so difficult to cut they are used for industrial purposes only. They apparently contain many "knots" and, therefore, are very tough to saw and dangerous to cleave. However, they make superior industrial stones.

Since the lattice constants of diamonds do not vary from deposit to deposit, there is no reason other than gnarled grain or knots that would cause one diamond to be harder than another.

Diamonds at Jubilee. De Beers's international prospecting arm, Stockdale Prospecting, in a joint venture with United Nickel, Ltd., is expected to start drilling for diamonds at the Jubilee Prospect near Kalgoorlie, Western Australia, in the near future. (*Mining Magazine*, June 1984)

Guinea

Aredor diamonds. The Aredor Diamond Mine in Guinea will go to full production this year. Approximately 90% of the mine's total output is expected to be of gem quality, with rough crystals averaging between 0.8 and 1 ct. The reserves of this deposit are estimated to be able to maintain a production level of 250,000 ct per year over the next 14 years. The Aredor diamonds will be marketed through the Basel-registered Aredor Sales, which will be managed by the Industrial Diamond Company. (*Diamant*, February-March 1984)

India

Cutting Industry. Mr. Sharma also reports that more than 400,000 people are now employed in diamond cutting in India, with over 200,000 of these in the city of Surat (about 150 mi., or 242 km, north of Bombay) alone. Mr. Sharma estimates that another 100,000 workers are employed in colored-stone cutting in India.

Kenya

Prospecting in Kenya. The government of Kenya is issuing geological prospecting licenses to foreign companies. A consortium of four Belgian companies—Brai NV, Sanotec NV, Smet DB, and Vanhout NV, collectively known as the Kenyan Engineering, Mining and Construction Company (KEMICO)—is presently exploring the Siaya District, southwest of Kakamega. The company has reported finding indications of both diamond and gold deposits. (*Mining Journal*, April 1984)

COLORED STONES

Another corundum treatment! Surface pits and cavities are common in lower-quality rubies and sapphires. Even finer gems are plagued by such features.

Rather than grind away valuable weight in an attempt to remove them and thus lessen their impact on a stone's value, it has been a common practice for decades to use some type of filler in the largest and most prominent of these cavities and pits. The use of a filler accomplishes three things: (1) it seals the open voids and prevents the entry of dirt or other unwanted foreign matter, (2) it adds weight to the gem by replacing the air-filled space with a denser material, and (3) it improves the appearance of the gem.

In the past at GIA, we have seen everything from wax and plastic glues to epoxy resins used as fillers. But now entrepreneurs in Bangkok, Thailand, have apparently added a new twist to this old treatment: Instead of these relatively soft compounds, a molten glass is being used to seal these voids.

First noticed recently by gemologists at the Asian Institute of Gemmological Sciences (AIGS) in Bangkok, this surface treatment was initially thought to be an accidental by-product of routine heat treatment. However, a fairly constant influx of rubies displaying the characteristics of this process has prompted AIGS to

abandon this theory and to suspect that the cavities are being filled intentionally with a glass to improve the salability of these gems by lessening the visibility of their surface blemishes. AIGS suspects that a high-temperature heat treatment is involved because the material appears to have been fused into the pits and cavities.

The singly refractive filling material has an R.I. of 1.52 and has been tentatively identified as a glass by AIGS gemologists. When immersed in methylene iodide and viewed with diffused transmitted light (the same method used when checking corundum for diffusion treatment), the treated areas of these rubies stand out in high relief under the microscope. Magnification also reveals that the filling material often contains one or more gas bubbles of varying size. AIGS warns that under immersion any highly reflecting areas that break a stone's surface should be suspect, but cautions gemologists not to mistake natural included crystals, which may also break the stone's surface, for this type of treatment.

GEM NEWS Editor's note: In Thailand, it is common practice to use borax ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) or a borax-based solution in the heat treatment of corundum. Borax melts at 742°C and may form a glassy material (remember the old borax bead tests in high school chemistry?). It is therefore possible that at least some of these filled cavities might still be an accidental product of borax glass formation resulting from common heat or diffusion treatment. Perhaps this treatment technique was accidentally discovered in this way.

A word of caution is also in order. Thai rubies have, as natural inclusions, negative crystals filled with a glassy type of material that may in turn contain one or more gas bubbles. If such an inclusion were cut into during faceting it would then break the surface of the ruby. If a gemologist later encountered this gem and identified it as a surface-treated ruby on the basis of the glassy inclusion, a costly error would result.

It is also possible that some of these glassy filled cavities with bubble(s) result from the melting of preexisting solid inclusions during a high-temperature heat treatment. Many of the inclusions found in natural corundum have melting points far below that of corundum. These may melt during heat treatment and expand sufficiently to fracture their host slightly, thereby relieving the internal pressure by leaking some of the original contents from the area. This rapid release of pressure would cause an instantaneous cavitation in the remaining liquid, producing one or more vapor bubbles. Depending on the chemistry of the environment and the speed of cooling, the inclusion might either form a natural glass or recrystallize. In either case, the gas bubbles would remain, giving it the appearance of a glass.

This writer has seen only one of these "new treated

stones" to date, and it was not available for detailed testing. This stone, a ruby, had a cavity in it with internal growth steps and hillocks decorating its inner walls. Filling it, even into the tightest convoluted corners, was a glassy substance containing numerous gas bubbles. The opening to the surface of the ruby was so small that it is difficult to imagine a mechanism in which a molten viscous glass could be injected into such a cavity, so perfectly, from the outside.

However, reports in the trade of parcels of rubies displaying these features must lead one to speculate that someone has found a way to accomplish such a treatment.

Gem auction in Pakistan. The Gemstones Corporation of Pakistan (GEMCP) held another gem auction in Karachi, from May 28 to May 30 of this year. A number of gemstones, notably emeralds and rubies (some of fine quality) from Pakistan, and lapis lazuli and red spinel smuggled across the border from Afghanistan, are offered to foreign buyers at these auctions. To decrease the problems of illegal mining and smuggling in the gem-mining areas of Pakistan itself, and to increase the volume of gems offered at these auctions, GEMCP is now offering joint mining ventures to the various tribes living in the mining areas. (*Journal of Gem Industry*, May-June 1984)

Manganese find. According to the Geological Survey of India, a 1.6-km zone bearing high-grade manganese ore has been found in the Nishikhal area of the Koraput District, Orissa, India. Reserves in the zone have been estimated at 323,444 total tons; 254,871 tons are expected to grade at 36% manganese, and the remainder at 29% manganese. With the discovery of a new manganese ore body, the potential exists that manganese-containing gems, such as sugilite, might be found. This deposit therefore deserves watching. (*Mining Magazine*, January 1984)

MMTC activities. In India, the Minerals and Metals Trading Corporation (MMTC) has been quite active. Rough gem-quality diamonds from Ghana are being marketed to diamond exporters. MMTC has just contracted to handle Brazilian emeralds and expects to market a large percentage of the Brazilian output of other gemstones. They are also attempting to import large quantities of rough emeralds from Africa, and negotiations are under way with the Soviet Union to handle some of the Soviet output of rough gem diamonds. (*Gem and Jewellery Business Intelligence*, 1984)

Zambia cancels emerald-mining contract. Zambia has cancelled an emerald-mining agreement with Saudi Arabia's International Development and Construction Company because of the Saudi company's failure to honor the contract. Zambia has now signed a new con-

tract with a consortium of emerald-mining companies from Europe and South America for the rights to mine the Zambian emeralds. (*Mining Journal*, June 1984)

PRECIOUS METALS

East Rand platinum. East Rand Consolidated, a South African investment finance company, will cultivate a new platinum prospect located in the Lydenburg District of Eastern Transvaal, South Africa. The mineral rights to the platinum are held by Erconovaal Ltd., a wholly owned subsidiary of East Rand. (*Mining Journal*, June 1984)

Gold production in Ghana. Ghana has announced its intentions to resurrect its gold-mining industry. The government has given foreign mining companies the right to retain 20% of their export earnings to help stimulate this effort. A large portion of monies received from the International Monetary Fund will also be allocated for this project. The State Gold Mining Corporation intends to triple its production within the next three years. (*Precious Metals Monthly Review*, May 1984)

Japanese gold find. Mitsubishi Metal Corp. has discovered a promising gold vein at its Yatani lead-zinc mine in northern Japan. Values averaging 50 g/ton gold and 220 g/ton silver have been reported.

The geologic extent of the gold-bearing vein has not yet been established, and drilling and analyses will be required before mining on a commercial scale can be considered. (*Mining Journal*, May 1984)

New reserves at Knob Hill. With the discovery of additional ore reserves, Hecla Mining Company of Wallace, Idaho, has decided to continue production at its Knob Hill gold and silver mine located at Republic, Washington. The newly discovered reserves are expected to yield approximately 15,000 oz. of gold, and between 60,000 and 70,000 oz. of silver, per year for at least the next two years. (*Precious Metals Monthly Review*, July 1984)

Pascalis gold reserves. Soquem and New Pascalis Mines have announced that preliminary exploration indicates a reserve of 834,000 tons of ore at a grade of 8.26 g (0.26 oz.) of gold per ton for their Soquem property. The property is located east of the Val d'Or district of Quebec on land owned by New Pascalis. The reserve tonnage estimate is based on 41 completed diamond drill holes placed to evaluate the mineralization to a depth of 155 m below the surface. Two of the holes intersected the gold-bearing dike at a greater depth, giving rise to plans for a further drilling program designed to determine if the gold mineralization is present as deep as 365 m below the surface. (*Mining Magazine*, January 1984)

Philippine gold. In 1983 a farmer located a rich gold lode at the foot of a mountain on the Island of Negros. Miners pouring into the area have since established a gold town called Hinoba-an. Some independent miners at the workings are producing from 12 to 15 g of gold a week. The mining town now produces a total of approximately 70,000 g of gold each week. Under protest from the individual miners, a gold-mining company has filed a claim to the lode in an attempt to take it over. (*Jewellery News Asia*, May-June 1984)

Zimbabwe gold. Plans have been announced to develop an open-cast gold mine in southwest Zimbabwe at Filabusi, 80 km south of Bulawayo. The developer is Cluff Mineral Exploration of Zimbabwe, a subsidiary of the U.K. Cluff Oil group. It is estimated that 326 kg of gold will be recovered over the next two years at this prospect. Active mining was scheduled to begin in June of this year. Further exploration continues, and Cluff Mineral Exploration expects to find similar prospects elsewhere in Zimbabwe. (*Mining Journal*, April 1984)

SYNTHETICS AND SIMULANTS

Simulated pearl ruling. The actions of some suppliers who recently began marketing simulated pearls as "premature cultured pearls" caused the Jewelers Vigilance Committee to submit to the Federal Trade Commission (FTC) an addendum to the rulings that deal with pearl definitions. The addendum states that it is an unfair trade practice to use the term *pearl*, *cultured pearl*, or *cultivated pearl* to describe a pearl-like product "whose outer surface does not consist wholly of naturally occurring concentric layers of nacre applied by a mollusk host."

Working with the JVC and FTC, Jill Fisher, of the Gemological Institute of America, said that the addendum was intended to clarify the difference between cultured pearls and the most sophisticated simulated pearls. (*Jewelry Appraiser*, May-June 1984)

An interesting man-made glass. In response to the Winter 1983 article by George Bosshart entitled "Cobalt Glass as a Lapis Lazuli Imitation," Mr. Kenzo Kato of Iimori Laboratory, Ltd., Tokyo, Japan, donated a collection of five interesting glasses manufactured by Iimori to *Gems & Gemology*. The glasses are "Victoria Stone," "Meta-Jade," "Cat's-Eye," "Iris Jasper," and "Maple Stone." This writer was familiar with all of these except the "Maple Stone," which has a dark brownish green body color with brownish red arborescent dendritic "flowers" of devitrification. The sample studied had a refractive index of 1.603. In hand-specimen form, this material resembles bloodstone chalcedony, but under the microscope (figure 1) the "flowers" are quite obvious. Once this pattern is observed and associated with this glass it is not soon forgotten.



Figure 1. Dendritic areas of synthetic cuprite devitrification in Iimori's "Maple Stone" glass. Magnified 20x.

ANNOUNCEMENTS

April 1984 marked the centennial of the **National Gem Collection**, which is located in the National Museum of Natural History (Smithsonian Institution) in Washington, D.C. The first public display of a portion of the collection took place in April 1884, when Curator of Mineralogy F. W. Clarke prepared an exhibition of American gemstones for the New Orleans Exposition.

To celebrate the centennial, two major new additions to the collection have been placed on display for the first time. They are the 318.44-ct Dark Jubilee, an Australian black opal donated by the Zale Corporation, and the 182-ct Star of Bombay sapphire (figure 2), a bequest from movie actress Mary Pickford.

The Society of Jewellery Historians of the British Museum in London is pleased to announce the advent of their new annual journal, *Jewellery Studies*. The 96-page publication will contain feature articles, exhibition news, book reviews, and a current bibliography. The journal will be highlighted by numerous black-



Figure 2. The 182-ct Star of Bombay sapphire, recently placed on display at the Smithsonian Institution, Washington, DC. Photo by Victor Krantz.

and-white and color photographs. The society meets approximately seven times a year, and holds a number of two-day symposia. They also publish two newsletters as well as the proceedings of their symposia. For information regarding memberships and subscriptions, please contact Ms. Judy Rudoe, Department of Medieval and Later Antiquities,

British Museum, London WC1B 3DG, England.

AGA Conference. The Accredited Gemologists Association (AGA) has set the dates for its 1985 conference to be held in Tucson, Arizona, in conjunction with the annual Tucson Gem and Mineral Show. The conference will be held February 4 and 5 at the Palo Verde Holiday Inn. For further information, please contact Neil H. Cohen, 99 Pratt St., Suite 211, Hartford, CT 06103.

A Special Request. GIA has a slide library that now numbers over 10,000. We are trying to obtain color 35 mm or other format transparencies from every gem locality in the world. Since GIA personnel cannot travel to and photograph all of the world's gemstone localities, we would very much appreciate receiving any labeled or otherwise explained slides taken at any and all gemstone localities both major and minor. Such slides are invaluable educational tools. As with any donation made to GIA, all donors of slides will be duly acknowledged.

GEM & CRYSTAL TREASURES

By Peter Bancroft, 488 pp., illus., publ. by Western Enterprises and Mineralogical Record, Fallbrook, California, 1984. US\$60.00*

One might expect *Gem & Crystal Treasures* to be another of those beautiful coffee-table publications that mainly consist of colorful mineral photographs. It is a striking book, but Dr. Bancroft has given us much more than spectacular photographs of minerals. The book is a compendium of thumbnail sketches of 100 of the most famous gem and mineral localities in the world. It contains much previously unavailable information the author gathered through personal visits to localities and interviews with hundreds of people over a period of more than 11 years. He supplements this information with 667 black-and-white and 320 color photographs, including beautiful "world-class" mineral specimens and hundreds of historical and modern mining photographs never before published. Most of the superb color photographs of specimens were taken by Erica and Harold Van Pelt. Bancroft's selection of mining photographs shows his appreciation of the human element of the gem and mineral world as well.

The localities covered in the book are organized by continent, starting with North America, then going to South America, Australia, Asia, Africa, and Europe (concluding with the Soviet Union). Unfortunately, Dr. Bancroft never explains this organization system, which may be slightly frustrating to some readers.

Most of the "classic" gem deposits are included in this book. In North America, the sapphire deposit at Yogo Gulch, Montana, the major gem pegmatite mines of San Diego County, California, the opal mines of Virgin Valley, Nevada, the gem pegmatites of Oxford County, Maine, and the hiddenite deposits of North Carolina are all covered. In South America, both the Muzo and Chivor emerald deposits in Colombia are discussed, as are nine of the most

BOOK REVIEWS

Michael Ross, Editor

important Brazilian gem pegmatites. For Australia, Bancroft included the Coober Pedy and Lightning Ridge opal deposits, but omitted the famous opal deposits of Queensland and Andamooka in southern Australia. He mentions such classic Oriental localities as the Mogok (Burma) Ruby Tract and Sri Lanka, but notably missing are the Burmese jadeite mines and the famous sapphire mines of Kashmir. Bancroft then takes us westward to cover lapis lazuli from Afghanistan, turquoise from Iran, peridot from the Red Sea island of Zabargad, and even Cleopatra's emerald mines in Egypt. The full complement of gem-mining areas in East Africa are presented, including the Lualenyi tsavorite mines of Kenya and the Merelani tanzanite mines in Tanzania. Further south come the African pegmatite mines of Zimbabwe, Madagascar, and Mozambique. He concludes his survey of Africa with the famous Premier diamond mine in South Africa. The journey ends with vignettes of the famous, but little known, topaz deposits at Mursinka and the Tokovaya alexandrite/emerald deposits in the Soviet Union.

At the end of the book is a helpful map showing the location of each deposit plus a list of 196 suggested additional readings.

This book is a must for anyone with an interest in gem and mineral specimens, history, and mining. Dr. Bancroft is to be thanked for providing our community with a book of such enormous importance.

PETER C. KELLER, Ph.D.
*Los Angeles County Museum of
Natural History*

A GUIDE TO MAN-MADE GEMSTONES

By Michael O'Donoghue, 223 pp., illus., publ. by Van Nostrand Reinhold, New York, 1983. US\$35.00*

It is refreshing to see a book that promotes a better understanding of synthetics and how to identify them—a topic of great concern to today's jewelry industry. Although the book is primarily aimed at gemologists, even the general reader can benefit from it.

After a brief summary of basic crystallography, O'Donoghue discusses the major processes of gemstone synthesis, listing them in three main categories: flame fusion, hydrothermal, and growth from the melt. The last includes Czochralski pulling, skull melting, and the flux melt process. He devotes most of the book to identifying synthetics, which are listed by species. He covers all the major synthetics as well as less common ones such as synthetic apatite and fluorite. O'Donoghue also includes a number of materials usually manufactured for industrial purposes that have no naturally occurring counterparts but are sometimes cut as gemstones. Glass as a gem simulant, doublets, and triplets are included as well. In addition, one chapter is devoted to inclusion photography as an aid to gem identification.

While most of the information is complete and concise, there are a few areas that are misleading and, in some cases, inaccurate. For example, when discussing the separation of natural from synthetic sapphires, O'Donoghue states that natural sapphires never fluoresce greenish or bluish white. Contradicting this, he later states that heat-treated natural sapphires can show a "dull chalky green fluorescence" with short-wave ultraviolet radiation. On page 33 he states that synthetic yellow sapphires do not fluoresce, when, in fact, many will fluoresce red when exposed to long-wave ultraviolet radiation. When discussing detection of cyclotron treatment of diamonds,

Continued on page 180

Editorial Forum

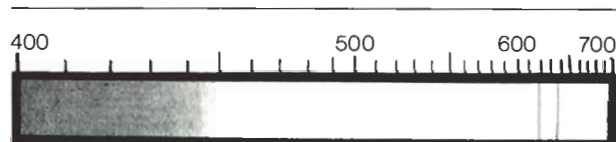
"FINE GREEN" DEMANTOIDS

Since the publication of "Gem Andradite Garnets" in the Winter 1983 issue of *Gems & Gemology*, we have had the opportunity to examine demantoids of a considerably more intense green than those described in our article. In response to a comment in the article that no such stones had been available to us, we were recently given the opportunity to examine three additional demantoids (figure 1). Two of these stones clearly exhibit the characteristic bands at about 620 and 640 nm that have been described in the gemological literature. A high-wavelength doublet was located with the spectrophotometer at about 684 and 687 nm, but was not visible with the hand spectroscopy. The spectrum of one of these stones is reproduced in figure 2. The Cr₂O₃ content



Figure 1. Three intense green demantoid garnets, weighing (from left to right) 1.18 ct, 4.11 ct, and 1.38 ct. Photo by Michael Havstad.

Figure 2. Spectrum of one of the green demantoids pictured in figure 1.



of this stone (which was the highest of the three) is about 0.14 wt.%, which is no higher than that of several of the specimens in our previous study. However, the stones described here are considerably larger (over 1.0 ct) than the ones examined earlier that have a comparable chromium content (less than 0.4 wt.%). The distance light travels through a stone (the "path length") affects the strength of absorption features detected for a given concentration of color-causing agent; the longer the path length, the stronger the absorption. Characteristic features that normally are weakly resolved may thus drop below the detection limits of the spectroscope and spectrophotometer for very small specimens. This no doubt accounts for the difference in absorption bands seen in the demantoids of different sizes that we have examined. Gemologists are advised to keep this effect in mind when using spectral characteristics to identify small stones.

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and D. Vincent Manson, Ph.D.
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IRRADIATED TOPAZ AND RADIOACTIVITY

In his article, "Irradiated Topaz and Radioactivity" (*Gems & Gemology*, Winter 1981, p. 215), Robert Crowningshield writes: "Large quantities of colorless topaz are currently being treated by gamma irradiation to turn them blue, a process that does not produce radioactivity in the stone (Nassau, 1980). The resulting color is a medium deep blue that is significantly darker than that of most natural blue topaz. A considerably darker color does result in rare instances (M. Welt, pers. comm., 1981); this blue color is produced by a treatment (nature unknown) that is purportedly used on colorless topaz that will not turn blue with gamma rays (M. Welt, pers. comm., 1981)." I would like to contribute some new information about the process used in Brazil to turn natural colorless topaz blue and about those stones that will not turn blue with gamma rays. My sources include

persons who work with treated topaz and an article that recently appeared in a Brazilian magazine.

The topaz is irradiated inside a nuclear reactor in an iron box that has been lined with cadmium. The iron (Fe) and cadmium (Cd) absorb the thermal neutrons that can activate the impurities present in the topaz that is being irradiated, forming radioisotopes with long half-lives. These thermal neutrons serve as the source of the high-energy gamma rays. During the irradiation process, the iron box and the cadmium lining are both converted into an intense source of gamma irradiation with variable energy. Since the topaz crystals are in the center of this source, they can be subjected to very high intensity irradiation.

The epithermic neutrons that pass beyond the barriers of the Fe and the Cd, striking the atoms of the

crystal, cause faults in its crystalline structure. These can be converted into a new color center by a subsequent process of ionization. This method of neutron irradiation produces the permanent blue color in the topaz crystal, even in those colorless topaz crystals that will not turn blue with gamma irradiation (about 90% turn a deep blue). After irradiation (for approximately eight to 16 hours), the topaz is treated in an oven at a temperature that varies between 250°C and 350°C to stabilize the color.

According to observations made during the irradiation of colorless topaz, only two radioactive elements remain after the irradiation: 24 Na and 47 Sc, with half-lives of 15 hours and 3.4 days, respectively.

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Continued from page 178

O'Donoghue mentions the umbrella effect around the culet, but not the color duplication of crown facets that is present in a table-treated stone. And, in his discussion of the color origin of green diamonds, he states that, "if no green naturals are seen, the stone must have been treated." This suggests that *all* natural green diamonds owe their color to a green "skin" on the surface and not a green body color. While this is true of some stones, there is no scientific evidence to support such a generalized statement for all green diamonds.

Although the author does discuss gemstone treatments as well as

synthetics, the material is not well organized. There is a chapter titled "Irradiation, Staining and Coating," but it is only nine pages long and consists almost entirely of a listing of individual case reports. More information on these subjects, as well as on other treatments, is listed at the end of each chapter, in a section entitled "Reports on Individual Cases from the Literature." A paragraph is devoted to each case, but the entries are not arranged in any discernible order.

Despite its few inaccuracies and some organizational problems, this book contains much information that gemologists will find very useful. The text is written as nontech-

nically as possible, and, for the most part, reads well. Its 223 pages are printed on heavy stock and carefully edited. It also features many black-and-white photographs and line drawings, as well as a center section of color plates photographed by Dr. Edward Gübelin.

With all the concern about synthetics and gemstone treatments in the industry today, this book will be a welcome addition to any gem reference library.

SHANE McCLURE
GIA Gem Trade Laboratory,
Los Angeles

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

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Durchsichtiger Analcim aus Australien [Transparent analcime from Australia]. H. Bank, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 32, No. 4, 1983, pp. 204–205.

Bank describes analcime from Australia, which is occasionally faceted for collectors. With refractive indices of n_e 1.486 and n_o 1.487, and a very low birefringence of 0.001, it is easily misidentified as leucite. Analcime is chemically $\text{Na}[\text{AlSi}_2\text{O}_6] \cdot \text{H}_2\text{O}$ and belongs to the zeolite group of minerals. The hardness is 5–5½; density is 2.22–2.29 g/cm³. Often occurring as crystals shaped like trapezohedrons or modified cubes, it is a common

mineral in basalts and other igneous rocks as well as in some sediments. MG

The formation of chrysoberyl in metamorphosed pegmatites. G. Franz and G. Morteani, *Journal of Petrology*, Vol. 25, No. 1, 1984, pp. 27–52.

The gem mineral chrysoberyl (BeAl_2O_4), best known by its varietal names alexandrite and cat's-eye, occurs in pegmatites and certain metamorphic rocks. Since Al_2O_3 -rich minerals such as chrysoberyl are not commonly found in pegmatites, geologists have resorted to explaining this occurrence by various reaction mechanisms in which Al_2O_3 is either lost or gained by the pegmatite magma during its crystallization in crustal host rocks. From a study of mineral assemblages in pegmatite samples from Kolsva, Sweden, and Marsikov, Czechoslovakia, Franz and Morteani dispute this traditional hypothesis. Petrographic investigations have shown that many chrysoberyl-bearing pegmatites are metamorphosed. These authors suggest that the formation of chrysoberyl may be the result of a reaction between pegmatitic beryl and alkali feldspar under high pressure-temperature metamorphic conditions. Such conditions arise following the complete crystallization of the pegmatite. Beryl and alkali feldspar, which crystallize from the pegmatite magma, become an unstable assemblage during these subsequent metamorphic conditions, and react to form chrysoberyl and quartz. Details of the proposed metamorphic reactions involved

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

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

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

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in chrysoberyl formation are discussed, as are some still-unresolved questions. JES

A new look at Dominican amber. L. Montgomery de Merette, *Jeweler/Gem Business*, Vol. 7, No. 5, 1983, pp. 9–19.

For years most amber has come from one area—the Baltic. Today that venerable locality is becoming eclipsed by a newer one in the Dominican Republic. This Caribbean amber is the subject of de Merette's thorough article, which describes in detail the occurrence of the material, the history of its mining (which essentially dates back only to the 1960s), and the distinctive characteristics of the amber itself.

The Dominican Republic is the first sizable source of amber to be discovered in the Western Hemisphere since ancient times. This particular amber is distinguished by its clarity and high refractive index, its clear and abundant inclusions, and a striking range of color. Almost an entire spectrum is represented: light yellow, deep yellow, honey colored, deep red, brown, olive green, and even "blue" amber—a fluorescent amber that is yellow to brown with back lighting, and vivid "oil-slick" blue in daylight. Dominican amber is more affordable and available than Baltic amber, because of the strict Soviet controls on the Baltic material and because the Dominican government imposes no mining controls and the country's labor costs are low. (As a result, Dominican amber is roughly half the price of comparable Baltic rough.) The author provides a list of criteria for appraising Dominican amber, including a detailed roster of desirable inclusions such as (in order of their abundance) bubbles, spangles, insects, and plants.

The article also appears in its entirety in a French translation by Emmanuel Fritsch (*Monde et Minéraux*, No. 61, May-June 1984, pp. 36–41); this version is notable for the dazzling color photographs of the amber taken by Nelly Bariand which, regrettably, did not appear in the English original. JMB

DIAMONDS

Argyle gathers momentum. J. Mitchell, *Indiaqua*, Vol. 37, No. 1, 1984, pp. 19–21.

This article traces the development of the diamond mine at Smoke Creek, Western Australia, which is owned by the Argyle Diamond Mines Joint Venture. The Argyle kimberlite pipe, known as the AK-1, was discovered in October 1979. Exploratory drilling in 1982 indicated that the southern section has more than 100 million tons of kimberlite, 61 million of which are proven reserves with 14 million tons of probable reserves. This section has an unusually high average grade of seven carats per ton. The Joint Venture plans to develop an open-cut mine capable of processing three million tons, or 25 million carats, a year by 1986-87. This will increase the world supply of diamonds by

about 50%; however, since Argyle diamonds are small and have very low cutting yields, the AK-1 diamonds will add only 5% to the value of world production. These diamonds do make excellent industrial-quality stones, and their production will boost Australia's economy, making Australia the world's largest diamond supplier by 1986.

The Joint Venture is hoping to discover a faulted extension of the AK-1 pipe, and also plans to search for other related economic kimberlites (such "clustering" has been known to occur in Africa and the Soviet Union). In addition, diamonds from the nearby Ellendale mine (also owned by the Joint Venture) will be processed at the AK-1 plant, which should make the Ellendale economic by 1987. SAT

Famous diamonds of the world (XVI): the "Excelsior" diamond. I. Balfour, *Indiaqua*, Vol. 35, No. 2, 1983, pp. 131–134.

In 1893, an African miner found an extremely large diamond in the Jagersfontein mine, the first pipe mine to be discovered in South Africa. This high-color stone weighed 995.2 ct, the largest diamond found up to that time; it was not bested until the 3,106-ct Cullinan was found 12 years later. Mr. Balfour refers to this diamond, named the Excelsior, as the "Great Unknown" because it has received little historical notoriety even though it is the second largest rough stone ever found.

After its discovery, the Excelsior was sent to a London syndicate where it was soon joined by another large diamond also found in the Jagersfontein mine. This diamond, initially named the Reitz, was renamed the Jubilee after it was cut in 1897, the year of Queen Victoria's Diamond Jubilee. The Jubilee is a cushion shape weighing 245.35 ct, making it the third largest cut diamond on record, far larger than any of the stones fashioned from the Excelsior.

In 1903, after futile attempts to sell it whole, the Excelsior was cleaved into 10 pieces which yielded 21 gems ranging from 70 ct to less than one carat. Considering the original size of the rough, it is unfortunate that because of troublesome dark inclusions and economic considerations, the Excelsior provided no significant gems to spark our imagination. Furthermore, little is known of the fate of these cut diamonds.

Three drawings and nine photographs accompany the text. FLG

GEM LOCALITIES

'RJ' study tour to Brazil proves a mine of information.

Retail Jeweller, Vol. 22, No. 569, 1984, p. 6.

Members of the 1984 *Retail Jeweller's* study tour visited several different gemstone mines in Brazil. First they were taken to the Socoto emerald mine in the area of Turutiba, which was discovered in 1983. The garim-

peiros (independent miners) sink pits down to the micaceous schist zones—generally 5–10 cm thick—that contain the emeralds. The miners lower themselves into the pits and pry the emeralds out with hammers and chisels. Rough emerald crystals are sold to licensed buyers only; from February 1983 through March 1984 they purchased 5,017.6 kg of emeralds for a total of US\$1,600,000. The government is providing small lapidaries with the equivalent of US\$20,000 in working capital to encourage local industry.

The tour also visited the Imperial topaz mine in Ouro Preto near the village of Rodrigo Silva. Open-pit mining is performed with a bulldozer and high-pressure water jets. Most of the topaz crystals recovered here average 2.3–3.5 cm long. A cubic meter of mineralized soil usually contains 0.40 ct (faceted weight) of topaz, with a daily average of 320 ct.

The article also gives insights into gem retailing in Rio de Janeiro, especially the practices of the firm H. Stern, which purchases about 60% of all Brazil's gem production. SAT

The rubies of Cowee Valley. W. D. Hadley, *Rock and Gem*, Vol. 14, No. 5, 1984, pp. 36–39; No. 6, 1984, pp. 37–39.

In this two-part article, Hadley provides an interesting and informative review of the rubies of Cowee Valley, North Carolina. The ruby-rich area lies close to the western central border of North Carolina, surrounded by the Appalachian, Great Smoky, and Blue Ridge Mountains. Cowee Creek, a tributary of the Little Tennessee River, is the largest source of rubies. The city of Franklin contains more than a dozen ruby mines as well as several mines of sapphire and rhodolite garnet.

In part 2 of his article, the author traces the geological history of the mining area and furnishes an overview of gem corundum. He emphasizes the beauty of the area for the vacationer, with the added bonus of mining for rubies in the Cowee Valley. The mines are open to the public on a fee basis from about May 1 to October 1. The numerous rock and gem shops and gem museums make this area an ideal setting for the gem enthusiast. WEB

INSTRUMENTS AND TECHNIQUES

Diagnostic irradiation: how irradiation can be used to identify gemstones. P. Read, *Canadian Jeweller*, Vol. 105, No. 5, 1984, p. 23.

Mr. Read begins this article by briefly reviewing the use of irradiation treatment to enhance the color of gemstones. He then discusses the various uses of electromagnetic radiation (ultraviolet or X-ray) in the separation of natural from synthetic stones. Most gem materials contain iron oxides which greatly inhibit the presence of fluorescence when the material is exposed to long-wave ultraviolet radiation. The absence of this el-

ement in all but the most recent synthetics results in the pronounced fluorescence of most synthetic material.

Mr. Read also mentions that the new Culti Colored Stone Checker detects the presence of iron in a gemstone by testing the ability of the stone to transmit short-wave ultraviolet light. Stones that contain iron will absorb this light; those that do not, transmit these rays. Although the information given in this article can be gleaned from other sources, it is a concise and useful review of applications of electromagnetic radiation in gem identification. Patricia Reynolds

Emissionsspektralanalyse von natürlichen und synthetischen Rubinen, Saphiren, Smaragden und Alexandriten (Emission spectrum analysis of natural and synthetic ruby, sapphire, emerald and alexandrite). H. Kuhlmann, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 32, No. 4, 1983, pp. 179–195.

The author analyzed the emission spectra of 207 samples of natural ruby, sapphire, emerald, and alexandrite and 61 samples of their synthetic counterparts. The analytic data on 11 trace elements (Be, Cr, Cu, Fe, Mn, Mo, Ni, Si, Sn, Ti, and V) in each group of gem minerals and synthetics are summarized. The trace-element patterns for natural rubies from Kenya, Tanzania, Afghanistan, India, Burma, and Greenland reveal Cr, Si, Ti, V, Mn, Fe, Sn, and minute traces of Cu without any sign of Mo. The synthetic rubies made by Chatham and Verneuil, however, show a distinct presence of Mo. The Kashan and Knischka products contain a higher percentage of Cu. Sapphires from Kenya, Tanzania, Sri Lanka, Burma, Cambodia, Australia, and the United States contain Fe, Ti, Si, and Cu as important trace elements. The Verneuil synthetic sapphire shows Ti, Fe, and Si; the Chatham blue sapphire, Ti, Fe, and V. Although analyses of natural emeralds from South Africa, Zimbabwe, Zambia, Tanzania, Mozambique, Egypt, Madagascar, Brazil, Colombia, Austria, and Norway show the presence of Ti, V, Cr, Mn, Fe, Ni, Cu, Ag, Sn, and Bi, no Mo was found. The man-made emeralds produced by Chatham, Gilson, Lechleitner, Linares, Linde, and Zeffass revealed no Ti or Bi, but often showed the presence of Mo. Linares and Linde emeralds contained no Mo but showed Cu and Sn patterns, respectively. The author does not include the trace-element patterns of Thai rubies or synthetic alexandrite. MG

The jeweler's refractometer as a mineralogical tool. C. S. Hurlbut, Jr., *American Mineralogist*, Vol. 69, No. 3/4, 1984, pp. 391–398.

Although widely employed in gemology, the standard jeweler's refractometer has not been as fully appreciated in mineralogy. This is due to the requirement that the crystal under study have a small, flat, polished surface (as is the case with faceted gemstones but is uncommon with minerals), and to the widespread adoption in min-

eralogy of the immersion method for refractive index determination. However, this article describes how a simple refractometer can aid in determining the optical properties of a mineral either in a small grain or mounted in a polished thin section. Examples are given of obtaining information: (1) for isotropic substances, the single refractive index; (2) for uniaxial crystals, both principal refractive indices and the optic sign; and (3) for biaxial crystals, the three principal refractive indices and the optic sign. This information results from the standard observation of the shadow edge in the refractometer eyepiece, and also by noting the relative positions of both the crystal on the hemicylinder and the rotatable cap polarizer. The method is described in some detail. Refractive indices can be determined to a precision of about 0.002, which compares favorably with the precision of the immersion method, i.e., 0.001. JES

JEWELRY ARTS

Enamelling—II: grinding, washing, laying and firing enamels. C. Walton, *Aurum*, No. 17, 1984, pp. 57–63.

"Enamelling—II" runs true to the form established in part 1 (abstracted in the Summer 1984 issue of *Gems & Gemology*). The title is almost as informative as the rest of the article. The tedium of grinding and washing is carried into the text, with the majority of the article devoted to this most uninteresting aspect of the art form.

With regard to laying and firing enamels, once again attention is given to the difficulty of execution with little insight into the actual process. One or two interesting concepts are mentioned, but only fleetingly, and the processes of laying, firing, grinding, and finishing are polished off in about a dozen uninformative paragraphs. As in part 1, the photographs add greatly to reader interest, and the finished product must be admired. If these articles were written for the reader with no technical knowledge of enameling, they are well done. But for those of us with an enameling background, they provide only ho-hum reading and elicit the reaction that, "We know how difficult it is. Where are the tips to ease the problems?" Archie V. Curtis

Eugenia's jewels. W. Davies, *Connoisseur*, Vol. 214, No. 863, 1984, pp. 76–81.

This article reads like a fairy tale: The Countess Eugenia de Serigny, pursuing a life-long interest in jewels and gems, begins to design her own jewelry. Following design ideas from the turn of the century, she has her jewels made so that the gems can be interchanged and the jewelry broken down into smaller units for style, convenience, and maximum security when traveling. Soon, she is designing and manufacturing for friends and before you can say "haute joailliere," Eugenia de S. has a full-scale business going, with factories in Paris and Geneva, wealthy and influential clients all over the

world, and distribution agreements with two prestigious retail jewelers—O. J. Perrin in Paris and Black, Starr & Frost in the United States.

It is true that the countess has everything going for her: beauty, charm, connections, time, and money. But she is not a dilettante. Using the advantages that life has given her, and making the most of opportunities offered her, she has successfully launched a career that many of us have always dreamed of. EBM

Jewelry design: the art and the profession. A. Durante, *Metalsmith*, Vol. 2, No. 3, 1982, pp. 14–16.

In the first of a two-part series on jewelry rendering, Durante discusses jewelry design as a profession and the problems encountered by the neophyte designer. Drawing from personal experiences as design director at Cartier and as an instructor at Parsons School of Design in New York, Durante stresses the need for designers to be well rounded. Skills should include product rendering as well as jewelry rendering plus a background in metals, gemology, and marketing.

Learning jewelry design is the first step to becoming a professional designer; obtaining a job is the second. Before looking for employment, assess your capabilities as well as your limitations. Do not sell yourself short, nor overextend yourself. Be ready to undergo a three- or four-day trial period, during which time your work will be evaluated. Because your portfolio represents your capabilities, it ought to range from the simple to the complex, from the inexpensive to the very expensive. When you meet people in the trade, present your portfolio and ask for suggestions and reactions. Be ready for criticism, and accept it in a "workmanlike" way. Designing is a job. Once hired, be ready to produce; personal problems are not excuses for nonproduction. Designing is a profession: Maintaining a professional demeanor is essential and expected. Lorraine Gruys

Rendering—design and process. R. Palermo and A. Durante, *Metalsmith*, Vol. 4, No. 2, 1984, pp. 23–27.

Jewelry rendering is experiencing a renaissance. Durante and Palermo, co-authors on this second of a two-part series, attribute this to the competitive nature of jewelry designing, rapidly changing fashions, and the cost of producing prototypes. Rendering is a skill which enables a designer to quickly and realistically present a concept. A good rendering is a form of "photorealism." Nothing exists to photograph except what is in the designer's mind; the rendering shows highlights and minute details—it "leaps" off the page. A rendering must tell the whole story.

A rendering is developed with three major considerations in mind: the design of the piece, the characteristics and cost of the materials, and the way the piece will look when worn. A successful renderer must know the mechanics of jewelry: jewelry aesthetics, good taste, and

the market. Individuality of design and the needs of the client are also considerations. A rendering should take a few hours but appear as if it took a week. It should never look overdone.

Fourteen renderings—ranging from pencil roughs to full-color drawings—accompany the article.

Lorraine Gruys

RETAILING

The embattled emerald market. D. Federman, *Modern Jeweler*, Vol. 83, No. 5, 1984, pp. 44–48.

In his captivating article on the world emerald market, David Federman narrates the business intrigues that he admits resemble the twisted plots of TV's "Dallas." His article depicts the tension between old and new players in the market as sources change, supply and demand is altered, and cutting standards affect the pricing values. The market is in such a state of flux that it is difficult to predict the next stage, but Federman does an excellent job of describing the complex interrelationships of business and politics that dominate today.

The tale begins 10 years ago in Zambia, with the first emerald finds there. At this time, the material contained numerous inclusions that made these stones less desirable than their Brazilian and Colombian counterparts. Two years later, in 1976, deposits of better-quality emeralds were found in Zambia and the stones were faceted by the excellent Israeli cutters. Demand soared, making the Zambian material about twice as expensive per carat as the Indian-cut Brazilian stones. Federman reports that by 1980 Zambian emeralds had proved a serious threat to low- and middle-sector Brazilian goods. However, these initial Zambian stones were so clean and superbly cut that jewelers expected all of the material to be flawless, which made it more difficult to sell the slightly included stones; buyers were beginning to loupe emeralds as they would diamonds. This forced higher prices for the better Zambian emeralds, clogged the Israeli inventories with poorer goods, and brought medium-grade Zambian and Colombian material into a similar price range. Since 1983, supply has lagged behind demand for medium- to fine-quality Zambian emeralds.

Federman notes that the market for rough emeralds is based in Geneva, Switzerland, where Indians have battled with Israeli dealers over the escalating price of rough. With the Israelis taking hold of the primary market, Indian dealers have turned to Zimbabwe's emeralds (and have hopes for better-quality emeralds from Brazil). Brazil has been a noted player in commercial-quality emeralds. Since 1980, with the mining of emeralds from Santa Terezinha, in Goiás, it has threatened to become a stronger presence. Since the brilliance and clarity of this material is good, it competes with the commercial quality of African and Colombian material of 1 ct or less.

The availability of cleaner commercial goods from other localities has shaken the market for medium-

grade Colombian material. While Colombia is the undisputed leader for fine stones and stones over 3 ct, competition for the commercial grades has caused factories in Bogotá to improve their cutting and produce more fancy shapes than before.

Currently, speculation is brewing over emerald deposits in Afghanistan and Pakistan. Even though they have been virtually inaccessible thus far for geographic and political reasons, these countries are potential future players. The Afghanistan material is chiefly under 1 ct to date.

JMW

Pearls: will pearls' luster rub off? E. Farrell, *Goldsmith*, Vol. 165, No. 4, 1984, pp. 45–48.

Farrell brings to light some very pertinent information on the current status of the Japanese pearl industry as it relates to the U.S. pearl market. A discussion of the history of the Japanese pearl industry gives some background to what is happening today. The sudden popularity of pearls in the U.S. has enticed many new pearl growers into the industry to meet the growing demand. Many of the new cultivators view this as an opportunity to make fast money. Not only are some growers cultivating twice as many oysters a year, but they are also cutting the growth time of the pearls by as much as 50% (from two seasons to one season of eight months). This has produced a larger number of pearls of lower quality. In the U.S., there are also many new dealers in the market who know little if anything about pearls and are committed to the industry only as long as the pearl craze lasts. Consequently, the influx of pearls into the American market has included many that are low in quality but carry high prices. The author's advice to the American jeweler is to buy the better-quality strands and educate the customer to recognize a better-quality pearl.

Mary Hanns

SYNTHETICS AND SIMULANTS

How to recognise the new Seiko synthetics. K. Scarratt, *Retail Jeweller*, Vol. 22, No. 569, 1984, pp. 16 and 26.

Ken Scarratt reports on the identifying characteristics of the new Seiko synthetics he has examined to date. These new synthetics are manufactured by Matsushima Kogyo Co., Ltd., one of the Suwa Seikosha-affiliated companies that also produces quartz-crystal oscillators for Seiko watches. This division of Seiko is currently synthesizing corundum, alexandrite, and emerald. The synthetic corundum (ruby, orange sapphire, and pink sapphire) and synthetic alexandrite are manufactured using the floating-zone process, while the synthetic emerald is made by a flux process. The characteristic inclusions of the floating-zone material are similar to those of Verneuil material: curved or swirled growth lines and bubbles that appear in various forms such as tadpole-like structures or clouds. According to Scarratt, the curved or swirled growth is most easily seen when the stones are

immersed, or when they are viewed with diffused light. Other than inclusions, the gemological properties of this synthetic alexandrite and synthetic corundum are too similar to the natural to assist in their separation.

The Seiko synthetic emerald, however, is readily separated from natural emerald by its refractive index of 1.561 to 1.565 and its specific gravity of 2.66. The fluorescence of the material Scarratt tested was green when exposed to both long-wave and short-wave ultraviolet radiation. While this fluorescence is not characteristic of most other synthetic emeralds, the flux inclusions—such as two-phase feathers and venetian blind-type zoning—are typical. Scarratt notes that Seiko plans to market the new synthetics only in finished jewelry. Although loose stones may trickle into the market unintentionally, most of the Seiko synthetic material will be associated with the Bijorève trademark, so it may be wise for jewelers to familiarize themselves with the distinctive styles of the Bijorève rings, necklaces, and earrings. JMW

Inclusions in Biron® synthetic emeralds. G. Brown and J. Snow, *Australian Gemmologist*, Vol. 15, No. 5, 1984, pp. 167–171.

Since commercially released Biron synthetic emeralds generally contain very few inclusions, Brown and Snow obtained production rejects from the crystal grower to see if diagnostic inclusions might indeed be present. The most prevalent inclusions noted were partly healed cracks in "twisted-veil" patterns consisting of irregularly shaped one- and two-phase cavities. The refractive indices of the secondary cavities were lower than those of the host material, substantiating the hydrothermal origin of the Biron product. Also present were "spear-point" growth banding (peculiar to this synthetic emerald); small reddish brown granular masses; parallel growth layering on an external surface of one specimen; one coarse two-phase primary growth tube, and only one two-phase "dagger" extending from a phenakite crystal. The investigators conclude that of these inclusions, only small segments of the "twisted-veil" inclusions and the "spear-point" growth banding are likely to be found in commercially sold Biron synthetic emeralds, and that these have only limited diagnostic potential.

The article contains eight photomicrographs and two tables, summarizing the gemological properties of the Biron product and comparing these to the properties of the Linde and Regency hydrothermal emeralds. RCK

Ramaura—eine neue Rubinsynthese (erste Untersuchungsergebnisse) (Ramaura—a new synthetic ruby [the first investigation results]). G. Bosshart, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 32, No. 4, 1983, pp. 164–171.

The author analyzed seven intense red to pale violet-red Ramaura rubies. Distinctions are presented on the inclusions and ultraviolet absorption spectra of the two color tones. Bosshart notes that there were significantly

more inclusions in the intense red sample than in the paler violet stones. His ultraviolet and visible light spectrometry reveals two different types of absorption curves for the two types of stones. Most of these data appear in English in the article by R. Kane on the Ramaura ruby (*Gems & Gemology*, Fall 1983), to which Bosshart contributed the ultraviolet and visible light spectrometry. MG

MISCELLANEOUS

Falsification des mineraux (Falsification of minerals). G. Chaminant, *Monde et Mineraux*, No. 61, 1984, pp. 48–49.

Mineral specimens, like faceted stones, may be subjected to artificial enhancement or outright counterfeiture. Chaminant's article outlines with admirable economy the various ways crystal specimens may be altered, synthesized, or misrepresented. The article also furnishes helpful advice on how to detect these misleading specimens.

According to Chaminant, the most widespread techniques used to alter the appearance of gem mineral specimens involve embellishing the crystal face or placing a natural crystal in a foreign or artificial matrix. Crystal faces may be smoothed by polishing (which can be identified under magnification by circular scratches) or by the use of chemical or acid baths to promote planar surfaces. Varnishes and oils (most commonly silicone and ethylene glycol) are used to hide cleavage marks or other fractures. Those counterfeit specimens where the natural crystals have been glued to a foreign matrix can usually be distinguished by testing for the presence of glues, many of which either fluoresce when exposed to ultraviolet radiation or dissolve when a solvent is applied. Other counterfeits may be wholly synthetic or simulated. Some of the more intriguing mineralogical shams noted by Chaminant are bogus native gold and silver specimens, which are in fact copper that has been electroplated with these respective metals. (Simply scratching the surface of these specimens reveals their true cupric identity.)

After cataloguing the list of mineral falsifications and the means employed to detect them (most of which are analogous to techniques used to test cut gemstones), Chaminant concludes his essay with helpful advice for the collector: If you find you have obtained a counterfeit specimen, do not hesitate to notify the mineral dealer, at least to prevent him from acquiring such specimens in the future. If, on the other hand, you discover you possess a natural but enhanced specimen, nothing should prevent you from enjoying its beauty; simply be aware that any mineral's value is lessened by such alteration. The gemologist who appreciates the rough as well as the cut gemstone should find this article an informative thumbnail sketch, proving as it does that the techniques used in gemology are applicable in mineralogy as well. JMB