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ABOUT THE COVER: While natural black pearls have long been admired for their size and richness of color, their rarity made black pearls virtually unobtainable until the 1970s, when a culturing industry took hold in French Polynesia. The black pearls of Polynesia—their history and culturing, as well as grading and identification—is the topic of the lead article in this issue. The superb necklace on the cover contains 24 natural-color cultured black pearls that range from 12 to 16 mm. At the center of the diamond floral clasp is a 15-mm cultured black pearl. The background is the mother-of-pearl from a large Pinctada margaritifera, *the oyster in which black pearls are grown. Necklace designed by Gianmaria Buccellati; courtesy of Buccellati, Los Angeles, CA.*

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Richard T. Liddicoat

POLYNESIAN BLACK PEARLS

By Marisa Goebel and Dona Mary Dirlam

Historically, natural black pearls have been one of the rarest and most exotic of gem materials. In the 1960s, however, a black-pearl culturing industry was initiated. Today, cultured black pearls play a prominent role throughout the international jewelry community. This article reviews the history of Polynesian black pearls, the development of culturing and the techniques involved, grading, treatments and identification, and the factors responsible for their growing popularity in the 1980s.

ABOUT THE AUTHORS

Ms. Goebel is a Los Angeles–based goldsmith who specializes in designing black-pearl jewelry. Ms. Dirlam is senior librarian at the Gemological Institute of America, Santa Monica, California.

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The 1980s have seen an explosion of interest in the cultured black pearls of French Polynesia, five groups of island archipelagos in the South Pacific. Twenty years ago, black pearls were a mere curiosity appreciated by a handful of people. Today, cultured black pearls, often called Tahitian pearls or Tahitian cultured pearls, can be found in fine jewelry stores throughout the world.

The large black-lipped oyster that produces black pearls, *Pinctada margaritifera*, is found in the coastal waters of Peru, Baja California, Panama, Indonesia, Micronesia, the Red Sea, the Philippines, and Okinawa (a prefecture of Japan), as well as French Polynesia. Yet natural black pearls are extremely rare compared to their white counterparts. In the 1960s, however, with the aid of Japanese technicians, pearl farmers in French Polynesia mastered the culturing of black pearls. Like the natural black pearls, the Polynesian cultured pearls are large and often noted for their superb luster and orient, as well as for the unusual gray-to-black range of color (figure 1). To this day, the vast majority of black-pearl culturing is in Polynesia.

With the greater availability of black pearls has emerged a broader market in the jewelry industry, as is evidenced by their regular presence both in retail stores and at auction. Problems have also arisen, such as concern that the pearls might have been dyed or irradiated (Maitlins and Bonanno, 1987). To provide a better understanding of this exotic material, this article will review the history, biology, and culturing of black pearls. It will also describe grading parameters and how to detect treatments used on pearls from other mollusks to mimic the Polynesian blacks and, more recently, on some Polynesian cultured pearls as well.

THE SOURCE: FRENCH POLYNESIA

Midway between Australia and North America—at approximately 17° south latitude and 151° west longi-

Figure 1. This three-strand necklace illustrates some of the fine black cultured pearls that have been produced in French Polynesia in recent years. Note especially the superb luster and orient of these pearls, which range from 12 to 15 mm. Photo by Tino Hammid; courtesy of Christie's, New York.

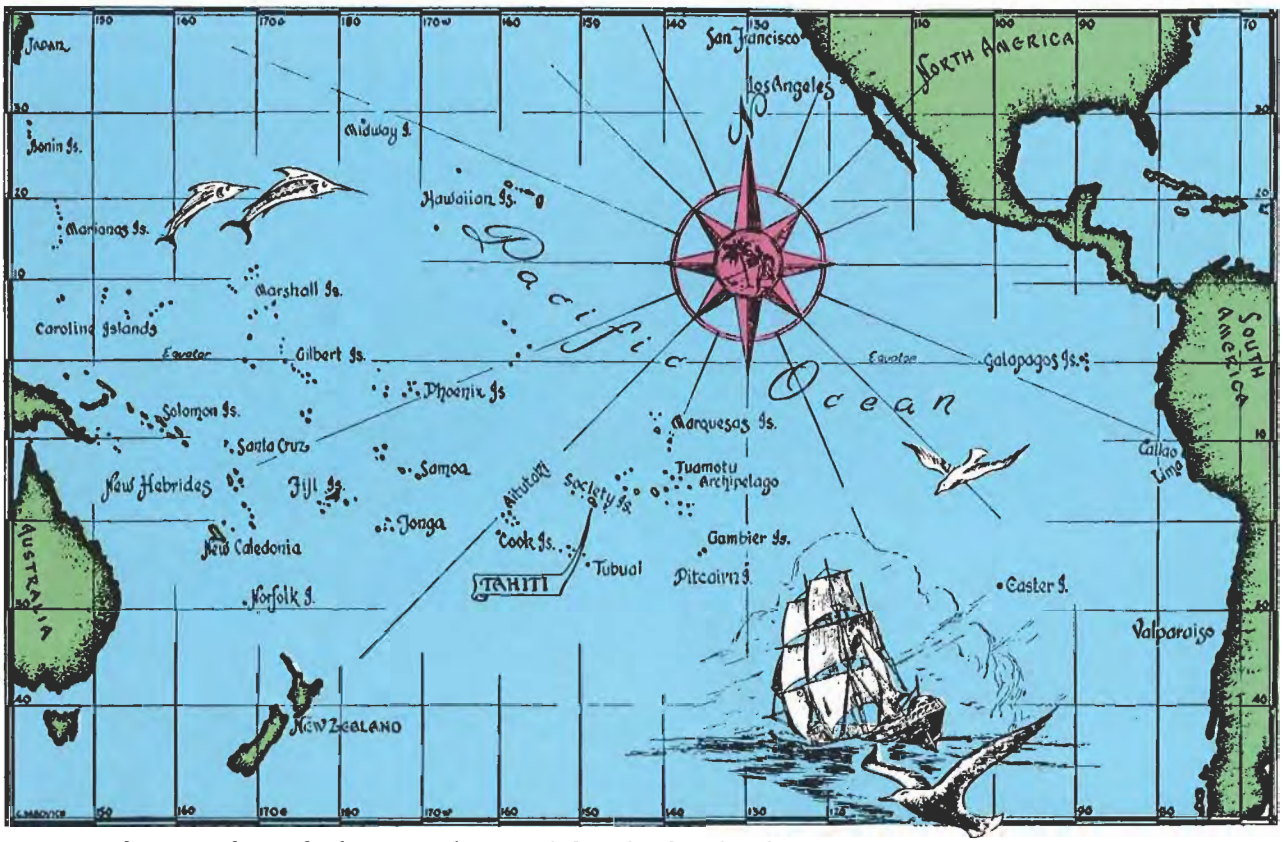

Figure 2. This map shows the location of some of the island archipelagos of French Polynesia, midway between South America and Australia. Adapted from Langdon (1975).

tude—is a group of 130 islands known as French Polynesia (see figure 2). This land mass of 1,550 square miles (9,600 km²) is divided into five archipelagos: the Society Islands, the Leeward Islands, the Tuamotu Archipelago, the Gambier Islands, and the Australes. The black pearls are cultivated primarily in the lagoons of the Tuamotu Archipelago (figure 3) and the Gambier Islands, the waters of which have been found to provide a perfect environment for *P. margaritifera* (Salomon and Roudnitska, 1986).

Figure 3. Black pearls are typically cultivated in lagoons such as this one on S. Marutea Island in the Tuamotu Archipelago. Photo © Fred Ward/Black Star.

HISTORICAL BACKGROUND

The shell of *P. margaritifera* was treasured by native Polynesians long before the European explorers arrived. According to Tahitian legends, black pearls were considered to be emanations from the gods. One important god, Oro, traveled to earth by means of his rainbow, which was believed to be the source of the iridescence in the pearl and its shell (Salomon and Roudnitska, 1986).

In September 1513, Spanish explorer Vasco Núñez de Balboa (1475–1519) first arrived in what is now French Polynesia and claimed the group of islands for Spain. Later, European sailors recounted in their logs and diaries the abundance of giant mollusks in the warm, shallow waters of the South Sea islands, and the ease with which they could be retrieved (Lintilhac, 1987). Unfortunately,

little is known about how the pearls were used by native Polynesians or the early European visitors. The earliest record of shell jewelry dates from 1722, when Roggeveen, a Dutch navigator, noted that the people wore silver disks in their ears and pendants of mother-of-pearl (see figure 4). Some of the ceremonial uses included decorating robes with shells and filling eyes in sculpture with mother-of-pearl. Kunz and Stevenson (1908) describe how Tahiti's monarch Queen Pomare played marbles with black pearls in the early 1800s.

In 1842, Polynesia became a protectorate of France, ending over 300 years of conflict with other European countries. During the 19th century, navigators from France, England, the Netherlands, and elsewhere traded flour, cloth, nails, and alcohol to the divers for mother-of-pearl shells that they used in jewelry, as inlay in furniture, and as buttons. They also brought back pearls, some of which were undoubtedly incorporated into fine jewelry. A few historically important natural black-pearl pieces are known today, although the source of the pearls cannot always be established. In May 1989, for example, Christie's Geneva auction sold (for $104,310) a stunning fringe necklace of 35 graduated natural black, silver, and gray pearls that had belonged to the Spanish ambassador to Russia, the Duke of Osuna, in the 1850s.

Twining (1960) describes "The Azra" black pearl, part of a famous necklace in the Russian crown jewels that eventually came into the possession of the Youssoupoff family. Another black pearl on a diamond necklace that had once been owned by the Youssoupoff family was auctioned for $130,000 by Christie's in 1980. The April 1984 Christie's auction of jewels from the estate of Florence J. Gould featured a period piece with

Figure 4. The shell of P. margaritifera *has been treasured by native Polynesians for centuries; this crude necklace represents one example of early usage. Photo © Alain Durand; courtesy of the Museum of Tahiti and Its Islands.*

Figure 5. This brooch from the estate of Florence J. Gould, whose father-in-law was railroad magnate Jay Gould, is one of the few period pieces with natural black pearls known today. The pearls range from 13 to 19 mm and are set with old mine–cut diamonds. The piece sold at auction for $82,500 in April 1984. Photo courtesy of Christie's, New York.

natural gray pearls set in a dramatic diamond, platinum, and white gold brooch (figure 5).

The 1840s were marked by heavy harvesting of the black- lipped oyster. By 1850, reports indicated concern that the oysters were becoming scarce and had to be recovered from greater depths of water (Lintilhac, 1987). As the overharvesting progressed, the French government intervened by establishing seasonal diving periods.

By 1885, the French government realized that the pearling industry would not survive in the South Sea islands unless more dramatic steps were taken. The government then hired biologists to determine ways to replenish *P. margaritifera*. One of these biologists, Bouchon Brandely, suggested a strict prohibition on fishing in certain oyster-bearing lagoons. More importantly, he recommended collecting spats, or young oysters, and placing them in a protected area. The resulting concentration of oysters created an ideal environment for reproduction, so much so that even today, spat cultivating is the primary way of guaranteeing the oyster population.

At the time Bouchon Brandely suggested cultivating spats, the economic impetus was the demand for mother-of-pearl; any pearls found were simply by-products. Black pearls did not become more than an attractive oddity until culturing in *P. margaritifera* was achieved in the 1960s. Early in that decade, French veterinarian Jean Marie Domard began to study culturing; in 1962, he brought a Japanese specialist to Polynesia, who implanted 5,000 oysters. By 1965, they had obtained 1,000 gem-quality cultured black pearls (Lintilhac, 1987).

Figure 6. These baroque cultured black pearls (the largest is 16 × 8 mm) came from the first harvest of the Rosenthal farm on Manihi Atoll. Courtesy of John Latendresse; photo by Robert Weldon.

The first pearl farm in French Polynesia was started in 1966 on the Manihi Atoll in the Tuamotu Archipelago by Hubert and Jacques Rosenthal, grandsons of "pearl king" Leonard Rosenthal, author (1920) and scion of a French jewelry family known for their fabulous pearl jewels. The Tahitian government encouraged the Rosenthals to help develop the culturing industry in Polynesia. Through the efforts of Japanese specialist Renji Wada and site manager Koko Chaze, the farm was in full operation by 1968 (figure 6). It continues today, managed by Leonard's great grandson, Cyril Rosenthal. Over the course of the next 20 years, culturing developed into a viable export industry as the technical expertise evolved to produce large, fine-quality black pearls for the jewelry community (figure 7).

ANATOMY OF THE OYSTER AND COMPOSITION OF THE PEARLS

Of the more than 70 species of mollusks (from the phyllum Mollusca) that can produce pearls, the majority belong to the *Pinctada* family. *Pinctada maxima*, the white-lipped or gold-lipped oyster, is prized for both its shell and the large gold-colored and white pearls it produces. It lives in the South Seas, Burma, New Guinea, the Philippines, Australia, and Indonesia. *Pinctada fucata martensii*, commonly called Akoya, has a thin shell of no commercial importance but is valued for its small (usually less than 9 mm) white pearls, which are abundant on the world market today. These mollusks are found in China and Japan. *Pinctada margaritifera*, the black-lipped oyster, is prized for both its mother-of-pearl shell and its large gray to black pearls. Pearl-bearing *P. margaritifera* are found in Peru, Baja California, Panama, Indonesia, Micronesia, the Red Sea, the Philippines, and Okinawa, as well as French Polynesia.

Oysters, bivalve mollusks like the *Pinctada*, have two symmetrical shells hinged together by a ligament. The life span of *P. margaritifera* ranges up to 30 years; a single oyster can weigh up to 11 lbs. (about 5 kg) and reach a diameter of 12 in. (about 30 cm). A powerful adductor muscle holds the two shells together, leaving an indentation on the inner surface. One of the most distinctive characteristics of the black-lipped shell is the

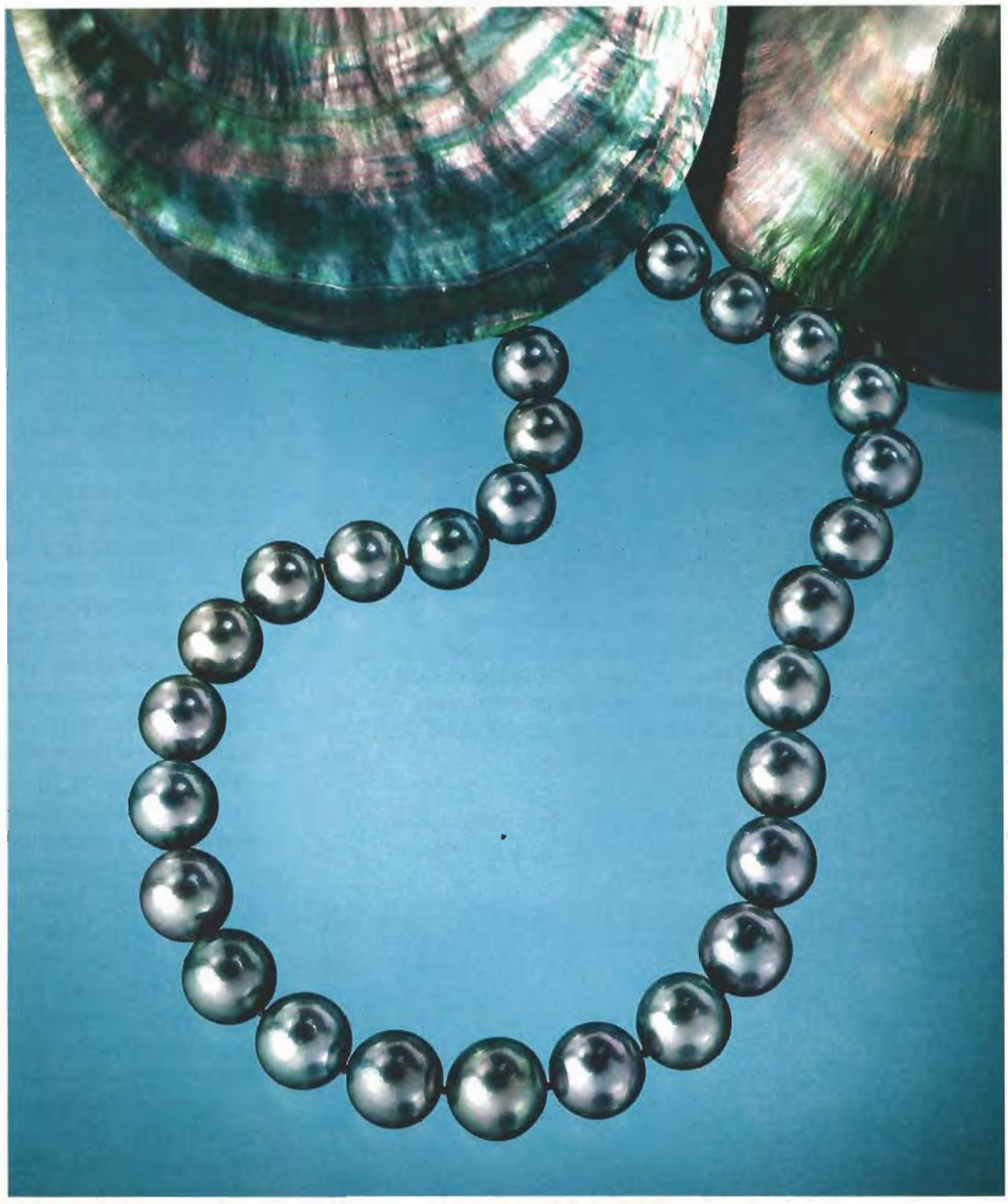

Figure 7. Today, pearl farmers in French Polynesia are producing superb cultured pearls. This natural-color cultured pearl necklace contains 29 fine round pearls that range from 12.5 mm to 15 mm. Two polished P. margaritifera *shells accompany it. Necklace courtesy of Assael International; photo © Harold & Erica Van Pelt.*

greenish black color on its inside edges, which is duplicated in many of the fine pearls from this mollusk. The two most important organs in producing pearls are the mantle and the gonad (figure 8). Not only does the mantle form the shell, but each part of the mantle also secretes different layers of nacre. The gonad is the reproductive gland, a large whitish sack that holds the eggs or sperm. In the culturing process, the bead nucleus and a piece of mantle tissue are inserted into the gonad to produce a cultured pearl.

Nacre, the essential ingredient of all pearls, is composed of approximately 90% aragonite (orthorhombic calcium carbonate crystals) and 5% conchiolin (an organic protein that binds the aragonite crystals together), together with other organic material; the most abundant trace elements in *P. margaritifera* are magnesium, strontium, and sodium (Wada, 1981, p. 154). The nacre is secreted in concentric layers about a micron thick. Cultured pearls have a refractive index of 1.53–1.69 and a specific gravity range of 2.72–2.78. The average hardness is 3.5.

CULTURING

While natural black pearls are still found occasionally, nearly all the black pearls on the market today are cultured. Most natural black pearls have slightly less luster and tend to be larger than their cultured equivalents.

Figure 8. A 14-mm cultured black pearl emerges from the gonad of this P. margaritifera *grown in the Marutea lagoon. Note the mantle surrounding the pearl, and the characteristic black color on the inside edges of the shell. Photo © Fred Ward/Black Star.*

Figure 9. At one of the spat-cultivating areas, a diver checks the growth of the young mollusks. Photo by Cyril Rosenthal.

Culturing is essentially a two-part process: first, the cultivation of the oyster, *P. margaritifera*, and second, the growth of the pearl in this oyster. The technique is essentially the same one Mikimoto used to develop the Japanese pearl-culturing industry (Shirai, 1970). Mikimoto even did some culturing experiments with *P. margaritifera* in 1920, when he established an experimental station at Palau (Cahn, 1949; George, 1979).

The oysters used in the culturing process are still drawn from the limited resources in the water around the islands. Although some are retrieved by independent divers (who continue to be restricted by the Tahiti government to certain zones of the atolls), most are produced by spat cultivation. In a contemporary adaptation of Bouchon Brandely's original program, young oysters are placed in nurseries, suspended from metal nets by stainless steel or nylon wires, until they are old enough—at least two to three years old—to be used for pearl culturing (figure 9). Some farms are also experimenting with growing mollusks in tanks; positive results are anticipated.

Pearl culturing consists of inserting into the gonad of the oyster a bead made of freshwater mussel shell along with a graft of mantle tissue from another live black-lipped oyster. The nucleus is typically made from the mother-of-pearl of a Mississippi River (U.S.) mollusk. Once, only the pigtoe mussel was used; today, three species found in central and southern tributaries of the Mississippi River also provide good nuclei. The mantle-tissue graft is an essential component of the culturing process, both in terms of stimulating the secretion of nacre and in determining the color and other features of the finished pearl. The entire operation of inserting the bead and tissue takes one to two minutes and is usually done by Japanese, Australian, or Polynesian technicians. The technician chooses the appropriate nucleus size for the oyster being used, typically a bead 5–9 mm in diameter, and then makes a small incision in the gonad, into which the nucleus and mantle-tissue graft are placed (figure 10). The experience of the technician is invaluable in ensuring that the oyster used is healthy, that the largest bead possible is selected, and that the various components are not damaged in the course of the operation.

Once the procedure is completed, the oysters are attached to a nylon rope through holes drilled in the shells. In some farms, the oysters are placed individually in net bags, which catch any beads

that are rejected. A diver then attaches the chain of oysters to an underwater platform (figure 11). The operation takes place typically between June and September, the winter months for this region, when the water is cooler and there is less risk of violent storms.

If an oyster rejects the bead, it will generally do so in the first two months following the surgery. Some well-equipped farms have been known to X-ray the oysters to see if the nucleus has been rejected or if it is in place properly, but this technique is used much less frequently today than it was in the past (R. Wan, pers. comm., 1989). Oysters that reject their beads can be re-operated on after a couple of months of rest. On some farms, these oysters are instead used to create mabes or assembled cultured blister pearls.

Approximately two years must pass before the success of this operation is known. At that time, a few mollusks are brought to the surface and checked to see if a pearl has formed and, if so, how thick the nacre is. With three or four layers of nacre deposited a day, a pearl cultured in *P. margaritifera* will develop a nacre thickness of 2 to 2.5 mm in two years, compared to 1 mm developed by an Akoya pearl over the same time span.

During the growth period, the oysters must be watched constantly. They are brought to the surface and the barnacles cleaned off several times a year. Predators, parasites, hurricanes, pollution, and piracy are a constant threat. In both 1983 and 1985, hurricanes did profound damage to oysters, equipment, and buildings in French Polynesia on farms in the Tuamotu Archipelago (Cohen, 1983; C. Rosenthal, pers. comm., 1989).

Currently the lagoons of two archipelagos—the Tuamotu Archipelago and the Gambier Islands—are used primarily for cultivating pearls and the mother-of-pearl shells that are now the by-product of this important industry in French Polynesia. Efforts are being made to find other suitable lagoons.

HARVESTING

If, at two years, all of the indications are good, the oysters are harvested. A number of farms now have two or more harvests a year. At this time, the oysters are brought to the installation or laboratory where the initial insertion took place and are opened by a technician who then examines the interior (figure 12).

If the operation is successful and a pearl is

Figure 10. An essential step in the culturing process is the insertion of the bead nucleus into the gonad. Photo © Fred Ward/Black Star.

Figure 11. Once the oysters have received their implantations, they are attached to a chain and taken to an underwater platform. Photo by Cyril Rosenthal.

Figure 12. A pearl can be seen lying within the gonad of this oyster, which has just been harvested. Photo by Marisa Goebel.

found, it is removed carefully. The harvested pearls are washed, dried, and lightly polished by rubbing in salt in preparation for sorting and grading. On a few of the farms, the oyster may be reoperated on after a period of rest (V. Dockendorf, pers. comm., 1989). On average, 55% of the oysters will accept the operation the first time. A return of 30% commercially acceptable pearls is considered a very good harvest (C. Rosenthal, pers. comm., 1989).

If the oyster has rejected the bead nucleus, the technician will check to see if a "keshi" (mantle tissue–nucleated pearl) has been created from the piece of mantle tissue that was inserted. In any case, if the mollusk that rejected the bead is deemed healthy, another implant may be attempted. Again, some farms will elect to make mabes at this stage rather than risk a second implant because of the high mortality rate for mollusks after the second insertion.

Figure 13. Polynesian cultured black pearls occur in a variety of colors. Photo © Fred Ward/ Black Star.

GRADING

Five factors are commonly used by the trade to grade Polynesian black pearls: color, luster, shape, size, and surface features.

Color and Orient. In the context of black pearls, one of the most important factors, "color," consists of two components: body color (the basic color presented by the pearl) and overtone (the hues seen superimposed on top of the body color). Body color can be subdivided into six groups: silver, silver blue, gold, brown-black, green-black, and black (figure 13). Overtone is typically a mixture of colors that is best observed as the pearl is rotated. Created by light passing through the layers of

nacre, the overtone may be any combination of pink, lavender, blue, "peacock" blue, gold, green, or a reddish purple called *aubergine* (after the French word for eggplant). The color most characteristic of fine Polynesian black pearls is a greenish black (also referred to as "peacock") that sometimes has an *aubergine* overtone. Because other South Sea pearl-bearing oysters may also produce silver, silver-blue, and golden pearls, these latter colors are more plentiful in the market and therefore may command a lower price than the various combinations of black-colored pearls.

Also caused by the passage of white light through the many layers of nacre is the rainbow-like play of color that seems to *hover* about the surface of some pearls. Called orient, it is not always prominent in black pearls, although it is readily visible in the finer grades.

Luster. Luster is the quality of light reflections from the surface of the pearl. As taught in the current GIA pearl course, luster is considered high when reflections are bright and sharp, and low when they are weak and fuzzy. In black pearls, much of the light is reflected from the surface, thus producing excellent luster in most. In the trade, this brilliance is called *éclat*, from the French word for shiny.

Shape. Shape can be divided into three main categories: round or spherical, symmetrical, and baroque. The most highly prized is the perfectly round pearl that will roll in every direction when placed on a flat surface (Lintilhac, p. 70). Symmetrical pearls are pear-, egg-, or button-shaped; some are evenly elongated. The baroque-pearl category contains all the irregular shapes and is the most interesting to many pearl enthusiasts.

Currently, there is an abundance of baroque pearls from the South Seas (see figure 14). American pearl grower John Latendresse feels that the disproportionate number of baroques is due to the poor quality of bead that has been supplied to the Polynesian pearl farmers. His examination of black-pearl nuclei reveals that many are infested with parasites whose presence alters to bits of organic material on the surface of the beads (figure 15), referred to in the trade as *wax*. "Nacre won't adhere to the nucleus in places where there is wax," Latendresse explains. "As a result, you get baroque pearls" (Federman, 1985). The desire for improved quality and a steady supply has led black-pearl producers to find beads outside the traditional sources of supply in Japan (C. Rosenthal, pers. comm., 1989).

Figure 14. Cultured black pearls are also found in a broad assortment of shapes. Pearls courtesy of Ocean Gems; photo by Robert Weldon.

Size. Size is the most readily determined feature of a pearl. Pearl sieves, much like diamond sieves, with holes ranging from 9 mm to 13 mm, are used initially to separate pearls into batches. Polynesian black cultured pearls generally average between 9 mm and 12 mm. Since the diameter of the typical

Figure 15. These three beads were created from U.S. freshwater mollusks for use as nuclei in the culturing process. The imperfect surfaces may influence the final shape of the pearl. The furrow may produce rings, the fish-eye may produce a fish-eye effect, and the organic residue may result in a baroque-shape pearl. Beads courtesy of John Latendresse; photo by Robert Weldon.

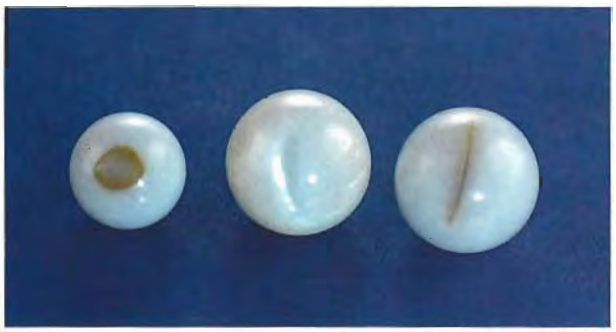

Figure 16. At 20.8 mm, the center pearl is the largest known round cultured black pearl. For comparison, the pearl on the left is 12 mm and the one on the right is 14 mm. Pearls courtesy of Robert Wan; photo by Marisa Goebel.

nucleus is 5–9 mm, the pearl's final size depends on the amount of nacre secreted by the oyster. Prior to sale, the pearls are then measured more precisely using a millimeter gauge (Lintilhac, p. 70).

Figure 17. This colorful strand contains 41 ringed Polynesian cultured pearls of greenish blue body color with aubergine *overtones. The two round pearls in the center measure 12.4 mm and 11.9 mm. Pearls courtesy of Ocean Gems; photo © Tino Hammid.*

The largest round cultured black pearl on record is 20.8 mm (figure 16).

Surface. As is the case with all pearls, surface imperfections such as pits, bumps, ridges, cracks, and spots lower the grade on a Polynesian black pearl. Rings, actually parallel furrows that encircle the pearl, represent an unusual though often attractive surface feature (figure 17). Most rings, according to Latendresse (pers. comm., 1989), result from the pearl being nucleated near the hinge of the two shells. In a cultured black pearl, a line on the surface of the nucleus bead may produce rings (again, see figure 15).

Pearl Grading System. Systems used in the trade to grade black pearls typically consist of a series of letters that indicate shape and surface features. Lintilhac (1987) describes one such system:

Shape

R = Round
D = Drop or pear
Brq = Baroque
But = Button
Circ = Circled (Ringed)

Surface and Luster (figure 18)

A = Pearls with a flawless skin and high brilliance with one pit or pinprick
B = Pearls that are less brilliant and have two or three surface blemishes
C = Pearls that are somewhat dull or have four or more surface blemishes
D = Pearls that are definitely dull or marred by deeper flaws

A similar system used by Assael International is outlined by Federman (1987).

CAUSE OF COLOR

As discussed above, color in pearls is a mixture of body color and overtones. The body color is determined by a combination of factors, including the biology of the mollusk (specifically the mantle tissue), the composition of the mother-of-pearl shell, and trace elements present in the water environment. Japanese researchers have investigated the body color in pearls extensively for over 50 years (Fox, 1979). They cite the presence of porphyrins (a group of water-soluble, nitrogenous

16-member ring organic compounds) in the shell of the mollusk as a primary cause of color in colored oyster pearls. In mollusks, the porphyrins combine with metals such as lead and zinc to form metalloporphyrins. These same porphyrins produce a red fluorescence that is useful in identifying natural color in black cultured pearls. Miyoshi et al. (1987) illustrate the diagnostic spectra produced by porphyrins present in the nacre.

Also contributing to the color of most black pearls is the presence of brownish organic substances that exist between the translucent porphyrin-containing nacre and the bead nucleus (Miyoshi et al., 1987; P. Galenon, pers. comm., 1989). This substance is thought to be conchiolin, but research to date has not been conclusive.

Fritsch and Rossman (1988) describe the cause of the "high order" interference colors—overtone and orient—seen in black pearls as "light passing through and reflected back by alternating layers of aragonite [in the nacre] and conchiolin." The finer the layers of nacre are, the more orient a pearl has (R. Wan, pers. comm., 1989).

Figure 18. This selection of six pearls shows the range of surface and luster quality seen in round cultured Polynesian black pearls. Beginning in the upper left-hand corner and moving from left to right and top to bottom, the grades would range from A to D on the system described by Lintillac (1987). Pearls courtesy of South Sea Pearls, Inc.; photo by Robert Weldon.

COLOR TREATMENTS

In a 1971 article, C. Denis George lamented his unsuccessful search for even one natural-color black pearl in visits to Mexico City, New York, and Paris. He was routinely offered treated black pearls that were represented to be natural color, and he railed against the "unscrupulous suppliers" who were perpetrating this "miserable and fraudulent" situation.

In fact, from 1900 to 1978 (when cultured black pearls first began to appear in quantity), there were far more treated than natural-color black pearls on the market. One result of the overharvesting of *P. margaritifera* in the 19th century was that by 1900 there was a shortage of natural-color black pearls. To fill this void, people began to use silver nitrate solutions to dye the smaller Akoya pearls common to Japan (figure 19). Even today, silver nitrate and other silver salts are probably the most common form of treatment to turn white and off-color Akoya pearls black (Komatsu and Akamatsu, 1978; Taburiaux, 1985).

Although pearl treaters are among the most secretive in the gem industry, we do know that the basic procedure involves soaking the pearls in a weak solution of silver nitrate and dilute ammonia and then exposing them to light or hydrogen sulfide gas. This produces a change of color in the conchiolin that makes the pearl appear black in reflected light. The resulting color is stable to light and heat (Nassau, 1984). Because the hues of brown-black, green-black, and black are similar to natural colors, it is virtually impossible to distinguish them by visual observation alone (Taburiaux, 1985).

Another, reportedly organic, dyeing technique was commonly practiced from approximately 1915 through the 1920s. Called the French Method, it was used by a few treaters in Paris on off-color natural pearls. Although little is recorded about the actual procedure, we do know that it can be detected with a microscope when dye concentrations are present. Pearls were shipped from Japan to Paris for treatment and then back to Japan for sale (R. Crowningshield, pers. comm., 1989). In 1920, Rosenthal cautioned jewelers to be aware of pearls treated by this process.

Although historically treatment has involved Akoya cultured pearls, it was inevitable that attempts would be made to enhance light-color *P.*

Figure 19. The black pearls in this fine necklace, signed by David Webb, are typical of the treated pearls commonly seen in the trade. Interestingly, the baroque pearls in the earrings and ring have also been treated. Photo by Tino Hammid; courtesy of Christie's, New York.

maxima and *P. margaritifera* cultured pearls as well. In 1987, Fryer et al. reported seeing a strand of 11- to 14-mm black cultured pearls that showed evidence of silver nitrate dye. More recently, in September 1989, the GIA Gem Trade Laboratory in New York examined two 12-mm black cultured pearls that showed evidence that they might have been dyed. The laboratory staff subsequently received confirmation from the trade that some South Sea pearls were being treated to darken the color (D. Hargett, pers. comm., 1989).

One of the more recent treatments used on *P. fucata martensii* (Akoyas) in an effort to darken mediocre-color cultured pearls is irradiation, specifically with a cobalt gamma source. According to Matsuda and Miyoshi (1988), gamma-ray irradiation can change off-color cultured Akoya pearls to an attractive bluish gray. These authors report that irradiation of Akoya pearls began in the 1950s with the "Atoms-for-Peace Program" and resulted in irradiated cultured pearls first appearing on the market in the 1960s.

Ken Tang Chow's patent on irradiating pearls, filed in 1960 and granted in 1963, sheds some light on the procedure used. The technique he patented involves exposure of the pearl to cobalt-60 with an intensity of 1,000 curies of gamma rays at a distance of 1 cm from the source for about 20 minutes at room temperature. Chow found that longer periods of irradiation did not produce any appreciable change in color. He also reported that the irradiated pearls were stable to light and heat.

Scientists have often noted that the color of freshwater shells and pearls can be changed by irradiation more easily than that of saltwater oysters. They attribute this to a change of manganese compounds ($MnCO_3 \rightarrow MnO$) which are more abundant in freshwater mollusks (Wada, 1981).

Irradiating Akoyas produces a darkening of color because the freshwater bead nucleus darkens and influences the body color. In *P. margaritifera*, the much thicker nacre would not allow the color shift of the nucleus to be visible (R. Crowningshield and D. Hargett, pers. comm., 1989). Dr. George Rossman, of the California Institute of Technology, recently experimented with the irradiation of three Polynesian black pearls following the procedure outlined in Chow's patent, but left them in the reactor for slightly longer than 24 hours. No appreciable change was observed in these pearls compared to their control samples, although a color shift was observed in the freshwater pearls irradiated at the same time (pers. comm., 1989).

Modern Pearl Identification. In 1920, Rosenthal recommended a relatively simple method for identifying dyed pearls: "When a [natural] black pearl is scraped, the powder is white, but in the case of an artificially colored pearl, the powder is black." While this procedure is accurate for some dyed pearls, it is also destructive. Similarly, successful experiments in the 1970s with a Vickers hardness machine (Komatsu and Akamatsu, 1978) were never adapted for routine testing because of their destructive nature. Today, because of the sophisticated equipment and experience needed to identify treatment, definitive pearl testing requires the resources of a well-equipped gemological or pearl-testing laboratory. Currently, gemologists at most Western gemological laboratories commonly use long-wave U.V. fluorescence, X-ray fluorescence, X-radiographs, visual observation, and microscopic examination to separate treated from natural-color pearls. These tests are often used in conjunction with other procedures to determine first whether the pearl is natural or cultured (figure 20). Our primary concern in the following discussion, however, is their application in separating natural-color from treated black pearls.

U.V. fluorescence can be diagnostic in this separation. For example, the fluorescence of natural-color black pearls commonly varies from bright red (pearls from Baja California) to dull reddish brown (Tahiti pearls) when exposed to long-wave U.V. radiation, while dyed pearls are usually inert or fluoresce a dull green (Benson, 1960; Crowningshield, 1970; Fryer et al., 1987; R. Crowningshield, pers. comm., 1989).

X-ray fluorescence spectral analysis involves exposing the sample to X-rays and measuring the wavelengths emitted with a spectrometer (Komatsu and Akamatsu, 1978). Silver used in the various silver salt treatments will be detected. This test must be performed carefully, by an experienced technician, since the sample pearls have been known to turn brown-black if exposed to the x-rays in a wave-length dispersive x-ray fluorescence unit. Therefore, most gem-testing laboratories use an energy-disersive XRF unit (as described in Liddicoat, 1987).

X-radiography, a technique developed in the 1920s to separate natural from cultured pearls, has been discussed in detail in the standard gemology

Figure 20. Some of the methods used by pearl testers to determine type and composition of the pearl are also used to separate natural- from treated-color pearls. Here, from top to bottom: X-ray fluorescence (to separate saltwater from freshwater pearls, as well as silver-treated from natural color), candling (to see thickness of nacre), Lauégram (to identify presence of nucleus in a cultured pearl), X-radiograph (to show presence of nucleus and evidence of silver treatment in some pearls), and a microsection (to examine the structural profile of a cultured pearl). All lead to a cultured South Sea pearl at the front. Photo © Michael Freeman.

texts (see, e.g., Webster, 1983; Liddicoat, 1987). The method works on the principle that different materials such as nacre, conchiolin, and silver vary in their degree of transparency to X-radiation (Brown, 1979). Cultured pearls usually show high relief between the nucleus, with its dark ring of conchiolin, and the nacre. In a silver-treated pearl, the silver tends to concentrate in the area of the conchiolin. Because silver is opaque to X-rays, this area commonly appears white on the X-radiograph. The white ring or area around the nucleus of a treated black pearl is sometimes called a reversal ring (Fryer et al., 1986, pp. 173 and 174).

Also used in pearl identification is visual observation supplemented by microscopic observation. To the unaided eye, dyed materials will sometimes show an unusually even distribution of color throughout the pearl and in some cases throughout an entire strand of pearls. With magnification, dye can be seen concentrated around the drill hole and even extending out into the pearl in a vein-like fashion (as illustrated in Fryer et al., 1984, p. 230).

Figure 21. Mantle tissue–nucleated "keshi" pearls are an interesting by-product of the culturing operation. This necklace shows the variety of shapes and colors in which black "keshis" can occur. The drop is the only pearl on this necklace that is bead nucleated and, therefore, not considered a "keshi." Photo by J. C. Bosmel; courtesy of Michel Fouchard.

In some instances, dye can be detected by using a cotton swab dipped in a *weak* (e.g., 2%) solution of nitric acid on an inconspicuous area of the pearl. This is, however, another destructive test (Fryer et al., 1984, p. 229).

Visual examination is also useful in identifying irradiation in the smaller Akoya pearls. Irradiation will darken freshwater pearls and shells, but not saltwater pearls. Therefore, since cultured pearls use freshwater-shell nuclei almost exclusively, the dark bead nucleus of an irradiated pearl is easily seen through the drill hole of the pearl. The color of the nacre is unchanged (Fryer et al., 1986, p. 173, and 1988, p. 244, figure 11). One must be careful, however, to make several tests on each pearl, since while irradiation changes the *color* of the bead, it does not change the reaction of the pearl to long-wave U.V. radiation (Matsuda and Miyoshi, 1988).

Even undrilled pearls can provide clues to the experienced pearl scientist by virtue of their visual appearance. The intense color and metallic luster have been cited as indications of treatment (see, e.g., Fryer et al., 1985).

It should be noted that size can be another important indicator of treatment. Small, rounded pearls 8 mm or less with very black, gray, green, or blue-green hues are generally treated pearls – that is, smaller Akoya pearls that have been dyed or irradiated – since the pearls grown in *P. margaritifera* are seldom smaller than 9 mm. Again, though, it is important to test pearls carefully, because some localities such as Baja California produce a lustrous black pearl of natural color in small sizes. Black "keshi" pearls can also occur in small sizes.

In recent years, Japanese scientists have led the way in pearl research. In 1978, Komatsu and Akamatsu reported the success of their experiments with infrared film to separate natural-color from dyed black pearls. Akamatsu (pers. comm., 1989) reports that the Mikimoto Research Laboratory now finds spectrometry to be an even more efficient method to make the separation between natural-color and silver-treated blacks. Pearls from *P. margaritifera* have a specific absorption at 700 nm that is caused by the black pigment and can be easily measured by a spectrophotometer.

The team of T. Miyoshi, Y. Matsuda, and H. Komatsu has focused on methods for determining

the parentage of cultured pearls using laser-induced fluorescence measured by a spectrofluorophotometer. In their 1987 paper, they reported their observation of two fluorescence peaks—at 450 nm and 620 nm—in *P. margaritifera*. The 620 peak was not observed in *P. maxima* or *P. fucata martensi*, because the shells of these oysters do not contain porphyrins. This makes it possible to separate *P. margaritifera* pearls from those produced by these two subgroups. Research such as this will provide the basis for more definitive pearl testing in the future.

DISTRIBUTION

Currently, culturing in Polynesia is carried out on privately owned pearl farms like the Rosenthals' or on pearl cooperatives. While there are many farms that produce less than 200 pearls annually, 24 farms have an annual production of over 5,000 cultured pearls. The farms tend to be more successful than the cooperatives because of the financial resources with which they are backed. The cooperatives were established in 1971 by the Department of Fisheries with loans from the Société de Crédit d'Océanie (SOCREDO) so that each atoll would have its own pearl-culturing industry. In 1988, there were approximately 40 cooperatives with 1,145 members. These cooperatives were reorganized in 1989 into 157 smaller family groups in an effort to improve production (M. Coeroli, pers. comm., 1989).

The cultured pearls are sold either through private sales or auctions. Most of the material produced on the farms is sold privately to pearl wholesalers and major jewelry companies. However, approximately 40% of the total production each year is sold at auction.

Auctions are usually held once a year, in October. They are coordinated by EVAAM and GIE Poe Rava Nui, the two government agencies that oversee the pearl-culturing cooperatives (M. Coeroli, pers. comm., 1989). These pearl auctions give the cooperatives the opportunity to help repay their government loans. They have also been important in making the international public and jewelry community more aware of Polynesian cultured black pearls.

The auctions are held in private, by invitation only, in Papeete, Tahiti. At the 1988 auction, 107 participants (co-ops and independent farms) presented their goods to an invited audience. The pearls were divided into lots of different pearl sizes and quantities. After examining the various pearls in a lot, buyers make specific offers for the particular lots in which they are interested. At the 1988 sale, approximately 70 lots were offered, with total sales exceeding $2 million (almost 10 times the total amount exported the first year the auction was held, 1981). In addition, 515 kg of "keshi" pearls, a by-product of culturing (figure 21), were sold (Cazassus, 1989).

TABLE 1. Exportation of black cultured pearls from French Polynesia 1972–1988[a].

Year	Weight (in grams)	Value (in US $)
1972	1,563	3,609
1973	800	23,528
1974	3,891	166,337
1975	15,631	100,918
1976	6,111	163,206
1977	6,128	213,184
1978	49,982	1,693,496
1979	86,092	2,162,821
1980	28,779	1,038,483
1981	86,527	3,873,993
1982	32,310	807,534
1983	139,888	4,689,822
1984	112,183	2,530,535
1985	206,463	10,201,822
1986	104,114	8,606,441
1987	407,620	22,937,512
1988	446,827	22,810,618

[a]*Translated from Ministère de la Mer (1989), with dollar amounts converted from Pacific French francs.*

In 1984, the principal buyers at auction were Japanese, 30%; U.S., 30%; and Swiss, 30%; with France and other countries, 10%. By 1988, the market was such that 84% of the production sold at auction went to Japanese buyers, with the remainder sold primarily to Tahitian jewelers (Cazassus, 1989).

It is important to remember that natural-color cultured black pearls have been commercially available for less than 20 years. Production has risen rapidly during this period (table 1), yet it appears that demand still exceeds supply. In Japan, in particular, demand increased sharply in the second half of 1988 and continues to rise (Chun, 1989).

MARKETING

The great popularity of black pearls today can be directly attributed to the marketing efforts of two large companies, Assael International and Golay Buchel Inc.

Figure 22. In recent years, black cultured pearls have appeared in the salons of some of the finest jewelers in the world. This necklace of white and black cultured pearls (9–13 mm) with emerald clasp and the accompanying earrings (11 and 16 mm) were created in 1985 by Harry Winston, Inc. Courtesy of Harry Winston, Inc.; photo © Harold & Erica Van Pelt.

Salvador Assael has been credited with having "almost single-handedly popularized the natural color Tahitian black pearl" (Federman, 1987). In the 1960s, he worked with Jean-Claude Brouillet, owner of the S. Marutea Atoll, to develop a viable black-pearl culturing operation. Eventually, they produced as many as 22,000 cultured pearls per harvest. Backed by this production, in the early 1970s Assael began to promote cultured black pearls directly to the jewelry industry, bypassing the traditional Japanese distribution system. Not only did he and Brouillet promote their pearls to tourists throughout French Polynesia, but they also wrote articles, placed advertisements in magazines around the world, and convinced major companies such as Harry Winston and Van Cleef

Figure 23. This 12–15 mm Polynesian black and gray cultured pearl necklace with emerald and diamond clasp sold for $649,000 in October 1988, at the time the highest price ever paid at auction for a Polynesian cultured black pearl necklace. Courtesy of Sotheby's & Co.

and Arpels to include black cultured pearls in their inventories of fine jewels (figure 22). Today, Assael continues to be a major force in the marketing of black cultured pearls, along with other distributors such as Golay Buchel, who plays the prominent role in the important Japanese market (A. Goetz, pers. comm., 1989).

Another key factor in raising the public's awareness of black pearls has been the jewelry auctions held by Christie's and Sotheby's. In 1969, a three-row strand of 141 black pearls sold for $168,000. Ever since, single pearls or pearl necklaces have been a routine item in the "magnificent jewelry" auctions. In October 1988, a double strand of black and gray cultured pearls sold at Sotheby's New York for $649,000 (figure 23). The three-strand necklace in figure 1 sold for $880,000 at Christie's October 24, 1989, auction in New York.

Pearls are marketed in Tahiti through different jewelry stores, some owned by the pearl producers themselves. For example, the Tahiti Pearl Center and Museum in Papeete is owned by Robert Wan, currently the largest producer of black cultured pearls. The museum not only sells pearl jewelry, but also educates through videos, photos, and displays. Most hotels display pearls and pearl jewelry, thus exposing travelers to the gem.

CARE OF PEARLS

Pearls are products of living organisms and thus react strongly to acids and chemicals, including those in perfumes, soaps, and hairsprays. Because soaps and dishwashing detergents that contain bleaching agents may discolor pearls, it is particularly important that rings containing black pearls be removed before immersion of the hands in these solutions. To avoid dehydration and cracking due to dryness, some members of the trade recommend rubbing pearls with a dab of a natural oil placed on a soft cloth; this will also enhance the pearl's

beauty and luster. Historically, sandalwood oil has been preferred for this purpose (C. Rosenthal, pers. comm., 1989).

Because pearls are not very hard—only 3.5 on the Mohs scale—they can be scratched fairly easily. In manufacturing, it is recommended that the jeweler not place the pearls in a design where they will rub against other gems or metal or will be in a position of tension with a metal, such as in a prong setting. In storing pearls, it is best to keep them separate from other jewelry and wipe them with a soft cloth after wear.

CONCLUSION

Polynesian cultured black pearls have been called the "rainbow gem of the 20th century" (Salomon and Roudnitska, 1986). Indeed, the development of the black-pearl culturing industry in the 1960s has now made the worldwide distribution of natural-color cultured black pearls feasible. Without this technology, black pearls would have remained the oddity they were for the first 70 years of this century. Technology has also given the major gemological and pearl-research laboratories the tools by which to separate natural-color black pearls from most of their treated counterparts.

Today, cultured black pearls are seen in fine jewelry stores everywhere. Given the level of government support and the broad scope of the pearl-culturing industry in French Polynesia, it appears that there will continue to be a steady supply of these attractive gems in the future.

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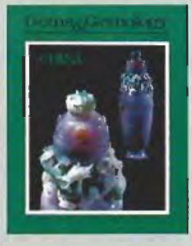

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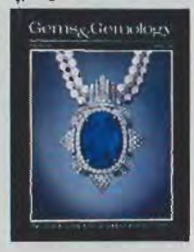

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THE CAPOEIRANA EMERALD DEPOSIT NEAR NOVA ERA, MINAS GERAIS, BRAZIL

By David Stanley Epstein

In 1988, a significant find of emeralds was made at Capoeirana, near Nova Era, in the state of Minas Gerais, Brazil. Hundreds of kilograms of potentially gem-quality material have been removed since the first pieces were discovered in July 1988. The nature of the biotite schist with which the emerald is associated and the gemological properties of the Capoeirana emeralds indicate that this occurrence is related to the Itabira (Belmont mine) emerald site, only 10 km away.

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Some of the earliest expeditions by Portuguese explorers into the interior of 16th-century Brazil were in search of green "precious stones" believed to be emeralds (Proctor, 1984). Yet Brazil did not actually become a major producer of emeralds until the 1960s (Cassedanne, 1985; Hänni et al., 1987). One important deposit, the Belmont mine, was discovered in 1978 near the town of Itabira in Minas Gerais. In late 1988, a new source of emeralds was found in the mineral-rich Nova Era area of Minas Gerais, only about 10 km southeast of the Belmont mine and 20 km southwest of the recently discovered Hematita alexandrite deposit (Proctor, 1988). The emeralds produced at this site, known as Capoeirana, range from medium to large and show good crystallization and color (figure 1). This article describes the discovery of the site, the geology and mining activities, production, nature of the emeralds, and their gemological properties.

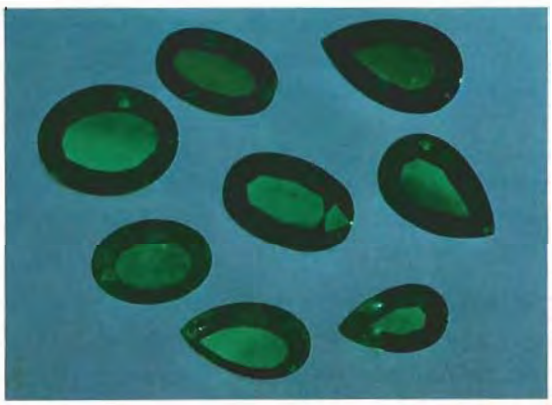
LOCATION AND ACCESS

The current diggings lie about 43°1′ west, 19°45′ south, at an altitude of 700 m above sea level. To reach the mining area (figure 2), take highway BR262 east from Belo Horizonte, the capital of the state of Minas Gerais, to BR381 and turn north to the small town of Nova Era. About 5 km north of Nova Era, turn west on a dirt road for approximately 10 km and, finally, veer south on another dirt road and travel about 1 km farther to the site.

As one leaves the mountains, valleys, and plateaus around Belo Horizonte, the countryside develops into steep hills and granitic batholiths. Although this is a tropical region, the altitude requires that a warm jacket be worn on winter nights. The temperature ranges from 14°C (57°F) to 36°C (96°F), and averages 23°C (73°F). High rainy season is from October through January.

The nearest town, Nova Era, has about 10,000 inhabitants. There are several cities within a few hours' driving

Figure 1. This 2.16-gram emerald crystal from the new Capoeirana locality shows the good crystallization that may be found there. The faceted stones, also from Capoeirana, weigh approximately 1.5–9 ct. Courtesy of Kalil Elawar; © Harold & Erica Van Pelt.



time, including Belo Horizonte, which has a population of over one million. Cattle, iron mining, and steel production are the major industries in the region.

HISTORY

In ancient times, emeralds came from Egypt and Austria. Currently, Colombia, Africa, Brazil, India, and Pakistan are commercial producers (Webster, 1983). Within Brazil, a number of significant occurrences are active in the states of Bahia (Carnaiba and Socotó), Goiás (Santa Terezinha), and Minas Gerais (Itabira).

Emeralds were first found at the Belmont mine, only 10 km northwest of Capoeirana, in 1978; within a few years, the mine had become a substantial producer (Hänni et al., 1987). In 1980, Adair Martins Guerra, a topographer for Companhia Vale do Rio Doce, began searching elsewhere in the Nova Era–Itabira region for emeralds, concentrating on schist-pegmatite formations similar to those at the Belmont mine. Although he had very little success for the first several years, Martins Guerra continued to support *garimpeiros* (independent miners) and offered them a percentage of future production. On July 20, 1988, a *garimpeiro* named Mario brought him some impressive pieces of greenish beryl and subsequently took him to the site now known as Capoeirana, in the municipality of Nova Era, on the border between the Mamão and Paolim ranches. Martins Guerra and his miners began to dig in earnest. In October 1988, the first promising signs appeared; word spread, and within two weeks nearly 100 miners were working at various pits (H. C. Reis, pers. comm., 1988). A few weeks later, at the height of the rainy season, a number of 20-gram pieces practically fell out of the soft, wet decomposed schist and clay; the rush was on.

GEOLOGIC SETTING

Júlio César Mendes, of the University of Ouro Preto Geology Department, has studied this area extensively (e.g., Mendes and Schwarz, 1985; Schwarz and Mendes, 1985; de Souza et al., 1987). He reports that if one projects a line through the points at Capoeirana where emeralds have been found and continues northwest approximately 10 km, one arrives at the Belmont mine. The geology of the area surrounding both mining sites consists of rocks of the Archean-age basement complex that underlies the topography of much of this part of Brazil. Included here are metamorphic schists and gneisses, some granitic rocks, and various metamorphosed sediments. Small pegmatite dikes cut through or lie along contacts in these basement complex rocks, but the dikes themselves do not seem to contain any emerald mineralization. A

geologic map of this area is provided in Hänni et al. (1987).

The emeralds of the Capoeirana mine generally occur as well-formed euhedral crystals or crystal fragments—some slightly stream tumbled—in association with a biotite-phlogopite mica schist sequence. This is a common type of emerald occurrence in many other parts of the world (Sinkankas, 1981). The emeralds apparently formed along with their associated schist minerals during a hydrothermal episode following the metamorphism of the original rocks.

The schist unit immediately under the clay overburden is largely decomposed. At greater depths, the schist becomes darker and firmer, and emeralds seem to be more prevalent (J. C. Mendes, pers. comm., 1989).

MINING AND PRODUCTION

In December 1988, at the height of mining activity, approximately 500–1000 men were directly involved in digging. By July, the number had diminished by almost half. Precise figures are impossible to obtain because numerous inspectors and guards, often indistinguishable from the miners, are invariably present.

The workings extend across the valley floor, along both sides of a small stream, and up the hillside (figure 3) in the form of open pits, wells, and tunnels (figures 4–6). In July 1989, the author observed open pits as deep as 7 m and shafts as deep as 35 m. Picks, shovels, and dynamite are the common means used to remove the red clay overburden and the biotite schist host rock. Water pumps and generators help combat the flooding that usually occurs in the deeper pits and shafts. Although for the most part the gravels are washed by hand, rotary drums have been installed at some operations. More sophisticated techniques, such as pneumatic drills for tunneling and layers of vibrating sieves to wash the gravels, have been introduced in recent months, as experienced miners arrived from the emerald deposits of both Bahia and Santa Terezinha de Goiás.

Exact production figures are impossible to obtain for security, tax, and other reasons, but the author estimates that in December 1988 more than a kilogram a week was being extracted. Although the quality of the material seen by the author could not be determined at the time, many of the pieces were several grams in size (figure 7), and some were as large as 30 grams. Production has

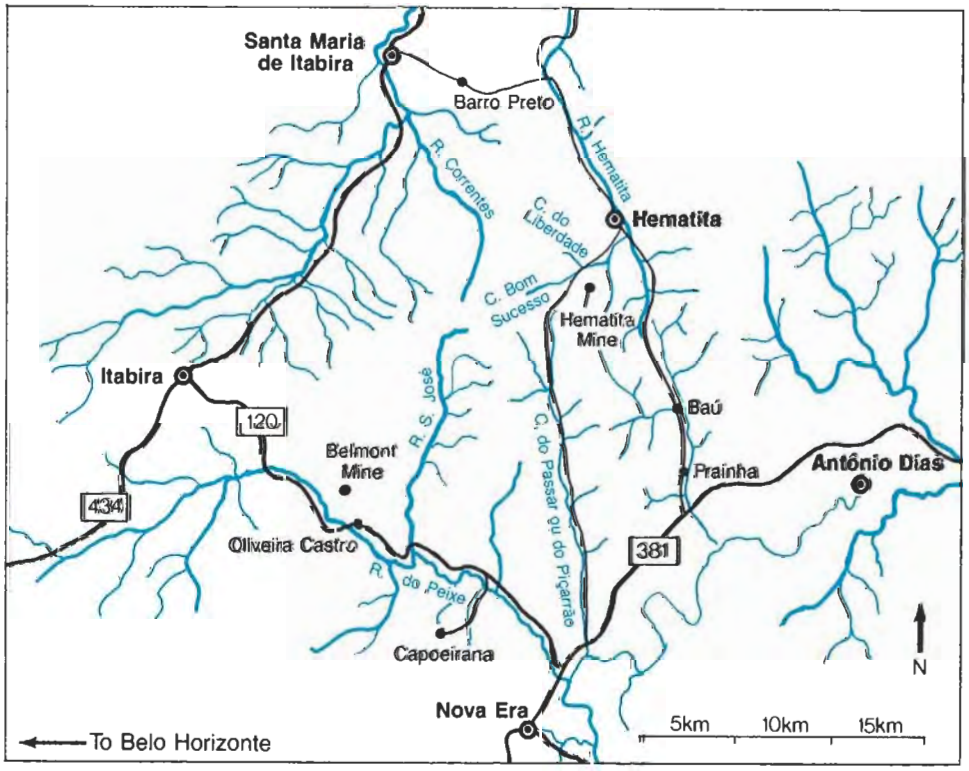


Figure 2. The new Capoeirana emerald locality lies only a few kilometers away from the established Belmont emerald mine and the recent alexandrite discovery at Hematita. Artwork by Jan Newell.

Figure 3. Workings at the Capoeirana emerald deposit extend across the valley floor and up the hillside. Photo © Bryan Swoboda.

been sporadic since then, but in July 1989 it appeared to have picked up again, with as much as 7 kg mined in one week despite the smaller number of miners.

The thickness and recurrence of the biotite schist suggests that potential reserves may be large. As of July of this year, the miners had not yet broken through the schist layer. Moreover, it is possible that emerald mineralization is more or less continuous between Capoeirana and Belmont,

Figure 4. Many of the Capoeirana workings are large open pits, dug through the overlying clay and into the schist where the emeralds are found. Photo courtesy of Gerhard Becker.

Figure 5. Extensive tunnels have also been dug into the hillside at Capoeirana. Photo © Bryan Swoboda.

Figure 7. Emeralds several grams in weight have been taken from the sieves at Capoeirana. Photo courtesy of Gerhard Becker.

and local geologists believe that the potential exists for other emerald finds in the area between the two sites (J. C. Mendes, pers. comm., 1989).

TYPE AND DESCRIPTION OF MATERIAL PRODUCED

While the Capoeirana emeralds vary considerably in tone (figure 8), the majority are light to medium green and of low color saturation. Deeper tones rarely occur in stones under 3 ct. Frequently, a

Figure 6. Shafts as deep as 35 m penetrate the schist rock at Capoeirana. Crude buckets are used to remove the soil overburden and the potentially gem-bearing rock. Photo © Bryan Swoboda.

strong secondary modifying blue hue is present. Although the gem-quality beryl found thus far is almost entirely emerald, some of the lightest of the green and, especially, bluish green specimens may be better described as green beryl.

Well-formed hexagonal prisms as large as 280 grams have been found. The finest faceted emerald the author has seen to date is a transparent 9.92-ct, very slightly included gem of medium-dark tone. Also notable were some slightly included and slightly milky medium-dark cabochons in the 10- to 15-ct range.

Although Brazil is known to produce emeralds of fine quality, traditionally they have been limited to small sizes. This new site provides larger gems of good quality. However, the smaller cut stones (under one-half carat) from Capoeirana are generally considerably lighter than those from Santa Terezinha and Socotó, which will limit the commercial competitiveness of the Capoeirana material in this size range.

Figure 8. The Capoeirana emeralds vary considerably in tone, with smaller stones tending to be a lighter, lower-saturation green. Many stones show a strong secondary modifying blue hue. These stones, 3.23–10.37 ct, are courtesy of Edward Swoboda; photo by Shane McClure.

GEMOLOGICAL PROPERTIES

John I. Koivula of GIA–Santa Monica examined six oval modified brilliant-cut, two pear-shaped modified brilliant-cut, and two emerald-cut emeralds from Capoeirana (figure 9). The stones ranged in weight from 0.66 ct to 4.20 ct and in size from 6.59 × 4.76 × 3.61 mm (oval) to 9.79 × 8.76 × 6.79 mm (emerald cut). All were relatively light in color. Mr. Koivula provided the following discussion of gemological properties determined and the summary provided in table 1.

Refractive Index. Refractive indices, obtained with a Duplex II refractometer and sodium-equivalent light source, ranged from $\epsilon = 1.576–1.578$ and $\omega = 1.582–1.584$, with a corresponding birefringence of 0.006. These values fall within the range tabulated by Hänni et al. (1987) for emeralds from this region, although they are somewhat lower than those reported by Schwarz and Henn (1988) for Capoeirana material.

Specific Gravity. All 10 samples sank at about the same slow rate in a mixture of methylene iodide and benzyl benzoate calibrated at 2.67, indicating a specific gravity of about 2.71. Three hydrostatic measurements were then obtained at room temperature for each of the three largest stones (2.64, 3.77, and 4.20 ct). Average values obtained were 2.71, 2.73, and 2.73, respectively. These fall within the range listed for emeralds from the Itabira area by Hänni et al. (1987).

Ultraviolet Fluorescence. The 10 emeralds tested (again, all relatively light in color) were inert to long- and short-wave ultraviolet radiation, and showed no phosphorescence. Some of the stones contained oiled fractures that showed a moderate yellow-white fluorescence to long-wave U.V. radiation and a weaker reaction to short-wave U.V.

Optical Spectroscopy. The absorption characteristics, as observed with a Beck prism spectroscope, were relatively weak due to the light color of the specimens. When oriented for their darkest color, rather than for crystallographic axes, all 10 stones revealed typical emerald absorption features, including lines of weak to moderate strength in the red at about 682, 661, 641, and 639 nm. Visible only in the largest (and therefore darkest) stones was a very weak line at 484 nm. All 10 stones also showed general absorption from approximately 430 nm down. This characteristic emerald spectrum was confirmed by analysis with a Pye-

Figure 9. The 10 faceted Nova Era emeralds studied for the gemological report range from 0.66 to 4.20 ct. Stones courtesy of Edward Swoboda; photo by Robert Weldon.

Unicam 8800 UV-Vis spectrophotometer (Mike Moon, analyst).

Pleochroism. When viewed perpendicular to the optic axis through a calcite dichroscope, all 10 emeralds revealed very weak dichroism. The two colors observed were very slightly yellowish green and bluish green. Parallel to the optic axis, no pleochroism was possible, but a very slightly yellowish green was visible. Both the author and geologist J. C. Mendes have noted strong bluish green pleochroism in darker Capoeirana emeralds.

Color Filter Reaction. No reaction was observed in any of the 10 Capoeirana emeralds when each was placed on the tip of a fiber-optic illuminator and viewed through a Chelsea color filter, regardless of orientation.

TABLE 1. Gemological properties of emeralds from Capoeirana, Minas Gerais, Brazil.[a]

Color	Light to medium bluish green
Refractive index	
Extraordinary ray	1.576–1.578
Ordinary ray	1.582–1.584
Birefringence	0.006
Specific gravity[b]	2.71 (2.71–2.73 by the hydrostatic method)
Reaction to U.V. radiation	Inert to both long and short wave
Absorption characteristics	Weak to moderate lines at 682, 661, 641, and 639 nm; very weak line in the darkest stones examined at 484 nm; general absorption from 430 nm down in all stones.
Pleochroism	Weak; very slightly yellowish green and bluish green
Color filter reaction	None
Internal characteristics	Two- and three-phase inclusions; fine acicular growth tubes; flakes and booklets of (possibly) biotite mica and crystals of (possibly) calcite or dolomite.

[a]*Properties listed were obtained by John I. Koivula from 10 relatively pale faceted stones ranging from 0.66 to 4.20 ct.*
[b]*Determined with heavy liquids.*

Internal Characteristics. Two- and three-phase fluid inclusions were noted in all of the samples, as were very fine acicular growth tubes oriented parallel to the c-axis (figures 10 and 11). The two- and three-phase fluid inclusions were commonly found in small, short barrel-shaped primary negative crystals paralleling the c-axis. This is in direct contrast to the appearance of the ragged-edged two- and three-phase inclusions found in the planar relationship to the prism faces in Colombian emeralds. The solid phase in the three-phase Capoeirana inclusions did not appear to be cubic, unlike those common to Colombian emeralds. A few larger primary two-phase inclusions were also observed in the Capoeirana samples. A fluid immiscibility with a reaction to slight warming, as would be expected of carbon dioxide, was noted in some of the minutest fluid inclusions.

On the basis of general morphology and reaction to polarized light, two different mineral inclusions could be identified. The most common of these (observed in four of the 10 stones) were transparent to translucent slightly grayish brown flakes and booklets of what appeared to be biotite mica (figure 12). Two of the 10 stones contained slightly rounded, translucent grayish white crys-

Figure 10. This internal pattern of small primary fluid inclusions and growth tubes is typical of the Capoeirana emeralds examined. Photomicrograph by John I. Koivula; magnified 20×.

TABLE 2. Results (in wt.%) of the chemical analysis of three spots on one emerald from the Capoeirana mine, Minas Gerais, Brazil.[a]

Element	Average[b]	Oxide[c]	Average
Be[d]	5.03	BeOa	13.96
Na	1.05	Na_2O	1.41
Mg	1.09	MgO	1.80
Al	8.06	Al_2O_3	15.23
Si	29.61	SiO_2	63.33
K	0.05	K_2O	0.06
Ca	0.05	CaO	0.06
V	0.01	V_2O_3	0.01
Cr	0.12	Cr_2O_3	0.17
Fe	0.43	FeO	0.54
O	51.11		
Total[e]	96.61		96.57

[a]*Chemical analysis performed on a 1.25-ct light green stone by Paul Carpenter of the California Institute of Technology, Pasadena, CA, on a JEOL 733 Superprobe.*
[b]*Average of analyses on three spots.*
[c]*Oxides provided to facilitate comparison to previously published literature.*
[d]*Calculated from an ideal formula, not measured.*
[e]*Totals do not equal 100 because of the poor surface quality of the emerald (the electron beam could not be held perfectly perpendicular to the sample) and only significant elements were measured. Numbers have been rounded off to two decimal points.*

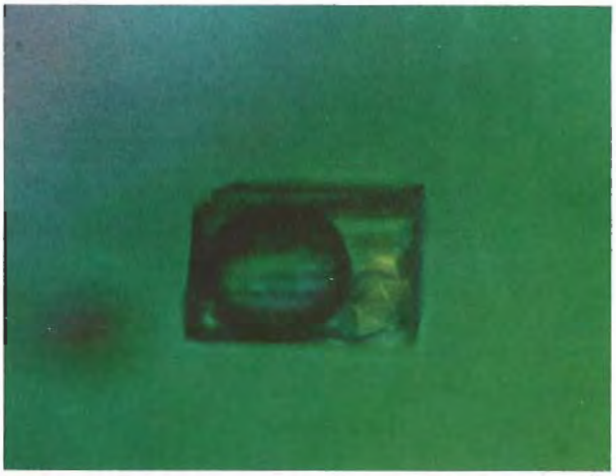


Figure 11. Three-phase—mineral, liquid, gas—inclusions have been observed throughout the Capoeirana emeralds. Photomicrograph by Júlio César Mendes and Juarez Leal de Souza; magnified 200×.

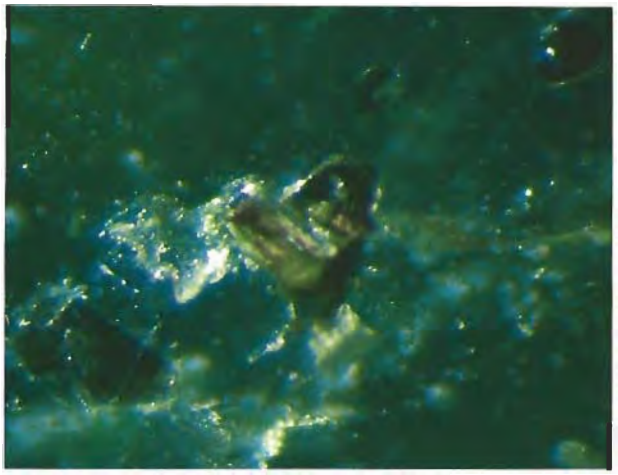


Figure 12. Inclusions of a transparent to translucent brown mineral observed in the Capoeirana emeralds appear to be biotite mica. Photomicrograph by John I. Koivula; magnified 35×.

tals of what appeared to be either calcite or dolomite. For the most part, the inclusions observed in the Capoeirana stones are similar to those identified in emeralds from the Belmont mine (Hänni et al., 1987). In general, however, the Capoeirana stones contain fewer inclusions.

CHEMISTRY

Chemical analysis was performed using a JEOL 733 Superprobe on a light green 1.25-ct lozenge-shaped stone. The results, averaged from three spot analyses, are listed in table 2. They appear to be

consistent with the compositions reported for the Belmont mine material by Hänni et al. (1987).

CONCLUSION

The Capoeirana emerald occurrence appears to be related to, or is possibly even a continuation of, the emerald mineralization in biotite-phlogopite mica schist at the Belmont mine, only 10 km away. Although production has been sporadic at Capoeirana, it appears to be significant in the quantity and size of emeralds produced, with as much as 7 kg of potentially gem-quality rough mined in one week. The material tends to be light, especially in smaller stones, but many stones over 5 ct with quite good color have been faceted to date. Capoeirana shows the potential to become another major emerald deposit in a country that today is one of the chief sources of this important gem material.

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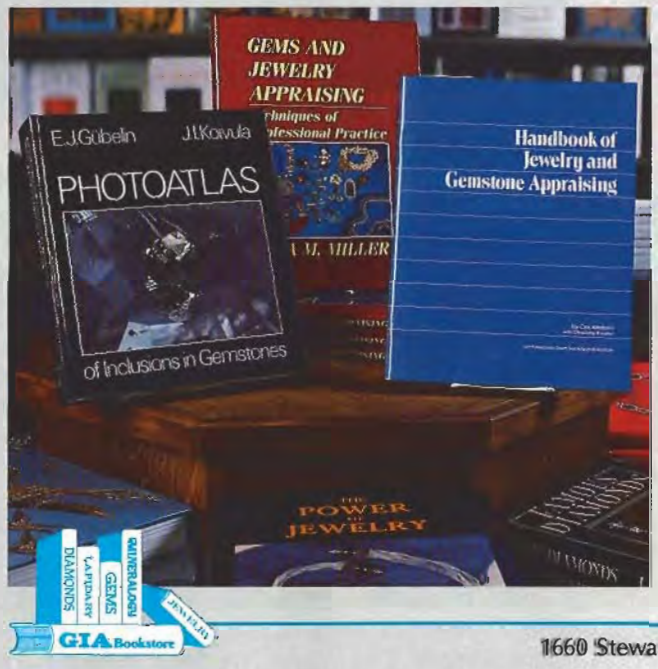

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NOTES
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NEW TECHNIQUES

THE GROWTH OF BRAZIL-TWINNED SYNTHETIC QUARTZ AND THE POTENTIAL FOR SYNTHETIC AMETHYST TWINNED ON THE BRAZIL LAW

By John I. Koivula and Emmanuel Fritsch

Colorless synthetic quartz that shows obvious Brazil-law twinning has been grown over a seed plate of natural amethyst that is twinned according to the Brazil law. Although commercially available Brazil-twinned synthetic amethyst has not been reported to date, the results of this experiment cast doubt on the long-term usefulness of the so-called twinning test for the separation of natural from synthetic quartz. The twinning, which was readily visible in polarized light, and some "breadcrumb" and tiny fluid inclusions were the only internal features observed in this synthetic quartz when it was examined using a standard gemological microscope.

It has been known since the first half of the 19th century that almost all natural amethyst is twinned on what mineralogists refer to as the Brazil law (Frondel, 1962). Twinning is visible with polarized light in the form of varying degrees of interruption in the spectral rings; an untwinned stone will show undisturbed rings of spectral colors. In 1980, Dr. Kurt Nassau issued the first report in the gemological literature regarding the usefulness of this feature in separating natural from synthetic amethyst, that is, that "a twinned crystal is almost certainly of natural origin."

Since then, the value of this feature in the identification of amethyst that is otherwise flawless has been documented by a number of gemologists (Schneider and Droschel, 1983; Lind et al., 1983 and 1985; Schmetzer, 1985; Lind and Schmetzer, 1985; Crowningshield et al., 1986). The presence or absence of Brazil-law twinning (also called optical twinning) when the stone is examined in polarized light is now widely used throughout the industry as evidence of natural or synthetic origin.

Cautions against using this test exclusively have also been presented by these and other authors (see, e.g., Fritsch and Koivula, 1987). Not only are some natural amethysts cut in such a way that they do not show twinning, but also some faceted synthetic amethysts from Japan have been observed to show a form of optically active twinning (Lind and Schmetzer, 1985 and 1987) in the shape of "an acutely angled, flame-like pattern" (figure 1; Crowningshield et al., 1986), even though these crystals were reportedly grown on un-

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Acknowledgments: The authors thank Dr. David Larson, of Sawyer Research Products, for growing the synthetic quartzes used in this study; Michael Gray for polishing the samples; Peter and Roberta Flusser for helping research the validity of rumors concerning the presence of "twinned" synthetic amethyst in the trade; and Dr. Kurt Nassau for his continued support of this project.

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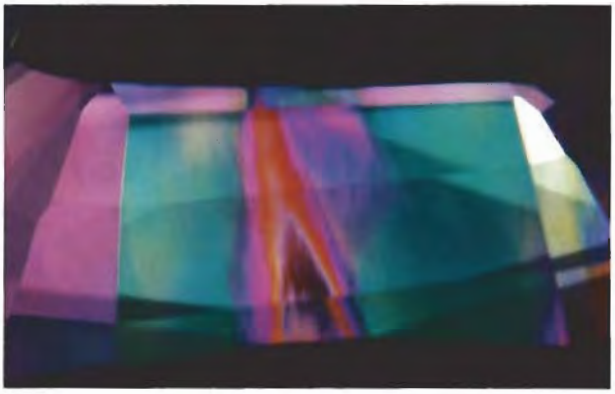

Figure 1. Flame-like Brazil law–twinned structures are seen in some synthetic amethysts in polarized light. Photomicrograph by John I. Koivula; magnified 6×.

twinned seeds. The same type of wedge- or cone-shaped twinning has been reported in USSR-produced synthetic amethyst as well. Tsinober et al. (1986, p. 316) state that "the formation of Dauphiné and especially Brazil law twins is quite typical in synthetic amethysts. . . . Brazil twins are quite frequent both in synthetic amethysts and in natural samples." They suggest that these wedge- or cone-shaped sectors in synthetic amethysts may be caused by the presence of minute inclusions, which—with the microscope—they were able to see in some specimens "at the apex of each twin cone." Earlier experiments by McLaren and Pitkethly (1982) with growing synthetic amethyst had shown that small regions of Brazil twinning were nucleated in synthetic quartz grown on an untwinned seed when iron was present, which might also explain the optically active (Brazil) twinning observed in some commercially available synthetic amethysts.

Crowningshield et al. (1986) maintain that this form of "flame-like" twinning is sufficiently different from the Brazil-law twinning shown by natural amethyst that no confusion should be created for the experienced gemologist. Yet any twinning in quartz that is observable optically in polarized light is Brazil twinning (Frondel, 1962). Thus, the twinning reported in synthetic amethyst is on the Brazil law. Additionally, as shown in figure 2, the Brazil-law twin patterns observed in natural amethyst vary considerably from one stone to the next.

For the most part, the twin sectors in synthetic amethyst usually do not look like those observed in natural quartz primarily because twinning morphology is a structural phenomenon dictated by the underlying framework of the seed and the crystal faces present during growth. However, many faceted natural amethysts show a partial pattern consisting of an incomplete wedge- or triangle-shaped sector (figure 3) that could be mistaken for the twinning that has been observed in synthetic stones (again, see figure 1). In such

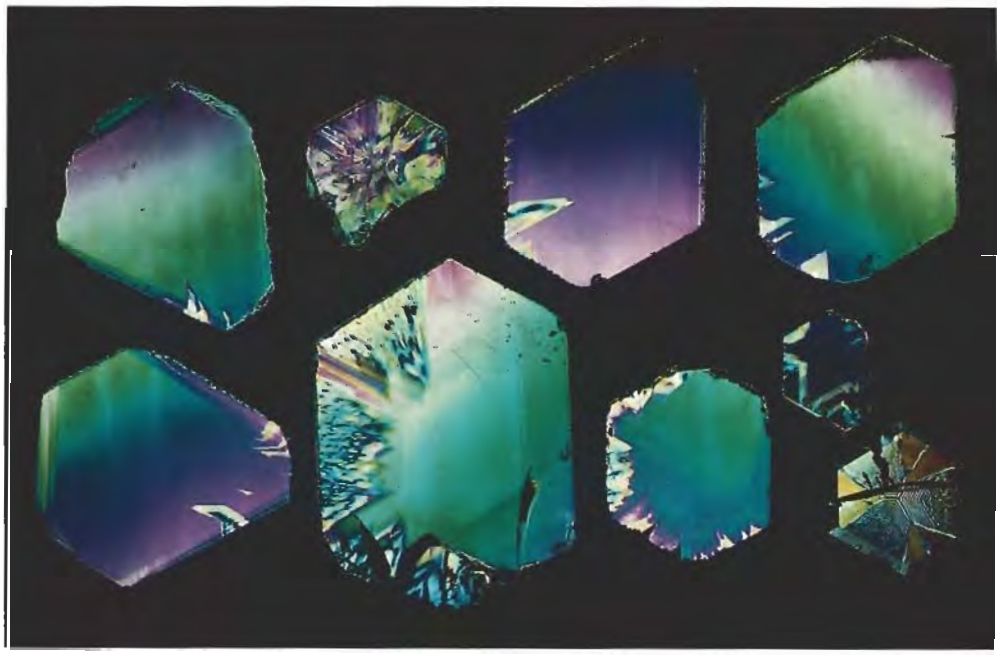

Figure 2. Various forms of Brazil-law twinning are evident in these cross sections of natural amethyst. The flame-like patterns in some of these slices resemble in shape those that have been seen in some synthetic amethyst. Photo taken with polarized light; courtesy of the American Museum of Natural History, New York.

Figure 3. Flame-like Brazil-law twin patterns are also observed in faceted natural amethyst. Photomicrograph by John I. Koivula; polarized light, magnified 4×.

cases, the gemologist must rely on other tests to make the separation (see, e.g., Crowningshield et al., 1986, pp. 134–139).

Virtually all of the synthetic amethyst sold in the gem market today results from the technology developed during World War II—borrowing on Giorgio Spezia's earlier achievements in hydrothermal quartz synthesis—to grow *untwinned* rock crystal quartz for use in communications as radio frequency oscillators (Gordon, 1945; Nassau, 1980; Trossarelli, 1984). Since 1970, synthetic amethyst has been produced specifically for gem purposes, but the manufacturers have continued to use the "recipes" developed originally for the special needs of the communications industry, that is, with an untwinned seed plate. The question arises, then, as to what would be the properties of a synthetic amethyst grown on a seed plate of natural amethyst that was twinned according to the Brazil law. Would the resulting synthetic crystal have the habit of a natural quartz crystal, and would the twinning propagate from the seed into the overgrowth? If so, would the resulting twin pattern observed in polarized light be confused with those patterns commonly observed in natural amethyst?

To seek answers to these questions, the authors arranged for the growth of two synthetic quartz crystals using seed plates with Brazil-law twinning cut from two small natural amethysts. The results of this experiment are reported below.

MATERIALS AND METHODS

At the suggestion of Dr. Nassau, the authors contacted Dr. David Larsen of Sawyer Research Products, a company that grows synthetic quartz commercially for the electronics industry. He agreed to use his company's equipment and technology to grow synthetic colorless quartz (since they were not set up to grow synthetic amethyst) on the two 2-mm-thick amethyst seed plates provided by the authors.

The two seed plates were approximately 1 cm^2 in surface area on each side; one plate was oriented near-perpendicular to, and the other near-parallel to, the c-axis. The Brazil-twinned seeds were attached to rhodium-plated silver wires and placed in one of Sawyer's hydrothermal autoclaves. A silicon dioxide feed material was used. In 30 days, over 10 mm of apparently flawless colorless quartz had grown over the seed oriented near-perpendicular to the c-axis, while the seed oriented near-parallel to *c* showed considerably less growth.

The two resulting synthetic crystals were distinctly different in morphology. As expected, the seed that was preoriented near-parallel to its c-axis produced a crystal that was flat and tabular (figure 4), unsuited to the needs of the gem industry. The seed that was oriented near-perpendicular to its c-axis produced a large volume of overgrowth and a more equant morphology (figure 5), reminiscent of the external habit of a natural quartz crystal (see Frondel, 1962, p. 51, figure 14). Once the seed plate was removed, the overgrowth from this crystal could easily be faceted into two nearly flawless stones of about 2–3 ct each.

EXAMINATION

The most obvious feature of the two synthetic crystals was the color alteration of the seed plate to yellow as a result of the heat generated in the autoclave. Amethyst from many localities turns yellow (citrine) when subjected to heat treatment at 450°C or above (Nassau, 1984; Epstein, 1988). In fact, the synthetic amethyst on the market today comes out of the autoclave as pale yellow or colorless and is subsequently irradiated to produce the amethyst hue (Nassau, 1980). Because the Sawyer system uses sodium carbonate to remove iron that might otherwise affect the piezoelectric and other qualities of the synthetic quartz, the crystals we grew using the natural amethyst seeds did not contain the iron necessary to convert the overgrowth to amethyst on irradiation. The growth of synthetic amethyst requires the presence of potassium or ammonium in the system for the iron to be incorporated as a color-causing

Figure 4. A natural Brazil law–twinned amethyst seed plate oriented near-parallel to the c-axis direction resulted in this 3-mm-thick, 15-mm-long tabular synthetic quartz crystal. Photo by Robert Weldon.

Figure 5. When a Brazil law–twinned amethyst seed plate oriented near-perpendicular to the c-axis direction was used, the resulting 16-mm-long synthetic quartz crystal took a form more closely resembling that of natural quartz. Heat generated during the growth process converted the amethyst seed to citrine. Irradiation would restore the purple color. Photo by Robert Weldon.

structural impurity and not crystallize out in a separate phase (Nassau, 1980; Tsinober, 1986).

When these two crystals were examined with the microscope in darkfield conditions, the rib-like structure of Brazil-law twinning was immediately visible as a phantom at the interface between the seed plate and the overgrowth (figure 6). "Breadcrumbs" of tiny eucryptite (Nassau, 1980; Sato, 1986) or acmite (Sawyer Research Products, technical information brochure), together with minute fluid inclusions, can be seen outlining the twinning lamellae to create a "zebra stripe" effect in the overgrowth close to the seed. Even without polarized light, it appeared that the twinning in the seed had influenced the overgrowth.

With the stones immersed in benzyl benzoate and examined in polarized light, it was immediately apparent that the colorless quartz overgrowth on both seeds was twinned according to the Brazil law (figure 7). This feature became even more obvious when a 2-mm slice of the overgrowth layer was cut 3 mm away from the seed, polished, and then examined in polarized light (figure 8). Totally separate from the original seed

Figure 6. The rib-like structure of the twinning appeared as a phantom at the interface between the seed plate and the synthetic overgrowth. Photomicrograph by John I. Koivula; darkfield and oblique illumination, magnified 4×.

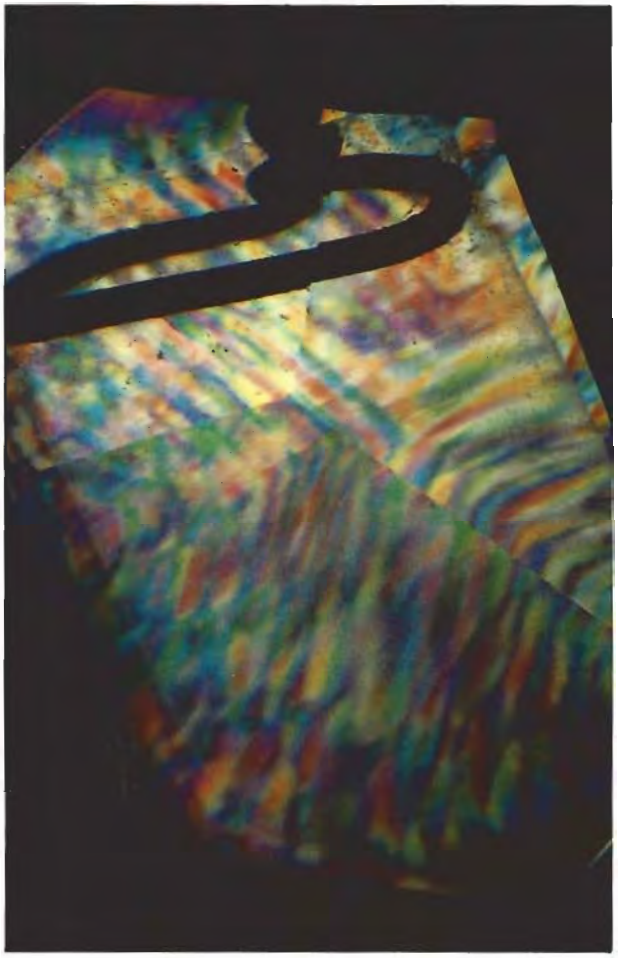

Figure 7. Both of the experimental crystals showed Brazil twinning in the overgrowth as well as in the seed plate. Photomicrograph by John I. Koivula; immersion and polarized light, magnified 3×.

plate, the overgrowth revealed Brazil twinning in a pattern very similar to that seen in natural quartz (again, see figure 2).

DISCUSSION

This experiment helps confirm earlier reports in the literature about the successful growth of Brazil law–twinned synthetic amethyst (McLaren and Pitkethly, 1982; Tsinober et al., 1986). The chief requirements, in addition to knowledge and skill, are a properly functioning hydrothermal autoclave, some silicon dioxide feed material, a Brazil-twinned seed plate, a trace of iron for color, a potassium or similar system in which the iron can be free, and a source of radiation to convert the autoclave product into amethyst.

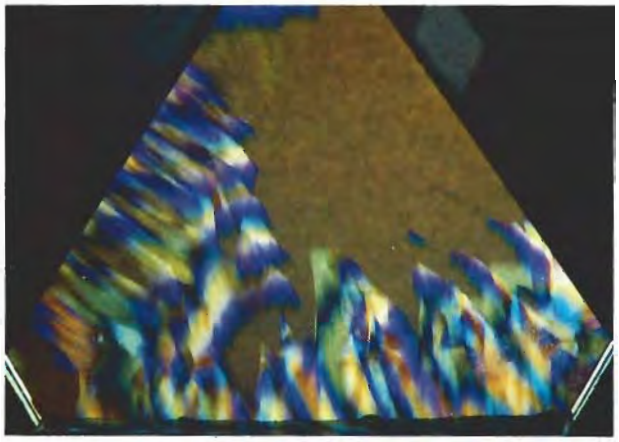

Figure 8. In this thin (2 mm) slice of one of the sample synthetic quartzes, Brazil-law twinning is evident even with the natural seed completely removed. Photomicrograph by John I. Koivula; polarized light, magnified 3×.

Because twinning is structural, it is doubtful that the small trace of iron required to ultimately produce synthetic amethyst would cause the twinned synthetic overgrowth to be flawed to the point that it could not be faceted. On the contrary, if an experienced synthetics manufacturer started out with a Brazil-twinned seed of high gem quality, it is very likely that the final product would also be of the same quality. According to McLaren and Pitkethly (1982), iron may actually promote the formation of Brazil-law twinning in synthetic quartz crystals grown in a potassium-containing system, and – as mentioned earlier – iron has been associated with the presence of small regions of Brazil-law twinning in synthetic stones grown using untwinned seed plates. In their study of Brazil-twinned amethysts, Schlossin and Lang (1965) found, through X-ray topography, that iron is present preferentially in the twinned areas (Brewster fringes), which further supports this iron-to-twinning relationship.

McLaren and Pitkethly also found that the use of iron with twinned amethyst seeds produced new areas of twinning in the overgrowth compared to those produced when iron was removed from the system. Although they appeared to be transparent, these newly grown regions were highly strained and contained high concentrations of submicroscopic structural defects that might, in some synthetic amethyst crystals, result in inclusions visible with the microscope or even with the unaided eye.

At this time, we have no tangible proof that any commercial synthetic amethyst growers are producing synthetic amethysts using Brazil-twinned seeds, although there have been numerous rumors as to the existence and commercial synthesis of "natural-looking twinned synthetic amethysts." Because twinned synthetic quartz is so easily grown, though, it is probable that we will see such twinned synthetic amethysts in the near future. Should this happen, the gemologist will once again need to rely primarily on the presence of distinctive inclusions, color zoning, and infrared spectrometry to separate synthetic from natural stones.

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THERMAL ALTERATION OF INCLUSIONS IN "RUTILATED" TOPAZ

By Robert C. Kammerling and John I. Koivula

***F**aceted colorless topaz containing acicular inclusions has been offered for sale as "rutilated" topaz. Earlier investigations have shown the inclusions to be limonite-stained etched dislocation channels. This article reports on the use of heat treatment to alter the limonite staining to hematite, thus changing the color of the inclusions and making them more prominent.*

The heat-induced alteration of iron-based impurities in gem materials is well documented in the literature. Such changes are often the goal of the gemstone enhancer, as in the heat treatment of colorless and light yellow sapphire to develop or intensify a yellow color (Abraham, 1982; Keller, 1982), the heating of light yellow to brown chalcedony to produce deep brown to red sard and carnelian colors (Nassau, 1984), and the heating of brownish yellow tiger's-eye quartz to produce a red stone (Webster, 1983).

Thermal exposure may also affect iron-based inclusions, a fact that is often used to detect treatment in a stone. For example, the conversion of goethite to hematite, together with associated dehydration fracturing, has been used as evidence of amethyst-to-citrine heat treatment (Koivula, 1987a).

During 1986, faceted Brazilian topazes containing brownish yellow acicular inclusions began to appear on the market. Because of the material's resemblance to rutilated quartz, dealers were describing these stones as "rutilated" topaz. Subsequent investigation by one of the authors revealed the "rutile" inclusions to be thin, etched dislocation channels colored by what appeared to be epigenetically derived (i.e., incorporated into the stone after formation) limonitic compounds (Koivula, 1987b).

In the fall of 1988, one of the authors (RCK) was shown some interesting faceted Brazilian topazes at a Santa Monica gem and mineral show. These stones had eye-visible inclusions similar to those described earlier (Koivula, 1987b), but with one significant difference: They were a dark red-brown rather than a medium brownish yellow (figure 1). The vendor, Mr. Terry Johnson of The Gemmary, explained that he had heat treated these stones to make the inclusions more prominent. Specifically, Mr. Johnson said that he had heated the stones in air at a temperature of approximately 300°C and had experienced virtually no fracturing problems. Since there were no prior reports in the literature of such an enhancement of this material, the authors decided to attempt to replicate the procedure.

Figure 1. This 11.77-ct colorless topaz was reportedly heat treated to alter the inclusions. Photo by William Videto.

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Acknowledgments: The authors thank Mr. Terry Johnson of The Gemmary for bringing this material to their attention.

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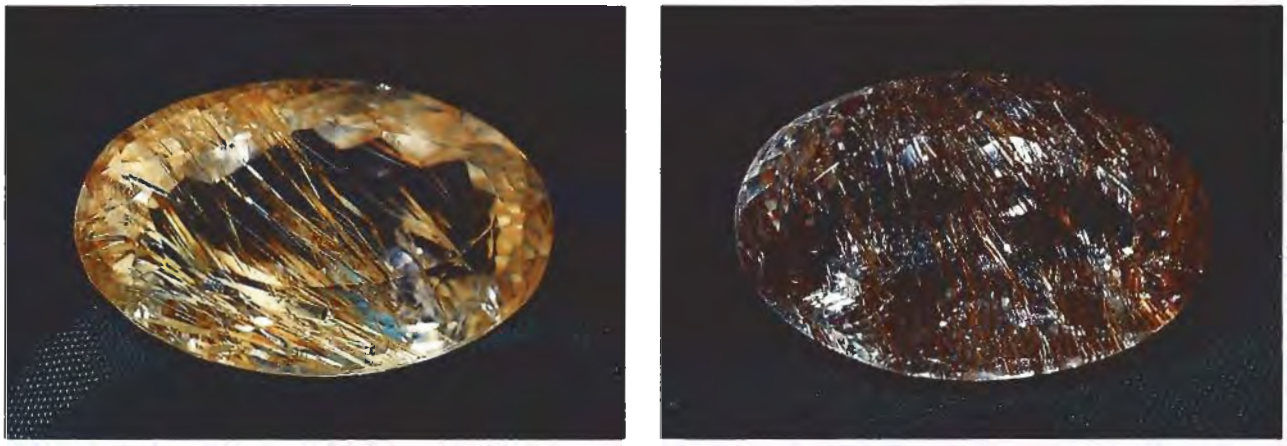


Figure 2. Before treatment, the inclusions (actually stained etch channels) in this otherwise colorless topaz were brownish yellow (left); exposure to 300°C–400°C heat for three hours resulted in the alteration of the inclusions to a dark red-brown (right). GIA collection no. 14490; photos by William Videto.

THE EXPERIMENT

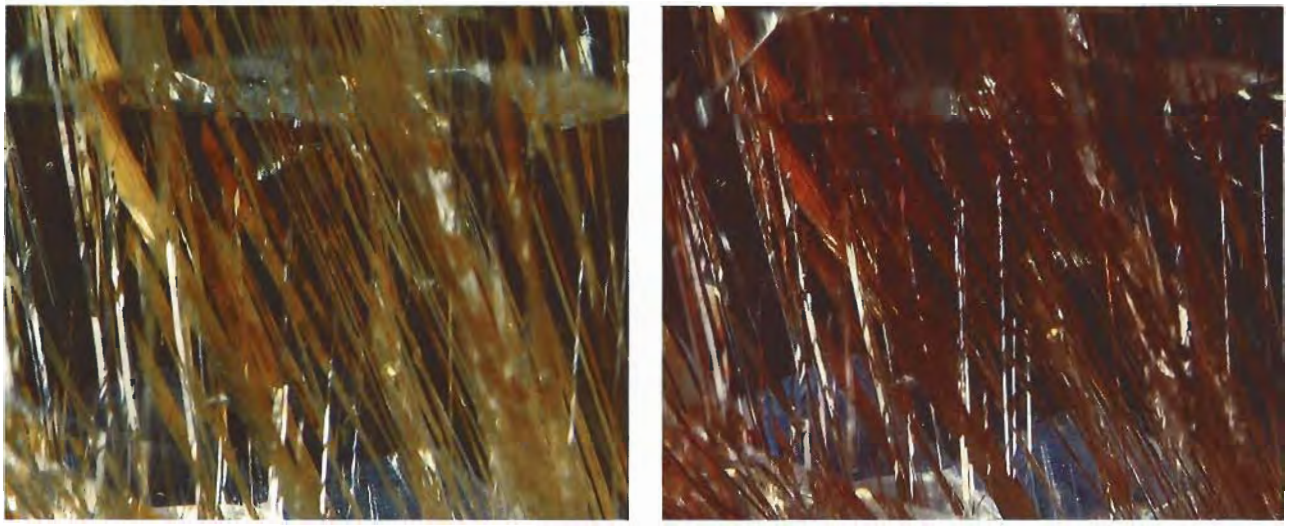
For the experiment, the authors selected a 40.410-ct colorless topaz (GIA collection no. 14490) containing limonite-stained etched dislocation channels (figures 2 left and 3 left). The weight was confirmed by six separate weighings on an electronic balance. The stone was then buried in white sand (to protect it from thermal shock) in an alumina crucible and heated in air for a period of three hours. The maximum temperature reached was 400°C, with a variation between 300° and 400°. The temperature was allowed to decrease slowly for three hours before the stone was removed from the oven.

The color alteration of the inclusions was quite apparent (see figures 2 right and 3 right). In addition, when the stone was reweighed, all six readings showed 40.406 ct, for a weight loss of 0.004 ct.

DISCUSSION

Limonite is a general term for hydrous cryptocrystalline iron oxides consisting mainly of goethite [α-FeO(OH)] and lepidocrocite [γ-

Figure 3. The effectiveness of the heat treatment is particularly evident in these photomicrographs of the stained etch channels in colorless topaz before (left) and after (right) the enhancement procedure. Photomicrographs by John I. Koivula; darkfield and oblique fiber-optic illumination, magnified 20×.



FeO(OH)] with variable absorbed water. Heating of the earthy yellow limonite causes a gradual dehydration (Palache et al., 1944) that starts at 100°C with the loss of excess water from the limonite. It continues with the conversion of the goethite and lepidocrocite in the limonite to dark red-brown hematite (α-Fe_2O_3), following the formula $2FeO(OH) + \text{heat}\ (400°C) \rightarrow Fe_2O_3 + H_2O$, with a resulting additional loss of water (Koivula, 1987a). Because the limonite may contain as much as 14% water (Deer et al., 1972) and there are a large number of limonite-filled etch channels in the test specimen, a recordable weight loss is not surprising. Although the inclusions in the topaz treated in this experiment showed the expected alteration in color, none of the fracturing that normally accompanies heat-induced dehydration of inclusions was observed (Koivula, 1987a). We believe that fracturing was avoided because the etch channels acted as vents, allowing the water and resulting pressure to escape.

There are no reports in the literature of hematite filling etched channels in topaz. It appears, then, that the presence of hematite in these channels is also evidence that the stone has been heated.

CONCLUSION

The purpose of the treatment described herein appears to have been simply to alter the appearance of so-called "rutilated" topaz as normally seen in the trade. The conversion of the untreated brownish yellow limonite to red-brown hematite does tend to make the otherwise colorless topazes treated this way look much darker. This conversion provides further proof that the original inclusions were not rutile. The presence of hematite as opposed to limonite staining in a topaz also proves that the stone has been heated to approximately 400°C or higher.

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CHICKEN-BLOOD STONE FROM CHINA

By Wang Fuquan and Guo Jingfeng

"Chicken-blood" stone is one of the most prized ornamental materials in China, especially for use in elaborate carvings and seals. A fine-grained mixture of dickite/kaolinite and quartz, with varying amounts of red cinnabar, chicken-blood stone is found in only two localities in China: Changhua and Balinyouqi. This article describes this material and its gemological properties as well as the occurrence at the two known localities.

One of the most unusual and sought-after carving materials found in China is the rich red "chicken-blood" stone (figure 1). Also called Changhua stone or Balinyouqi stone after the sole Chinese sources in Changhua, Zhejiang Province, and Balinyouqi, Inner Mongolia Autonomous Region, chicken-blood stone is actually a fine-grained mixture of dickite/kaolinite and quartz that contains varying quantities of minute crystals of cinnabar, which impart the color. To date, Changhua and Balinyouqi are the only known sources of this ornamental material, although it has been distributed throughout Asia and is especially popular in Southeast Asia.

Ancient writings reveal that chicken-blood stone has been known in China for more than 500 years. Listed among the palace treasures of the Ming Dynasty (1368–1644) is a seal carved from this material. Examples of early carvings are on exhibit today in the Imperial Palace in Beijing. Compared to the cinnabar-stained limestone from China reported by Keller and Wang (1986), chicken-blood stone is considered a superior gem material and one of the noblest of all native ornamental stones (Wang, 1979).

The authors have examined a number of representative samples of chicken-blood stone from the above-mentioned localities in Zhejiang Province and the Inner Mongolia Autonomous Region. This report looks at the composition and gemological properties of this material, as well as its occurrence in these two localities.

DESCRIPTION OF CHICKEN-BLOOD STONE: COMPOSITION AND GEMOLOGICAL PROPERTIES

Chicken-blood stone is actually a rock composed of dickite, kaolinite, quartz, and cinnabar. It should be noted here that earlier references to chicken-blood stone as pyrophyllite, a variety of agalmatolite (e.g., *Minerals in China*, 1980), are incorrect. Gem-quality chicken-blood stone is rich in cinnabar and semitranslucent to translucent. The body color may be white, yellow, or gray—various mixtures of microcrystalline dickite and kaolinite—with isolated spots, broad streaks, or clouds of dark to bright red cinnabar. Some specimens contain so much cinnabar that they are completely red. In China, the translucent base rock is referred to as *dong*, and specimens are categorized as white *dong*, yellow *dong*, and gray *dong* (figure 2). Wet chemical analyses of various *dong* samples by Mr. Wu Zhimin of the Zhejiang Geological Bureau showed that the light yellow color depends mainly on the presence of iron (0.22 wt. % Fe_2O_3) and that with increasing amounts of iron the color shifts from gray to green (0.41–1.98 wt.% Fe_2O_3).

The specimens of chicken-blood stone examined by the author have a subadamantine to pearly luster, a specific gravity of 2.6–3.0, and a Mohs hardness of 3. Since the material is a rock, the refractive index varies considerably, with an average around 1.55–1.56 for the *dong*. In thin section, the material is transparent. Compact massive, it appears microgranular when observed with a microscope (figure 3).

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Figure 1. This 16-cm-high fan screen, delicately carved with nine dragons playing with a pearl, is a particularly fine example of chicken-blood stone from China. The material from which this screen was carved is from Changhua, in Zhejiang Province. Courtesy of the Geological Museum of China, Beijing.

Because of the low hardness (especially when compared with jadeite, 6½–7, for example), this fine-textured material is easily carved with a small knife and lends itself well to intricate details. Its value depends on the amount of bright red coloration, the transparency of the *dong*, and the overall clarity. The more of the bright red a piece contains and the cleaner it is, the greater its desirability. A fine 10 × 2.5 × 2.5 cm seal made of chicken-blood stone recently sold for more than US$3,000 in China. On exhibit at the Geological Museum of China are some exceptional carvings from this material (see, e.g., figure 1).

GEOLOGY AND OCCURRENCE

In China, carving-quality chicken-blood stone has been found only in Cretaceous and Jurassic altered volcanic rocks—for example, welded tuffs and rhyolite—in which it generally occurs in bedding fracture zones. The larger masses commonly display porphyritic texture, as shown in figure 2, with substructures that resemble veinlets, disseminations of included material, cloudy areas, and, in places, brecciation. More than one vein may be found in a fracture zone; the veins usually exceed 15 cm in width and 10 m in length. Common associates in the veins are dickite, kaolinite, quartz, sericite, and pyrite. The presence of these species suggests that the host rock has been epithermally altered. The occurrence of chicken-blood stone at Changhua has been described in Cheng, et al. (1986).

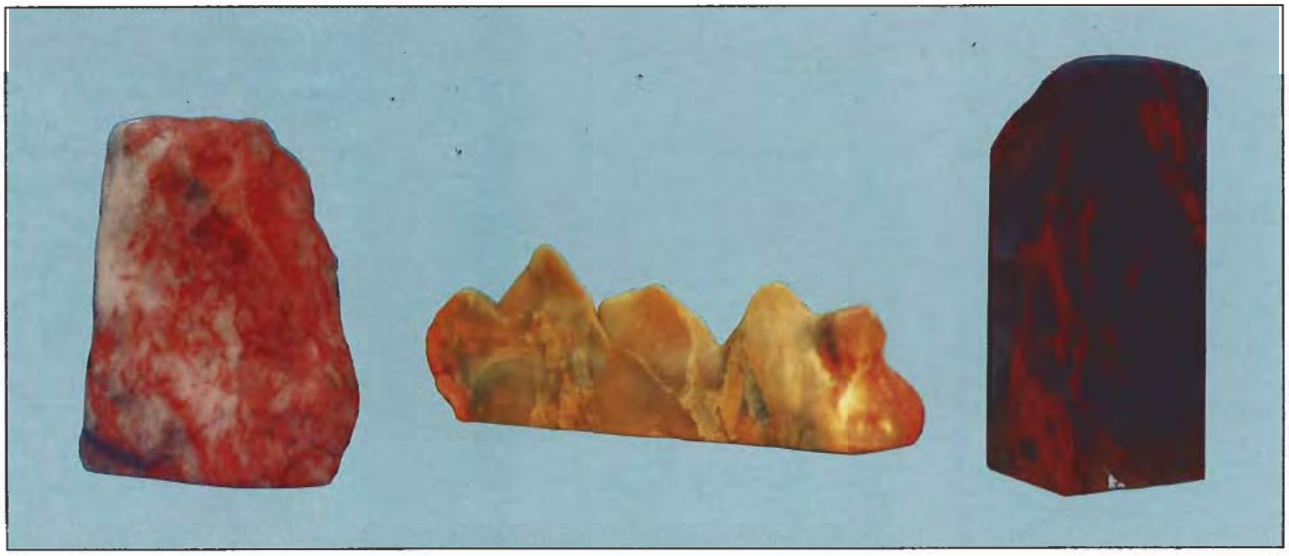

Figure 2. Left: The base rock in this example of chicken-blood stone is referred to as white dong *in China. Center: This pen rack is carved from yellow* dong *chicken-blood stone. Right: This seal has a deep gray* dong *groundmass. All three specimens are from Changhua.*

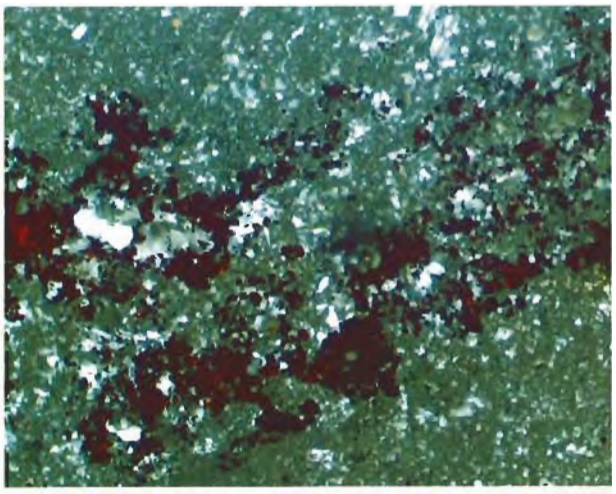

Figure 3. With microscopy, spots of disseminated cinnabar can be seen in a microgranular groundmass of dickite and kaolinite. Crossed nicols; magnified 25×.

At the Changhua occurrence, which one of the authors (WF) has visited, all mining for this material is in underground tunnels. Access to the actual mining operation was restricted at the time of the visit, so details are unavailable for this report. Although economic quantities of the material are being produced, precise production figures have not been released.

CONCLUSION

Significant quantities of chicken-blood stone are now being mined from the localities at Changhua, in Zhejiang Province, and Balinyouqi, in Inner Mongolia Autonomous Region. The presence of cinnabar in this rock provides splashes of a rich red color. Because it is so soft, it is commonly used for carvings, for large pieces as well as for seals and beads.

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Gem Trade LAB NOTES

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CHALCEDONY, Imitation "Black Onyx"

A large jewelry manufacturer recently submitted to the East Coast laboratory six opaque black cushion-shaped beveled tablets that had been centrally drilled for insets. Each tablet measured 16.00 × 12.00 × 2.15 mm. These samples were selected from several hundred that the manufacturer had purchased from Hong Kong as black "onyx" (dyed black chalcedony).

We found the refractive index to be 1.53. Hydrostatic measurement revealed the specific gravity to be 2.51. Although the drilled area in the center showed a dull granular surface consistent with chalcedony, with magnification we noticed that a few tablets had vitreous (glassy looking rather than dull) conchoidal fractures on the corners. While a hardness test is not usually done in a routine gemological examination, it was carefully applied to the back of one of the tablets, revealing a hardness of only 5 1/2 to 6.

To confirm our suspicions that these were well-disguised glass imitations, we X-radiographed the samples using a known dyed black chalcedony tablet as a control stone. In the resulting X-radiograph (figure 1), the known dyed black chalcedony tablet in the center is transparent to X-rays, whereas the glass tablets are moderately opaque, which also indicates that the glass contains an element with a relatively high atomic number. Although glass is frequently used to simulate dyed black chalcedony (see, e.g., the Summer 1986 Gem Trade Lab Notes), these simulants did not show the dendritic pattern typical of man-made devitrified glass. They were manufactured with unusual care to closely match the properties of chalcedony.

Tom Moses

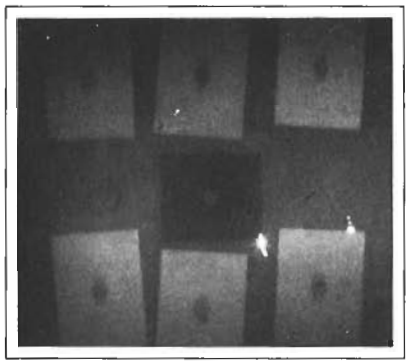

Figure 1. This X-radiograph shows how different the transparency of the known dyed black chalcedony tablet (center) is from the glass imitations.

DIAMOND

With a Concave Table

A gem merchant from Miami, Florida, purchased a 2.68-ct old mine–cut diamond with the thought of possibly recutting it. When he examined the stone closely, however, he discovered a unique feature that prompted him to call the West Coast laboratory for information: His stone had a concave table facet! He asked if we had ever seen this feature before and kindly offered to send the stone to us for study.

Although concave crown facets on two small triangular diamonds were described in the Fall 1981 Gem Trade Lab Notes section, the staff had never before encountered a concave table facet. In fact, these are the only three diamonds with concave facets we have ever seen in the laboratory.

When we examined the Florida diamond, we noted that the shape and facet arrangement were as to be expected for an old-mine cut, except that the table was indeed concave. Figure 2 illustrates the difference in table reflections between a flat table and the concave one. Note that the flat table reflects light evenly all across its surface, while the concave table acts like a lens and condenses the light to a spot in the table reflection. A side view of the same two tables is shown in figure 3 for further comparison.

It was evident that a spherical diamond-charged tool was used to form the table of this diamond during the polishing process. Since all crown facets, in particular those bordering the table, were abraded from extended wear, we concluded that the table of this diamond had not been recut recently. This may well be an example of the style of "cut diamond

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

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Figure 2. The flat diamond table on the left reflects light evenly, while the concave one on the right condenses the light to a single spot.

Figure 3. This side view provides another comparison of the flat table on the left and the concave one in the old mine–cut stone on the right.

Figure 4. The cross on this 2.22-ct faceted diamond tablet appears to have been engraved by hand and subsequently painted or stained.

having a concave table or facet" with the object of securing "increased brilliancy" for which Jean Louis Gonard was granted U.S. patent no. 946,939 in 1910. Our thanks go to this Florida jeweler for sending us this unusual stone. *KNH*

Engraved Faceted Tablet

One of our GIA graduates recently contacted Dr. John Hummel, manager of Course Development at GIA, regarding an engraved diamond (figure 4). The stone was subsequently loaned to the West Coast lab for examination.

Our graduate reports that this unusual estate piece was engraved in the 1930s. The 2.22-ct diamond tablet measures 14.01 × 9.96 × 1.97 mm. The engraving of the cross in the faceted tablet is very distinctive. The depth of the engraving ranges from 0.25 mm in the center of the cross to approximately 0.05 mm at the ends. The black coloration was added with a paint or similar substance. With magnification, we observed a very uniform texture. We speculated that the engraving was made mechanically using some type of machinist's tool fitted with a diamond point. The drill hole is also quite unusual: It was made by drilling a circle of tiny holes and then removing the "plug" in the center.

Engraved diamonds are rare,

probably because of the material's extreme hardness. In his book *Famous Diamonds*, noted diamond historian Ian Balfour reports on several well-known antique engraved diamonds from the Middle East: the "Shah" (88.7 ct), the "Jahangir" (approximately 83 ct), and the "Darya-i Nur" (estimated at 175–195 ct). Another interesting report in the literature is provided by P. Grodzinski in a 1955 issue of the *Gemmologist*, pp. 219–221. The examples of historic engraved diamonds he cites include ones with "the coat of arms of Mary Queen of Scots; the portrait of Don Carlos, the unfortunate son of Philip II of Spain; and the portrait of the Dutch Queen Fredrica."

From the following translation of first-century naturalist Pliny (as given by G. E. Lessing in Grodzinski), one can envision how these engravings in diamond were made by hand with a "scratching" motion: "If one has managed to burst the diamond in a favorable way, it breaks into such small splinters that they are almost invisible. These are desired by the gem engraver and fixed in iron, as they are able to engrave even in the hardest substance."

Today, it is possible to make inscriptions or engravings in diamond with a laser. The laser equipment used by GIA-GTL to inscribe small letters and numbers (40–80 microns high) into the girdle of a diamond produces a fine granular surface, quite unlike the texture of the surface of the engraved cross in the tablet we examined. *RK*

Figure 5. It is not likely that the abraded facet junctions on these diamonds were caused by unusual wear after setting. Magnified 10×.

With Mysterious Wear

Diamonds set in jewelry will usually wear or become abraded only when they come into contact with one another or with other diamond jewelry. Both scenarios were ruled out in the case of a heavy platinum and diamond bracelet seen recently in the East Coast laboratory, in which every diamond was mysteriously worn (figure 5). The damage to the diamonds in this well-made bracelet did not appear to be due to the stones rubbing against each other in the setting, since the abrasions were only along the facet junctions, not at the girdles. In addition, the pavilion facets were also evenly abraded.

One possible explanation is that these old-European brilliants might have been stored together in a parcel paper or some container for many years before they were set into jewelry. Clearly the pavilion facets could not have suffered such abrasion after mounting, or from the bracelet rubbing against other jewelry in a jewelry box. *DH*

Figure 6. The exoskeletons of green beetles (each approximately 15 mm long) have been set, along with diamonds, in this unusual pin.

INSECTS as Jewelry

A fancy yellow diamond submitted to the East Coast laboratory for color origin was found to be keeping unorthodox company (figure 6). The iridescent green "stones" embellishing the brooch were determined to be the chitinous exoskeletons of an unidentified beetle.

The fragility of the beetles is evident, since one exoskeleton has been damaged, thus exposing the dried inner remains. Another has been partially broken, exposing an underwing.

Such a piece is not entirely unique. French jeweler Gilbert Albert received an International Diamond Award in 1987 for similar work using diamonds and green Chinese scarab beetles. We could not determine whether the piece shown here was one of his, although we do know that the beetles in the photo are not scarabs. *RC and Nick DelRe*

PEARLS

Chipped

A retailer submitted a strand of natural pearls to the East Coast laboratory and asked if we could explain

why many of the pearls were chipped on one side. Damage was quite extensive, as can be seen on the 4-mm pearl in figure 7, which suggests that it was not the result of ordinary wear or even carelessness. After checking with our colleagues at the West Coast laboratory and a local pearl expert, we concluded that the damage was probably caused by the pearls being improperly drilled.

Fine pearls are ordinarily drilled in two steps: first from one side and then from the other, with the drill holes meeting in the center of the pearl. Apparently, these pearls were drilled in a single step. The force of the drill exiting the pearl pushed on the outer nacreous layer, chipping and weakening it on the side of the pearl where the drill bit came through. It was only a matter of time before other parts of this vulnerable area fell away. *DH*

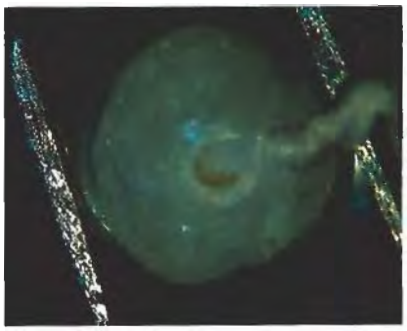


Figure 7. Severe chipping around the drill hole in this 4-mm pearl is probably due to the drilling of the hole all the way through from one side of the pearl, rather than drilling from both sides to the center as is usually done. Magnified 25×.

"Demi-pearl"

The West Coast laboratory received for examination a rare pearl formation that can appropriately be described as a "demi-pearl." This oval piece measured approximately 8 mm in diameter by 11 mm long. Although it appears to consist of two separate halves—one a dark pinkish brown and the other a very light

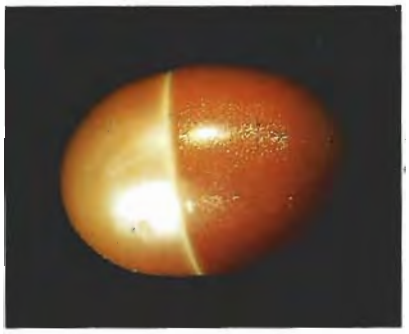


Figure 8. Although this "demi-pearl" (8 mm in diameter × 11 mm long) appears to consist of two separate halves, it is actually natural.

yellowish brown, separated by an opaque whitish circular growth line (see figure 8)—it is not assembled, but grew that way naturally; X-radiography showed no sign of culturing. Both parts also display different phenomena: The dark pinkish brown area has a sheen-like effect commonly seen in various calcareous concretions and the other half shows the orient associated with fine pearls.

With magnification, the structural differences between the two halves were readily visible: the alveolar or honeycomb structure in the nacreless half, and the fine orient in the nacre portion (figure 9). We also noticed that an alveolar structure was present underneath the very fine nacre, which was highly transparent. We do not know under what circumstances this particular "demi-pearl" was formed in the mollusk. *KNH*

Figure 9. High magnification (45×) reveals the orient on one part of the pearl shown in figure 8, and the honeycomb structure of a calcareous concretion on the other part.

"Pinked"

When we examine a strand or group of uniformly pink or rosé pearls we immediately suspect that they have been dyed. With the microscope, a gemologist can often see a ring of pink color in the drill hole (figure 10), between the bead nucleus and the nacre deposition, as this is where most of the dye is absorbed.

However, no microscope was needed at the East Coast laboratory for the 6-mm cultured pearl shown in figure 11. A large patch of excess dye was easily visible at the drill hole. Note also that if heavily dyed pink pearls are stored in tissue or cotton, the dye can sometimes be seen on the material it contacts. *DH*

Figure 10. Pink dye in a cultured pearl is commonly visible in the conchiolin layer at the drill hole, here magnified 25×.

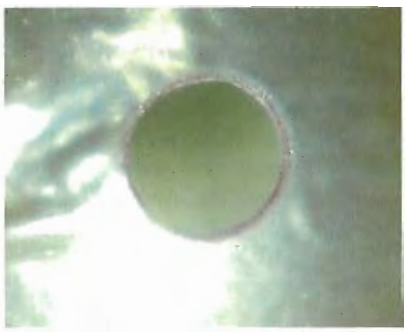
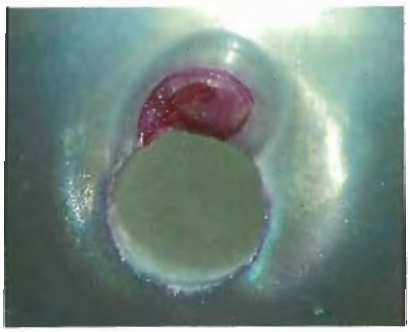


Figure 11. The excess dye is unusually apparent at the drill hole of this 6-mm "pinked" cultured pearl. Magnified 25×.



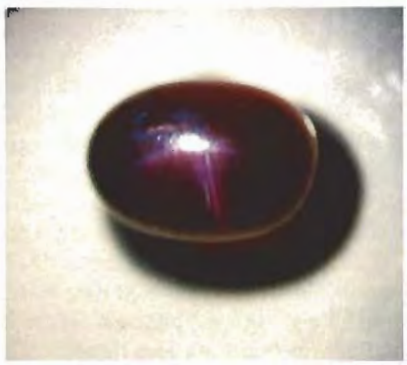
SYNTHETIC STAR RUBY
Early Flame-Fusion

Unlike most modern flame-fusion synthetic star rubies, which usually have a near-perfect star and may exhibit easily visible curved striae, some early flame-fusion star rubies have a more natural appearance. Figure 12 shows such a stone, a 5.99-ct semitransparent red oval that we recently encountered in our East Coast laboratory. The star is somewhat irregular, more like that of a natural star ruby. Also, the color is a desaturated purplish red that more closely resembles a natural stone than the vivid red commonly seen in modern synthetic star rubies.

Early synthetic star stones were cut first and then annealed to develop the rutile needles. This stone also appeared to contain silk-like inclusions, which might suggest natural origin. However, close examination at high magnification (45× in figure 13) revealed that the "silk" was in fact linear strings of tiny gas bubbles. Curved striae were also noted.

DH

Figure 12. This 5.99-ct flame-fusion synthetic ruby, probably of early manufacture, looks more like its natural counterpart than most recent flame-fusion synthetics.

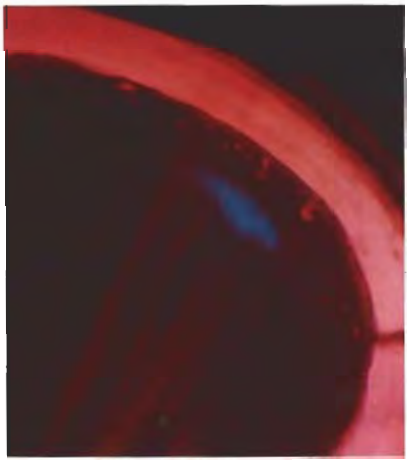


TANZANITE with Iridescent Coating

The West Coast laboratory recently examined a lady's yellow metal ring set with a transparent violetish blue, cushion-shaped mixed-cut stone (figure 14). Routine gemological testing confirmed the identity of the 4.53-ct stone as tanzanite. Catherine Saget, of GIA's Jewelry Manufacturing Arts Department, explained that the tanzanite had an iridescent coating on the crown (figure 15) that was not present when she originally set the stone about one year ago. Several attempts were made to remove the coating, including soaking and light brushing in BCR (an ultrasonic cleaning fluid) and acetone, all without success. The ring was brought to the lab for advice.

Figure 14. The 4.53-ct tanzanite in this ring was found to have a surface coating on the crown facets that was not present when the stone was set a year earlier.

Figure 13. With 45× magnification, what originally appeared to be needle-like inclusions are revealed to be strings of minute bubbles in this early flame-fusion synthetic ruby.



The effect observed on portions of every crown facet on this tanzanite appears visually to be nearly identical to the coating or "tarnish" that the lab has seen before on natural emeralds (*Gems & Gemology*, Fall 1960, p. 70 and Spring 1986, pp. 48–49), and at least one synthetic emerald (Spring 1984, p. 45), as well as on aquamarine (Spring 1984, p. 45) and on golden beryl (Summer 1977, pp. 310–311). However, this was the first time we had seen it on tanzanite. As in our previous reports, we still do not know the exact cause of this type of coating, but it undoubtedly results from contact with some substance during wear. As in all of the previous cases, this coating was easily removed with an ordinary ink eraser.

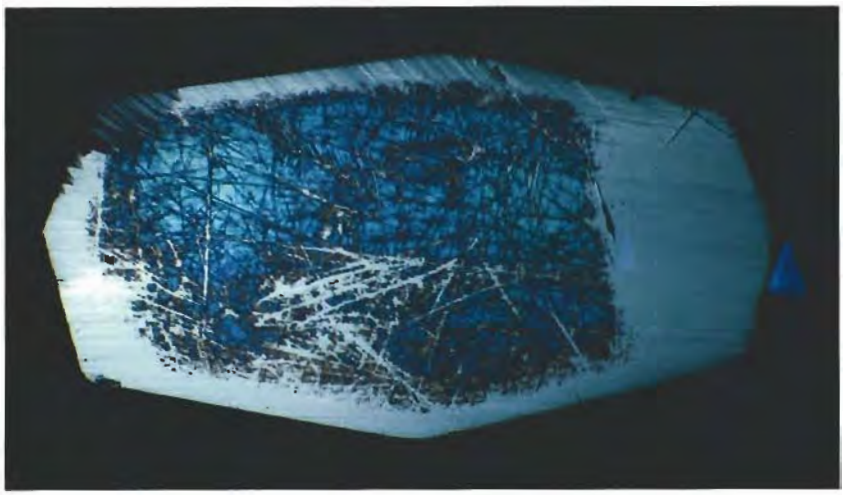


Figure 15. Magnification (10×) in reflected light clearly shows the surface tarnish on the tanzanite illustrated in figure 14. The coating was easily removed with an ordinary ink eraser.

The refractive indices obtained on the table of the coated stone were 1.69–1.70, which are typical for tanzanite. The coating did not affect the refractive index readings. In 1986, however, we examined a natural emerald on which the coated portion revealed an R.I. of 1.48, while the uncoated portion showed indices of 1.579 and 1.588. *RK*

FIGURE CREDITS

Figure 1 was supplied by Robert Crowningshield. Shane McClure produced figures 2–4 and 14, as well as the photo in the Historical Note section. Figures 5–7 and 10–13 were taken by Dave Hargett, with the assistance of Nick DelRe on number 6. John I. Koivula provided figures 8 and 9, and Robert Kane took the photomicrograph in figure 15.

A HISTORICAL NOTE

Highlights from the Gem Trade Lab 25, 15, and five years ago

FALL 1964

Several interesting items were seen by the New York laboratory at this time. Fourteen unusual tourmalines displayed an alexandrite-like color change when viewed in different lighting conditions. A unique watch crystal, estimated to be approximately 7.25 ct, was identified as diamond. Small true synthetic alexandrites were seen, as were several colors of a synthetic material having a garnet structure. Also new on the scene was an improved synthetic emerald overgrowth on beryl. The name proposed at that time was "Symerald," but it later was named after the manufacturer and became known in the trade as Lechleitner synthetic emerald.

The Los Angeles laboratory reported on the problem of determining whether periclase was synthetic or natural. Also mentioned was the pleasantly surprised dealer who was told by the lab that a 40-ct stone thought to be citrine was actually a natural sapphire.

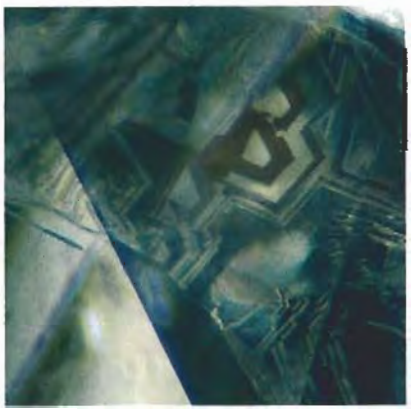
FALL 1974

A number of unusual inclusions in a variety of gemstones were illustrated and described by the Los Angeles laboratory, including ones in transparent sodalite and hessonite garnet, as well as a unique spicule-like inclusion seen at 126× magnification in a diamond. Needle-like inclusions in diamond are rare enough, but ones with a "nailhead" attached are unique in our experience. Another item of interest was the illustrated warning of what happens when borax is used in an attempt to protect corundum from heat in jewelry repair work.

The New York laboratory had the opportunity to examine some of the new rubies coming from Kenya, as well as four different imitations of lapis lazuli. Identification was also made of a "Maxixe" type beryl, actually a morganite that had been artificially gamma irradiated to turn it a deep blue color. Unfortunately, the color fades rather quickly.

FALL 1984

The laboratories mentioned a number of different pearls and imitation pearls. These include a strand of saltwater tissue-nucleated cultured pearls represented as *keshi* (keshi pearls are supposed to be "accidental" natural pearls found in cultured mollusks), coated mother-of-pearl imitations of Biwa cultured pearls, a 20-strand seed pearl necklace, and a large abalone pearl. Also of interest was a near-colorless enstatite crystal, metal-filled epoxy-backed turquoise, and a very unusual phantom growth pattern in diamond (see figure).



This unusual diamond revealed a variety of patterns in a large growth plane. Magnified 63×.

GEM NEWS

John I. Koivula and Robert C. Kammerling, *Editors*

DIAMOND

Increases in diamond sales. The Central Selling Organization reported diamond sales of $2.317 billion for the first six months of 1989, exceeding sales for the last six months of 1988 by $346 million, or 18%, and for the six months preceding that by $116 million, or 5%.

The new six-month sales figure is the highest ever reported by the CSO. The previous high was $2.201 billion, recorded in the first half of 1988.

Diamond cutting in China. An unexpected dividend of a visit to a craft emporium in Foshan, Guangzhou Province, People's Republic of China, was a chance for one of the Gem News editors to observe Chinese diamond cutters at work in an adjoining building. Diamonds were being cut using a variation of the jam peg method (figure 1), a technique normally used on colored stones. The apparatus consisted of a vertical metal rod to which a circular metal plate was attached by a thumbscrew. The base of the dop stick was inserted into an approximately 7.5-cm-wide plastic disc, which rested on the metal plate when the stone was brought in contact with the cutting wheel. The angle of the facet being cut was controlled by adjusting the height at which the metal plate was set on the vertical rod.

The diamonds appeared to be held to the dops by dopping wax of the kind generally used to cut colored stones; they were not held in mechanical heads. Cutters were seen working for less than a minute on a facet, at which point they would return the dop stick to a rack and take out another dopped stone on which they again worked on a single facet. Apparently the heat generated in the polishing operation, coupled with the material used to hold the stone to the dop, made it necessary to work back and forth between stones. Extended heat (i.e., that generated by completing even a single facet at one sitting) would no doubt loosen the stone in the dopping wax.

Strained relations between India and Australia. Argyle officials are refuting claims that they secretly recruited Indian cutters and polishers to work in China, as was reported in a Calcutta newspaper in March of this year.

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Figure 1. Diamonds are being cut in Foshan, China, using a variation of the jam peg method. Photo by Robert C. Kammerling.

The article, which appeared in the *Business Standard*, brought a harsh reaction from Indian diamond manufacturers, who angrily predicted a mass exodus of Indian labor. Other industry leaders joined them in calling the alleged recruitment unethical and potentially damaging to relations between India and Argyle. Currently, the Indian diamond industry cuts and polishes approximately 10 million carats of Australian goods per year.

Last June, in response to these concerns, Argyle issued a statement explaining that the company is working on a technical development program with China, which includes training approximately 50 people in diamond cutting and polishing. Argyle officials stated that the program is headed by an international team of eight experts, and does not involve the recruitment of 100 Indian cutters and polishers, as had been reported in the *Business Standard*.

Tests under way for diamonds in Canada. Corona Corp. is performing tests to determine if a diamondiferous kimberlite intersection drilled near Sturgeon Lake—30 km northwest of Prince Albert, Saskatchewan—is economically viable. Thus far, few kimberlite occurrences have been reported in Canada, and those that do exist have not proved to be commercially significant.

As reported in the July 14 issue of *Mining Journal*

(London), Corona became interested in the Sturgeon Lake area last year, when a small diamondiferous kimberlite was discovered by Monopros Ltd., De Beers's Canadian subsidiary. The project is a joint venture between Corona Corp. and Claude Resources.

Australians explore for diamonds in the United States. A major diamond exploration of seven kimberlite pipes in Wisconsin and the Upper Peninsula of Michigan will be undertaken as a joint venture between Dow Chemical Co. and Crystal Exploration Co. of Colorado. Crystal, which recently was purchased by Karonic Gold NL of Australia, retained the right to acquire up to 71% interest in the venture.

Gem-quality diamonds reportedly have been found in the sites marked for exploration. Further sampling and air/ground magnetics will be done to prepare for drilling.

Joint venture with De Beers in Australia. Stockdale, a De Beers subsidiary, will join with Max Resources of New Zealand to explore for diamonds in an area near Skull Creek, south of Darwin in Australia. Under the terms of the joint venture agreement, De Beers will get 80% interest by spending $400,000 on exploration. Max Resources will receive 20% interest by contributing pro-rata to the program. Initial samples from the area revealed a microscopic-size diamond and one, probably kimberlitic, chromite grain.

New De Beers mine in Namibia. Consolidated Diamond Mines, a De Beers subsidiary, will open a new diamond mine at Elizabeth Bay, Namibia. Production, scheduled to begin in 1991, is estimated at 250,000 ct annually.

In addition to the new mine, Namibia also is getting its first diamond-sorting facility, to be operated by the Central Selling Organization in the Namibian capital of Windhoek. The facility will process 95,000 ct per year. Previously, all Namibian diamonds were sorted in Kimberley, South Africa.

COLORED STONES

Amethyst in Maine. The only active amethyst mine in New England entered full operation this summer at the unlikely location of a summer music camp in the town of Sweden, near Stearns Pond in Maine. Crystals were first found in November 1987 by workers digging gravel for a septic system on land owned by the Saltman family adjacent to their Camp Encore-Coda. Plumbago Mining Corp. is working the operation for the Saltmans.

The mine got off to a slow start because of tight restrictions placed on the venture by the Planning Board of Sweden. Phillip McCrillis, of Plumbago Mining, reports that only 1,500 lbs. (about 680 kg) of gem- and specimen-quality amethyst were mined in summer 1988, compared to 5,000 lbs. (about 2,270 kg) from June 1–September 1, 1989. Most of the material is specimen quality, with the largest crystals measuring up to 4 in. (10 cm) × 6 in. (15 cm). Many of the crystals are doubly terminated.

Because Plumbago has been concentrating on the mining operation, little material has been cut thus far. To date, the largest faceted stone is 12 ct. McCrillis anticipates, however, that the material found most recently will yield stones in the 20+ ct range. Heavy zoning in the crystals makes it difficult to cut extremely large stones.

The amethyst is found in a quartz seam in schist. As of September 1989, Plumbago Mining had determined that the seam is at least 40 ft. long by 10–12 ft. deep, with no indication yet that it is "pinching out." Because the seam is very close to the surface, with a gravel layer of less than 6 ft. (2 m), mining requires only a small bulldozer and backhoe to move the gravels and small amounts of dynamite to penetrate the quartz. The crystals are then removed by hand. Two full-time miners and a number of volunteers work the deposit when weather permits.

Prior to the Sweden find, amethyst had been recovered from Pleasant Mountain in Sebago and from Deer Hill in Stow, which are located in the same region. All of the Sweden amethyst is currently being distributed through Plumbago Mining Corp., Rumford, Maine.

McCrillis also reported that Plumbago Mining Corp. would be reopening the famous Mt. Mica (Maine) tourmaline mine in fall 1990.

Amethyst scepters from Malawi. Si and Ann Frazier of El Cerrito, California, report a recent find of amethyst scepters from a previously unknown locality in Malawi, west of Mchinji, near the border with Zambia. The scepters reportedly have good luster and color; the most spectacular ones are asymmetrically set on their stems. Furthermore, the amethyst color is distributed fairly sectorially, with some showing both blue and purple sections. Most of the specimens have significant inclusions of lepidocrocite and/or goethite needles; in some, these inclusions outline phantom crystals. One of the Gem News editors has seen at least 50 of these crystals at one time, the largest about 3 cm high.

Amethyst-citrine update. GIA librarian Robert Weldon recently visited Bolivia and provided Gem News with an update on amethyst-citrine (figure 2). This quartz variety is produced at a locality known as La Gaiba, in the southeastern province of Santa Cruz, that is no longer being worked systematically. When the mine was in full operation, much of the material was obtained through arbitrary and destructive blasting with dynamite. In addition, large quantities of the material were reportedly smuggled across the border into Brazil and sold as Brazilian production. Although a May 30, 1989, report in the Bolivian newspaper *Los Tiempos* maintained that the mine was officially closed, amethyst-citrine continues to be readily available (even within Bolivia) and it

Figure 2. The amethyst-citrine (35 × 7 × 7 mm) in this pin came from La Gaiba, Bolivia. Brooch by C. Y. Sheng; photo by Robert Weldon.

is believed that much night-time "*guaquero*-style" mining occurs.

The above-cited report also stated that the Bolivian government was preparing to extend a public invitation to any Bolivian entities interested in exploiting the La Gaiba resources in a systematic and controlled manner.

Fine aquamarine from India. Good-quality aquamarine is known to come from the state of Orissa in eastern India. Less well known, however, is the occasional discovery of some exceptionally fine, large aquamarines in Madras State in the southeast of the country. Ms. Charlotte B. Crosby arranged for the Gem News editors to examine an exceptional 41.76-ct aquamarine (figure 3) from this locality.

Mr. Shanti Kumar Shah of Indogems, Inc., New York, reports that the stones are found near Kangyam, a small farming town located in a remote area several hundred kilometers inland from Madras City. There is no organized mining activity, and the stones are recovered from alluvial deposits by local villagers, farmers, and fishermen who search the river banks and bottom silt. Within about a 200 km radius of Kangyam are also found ruby, sapphire, iolite, amethyst, sphene, moonstone, enstatite, and cat's-eye quartz.

The gemological properties of the sample Kangyam aquamarine were consistent with those reported for aquamarines from other localities; magnification revealed only graining. The most notable feature of this stone—other than its exceptional color—was the presence of strain with a "laminated" appearance that was quite evident in polarized light. The strain also manifested itself in the form of a biaxial interference figure that was seen in only some areas of the stone. Mr. Shah reports that the stone has never been heat treated.

Brazil update. On a recent trip to Brazil, one of the Gem News editors had an opportunity to tour some of the mines in the area around Teófilo Otoni, in Minas Gerais.

Figure 3. This 41.76-ct aquamarine came from Madras State in India. Courtesy of Indogems, Inc.; photo by Robert Weldon.

Two of the mines were eluvial deposits located in the general area of Ponto de Marambaia. One was approximately 65 km north of the town of Teófilo Otoni and produces aquamarine and colorless topaz almost exclusively. The other, far more extensive, diggings were located approximately 20 km east of the town of Tres Barras. This area is currently producing a number of gem materials, most notably cat's-eye chrysoberyl and aquamarine; recently, a fine 30-gram piece of cat's-eye chrysoberyl and several fine aquamarines over 100 grams each were found there. The area also produces colorless beryl that reportedly is irradiated to a golden color, as well as alexandrite, cat's-eye alexandrite, colorless topaz, occasional morganite, and some diamonds.

The other area visited was reached by traveling 32 km south of Teófilo Otoni to the town of Itambacuri on a paved road, then west approximately 36 km on a dry-weather dirt road; the final 2 km were on little more than a cow path. The mine, a primary pegmatite (figure 4), was producing aquamarine crystals that showed evidence of extensive heat damage. Some of these, however, had good clean cores up to 10 grams (50 ct); according to one of the individuals involved in the mining, these produced faceted stones up to 10 ct (figure 5). It was also stated that the paler material was being irradiated to produce a golden color.

The editors would like to thank Marcus Catta Preta of Catta Preta Pedras Preciosas and Joseph Crescenzi of

Figure 4. A garimpeiro *examines the rock face in a Brazilian pegmatite mine after blasting with dynamite. Photo by Robert C. Kammerling.*

Minatex Export Ltda., both in Teófilo Otoni, for arranging the trips to the mines and providing information for this report.

Crystal chandeliers made by nature. An underground chamber lined with large quartz crystals was discovered in the mountains of the Namib desert in Southwest Africa. Hannes Kleynhans, the chief stockholder in the Amethyst Mining and Export Company, was exploring the site for tourmaline with his 100-man crew when two drillers suddenly had their 32-m-long drill disappear into an underground cavity. After months of work to open the chamber, Kleynhans and his team were rewarded with a bounty of quartz crystals that protruded out of the walls like porcupine spikes or chandeliers. One specimen is estimated to weigh 13 tons.

To retrieve the huge crystals, the miners loosen each one individually and lower it into a sleigh made of truck tires. The process is slow, but Kleynhans said he is willing to take as long as necessary to insure that none of the long crystal arms is chipped or damaged.

Figure 5. Heat-damaged aquamarine crystals from a primary deposit west of Itambacuri, Minas Gerais, Brazil, are trimmed with pliers to expose their cuttable cores. Photo by Robert C. Kammerling.

Santa Terezinha–emerald treatment. It is generally known that emeralds with surface-reaching fractures are routinely oiled or otherwise filled to lower the relative relief of the fractures, making them less noticeable and thereby improving the stone's overall appearance. A number of different filling agents have been used; two of the most popular in Colombia are Canada balsam (a resin) and cedarwood oil.

Recently the fracture-filling process used by miners on emeralds from Santa Terezinha de Goiás, Brazil, was described in detail to one of the Gem News editors by two individuals involved in the Brazilian gem trade. This process employs a synthetic fracture sealant marketed under the trade name Opticon (figure 6).

The stones are washed in hot soapy water and dried under a 100-watt incandescent bulb. At the same time, the Opticon is heated in a separate container also under a bulb. Once dried, the stones are placed in the filling

material for several hours again under the 100-watt bulb. They are then removed and those that have taken the treatment well enough are sold as rough, as is. Material requiring additional treatment is heated further, now under pressure, with more Opticon. Most of these stones, too, are sold as rough, although additional treatment, including the use of a fracture sealant, may be performed on some of the material after it is faceted. A detailed article on this procedure is in preparation.

The editors would like to thank Joseph Crescenzi of Minatex Export Ltda. and Acyr Tadeu Flores Catapreta Ramos, both in Teófilo Otoni, for providing the information contained in this report. Thanks also to David Stanley Epstein of Precious Resources Ltda., Teófilo Otoni, for providing a specimen for examination.

Large bicolored sapphire. Not only is Australia a major producer of sapphires, but some of the sapphires from that country are notable for the zones of different colors they exhibit. Particolored stones that range from yellow with a touch of green to green with a touch of yellow are sometimes referred to as "wattle" sapphires.

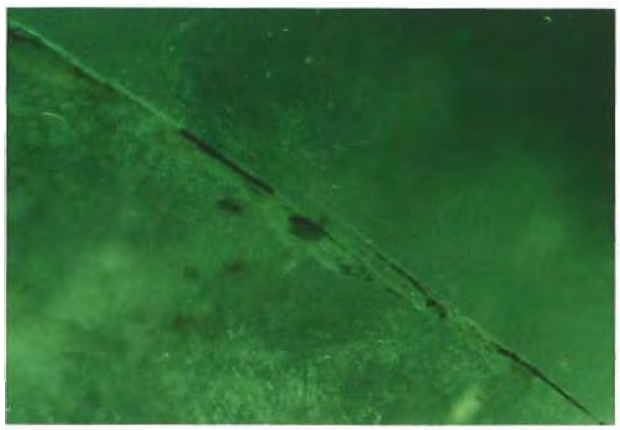
Donald L. Cook of Rio Linda, California, recently showed us a very large Australian sapphire with an unusually sharp demarcation between the sole yellow and green zones (figure 7). This waterworn crystal fragment was named the Kingsley sapphire after its discoverer, John Kingsley. He found the stone while shaft mining in an old river bed in an area known as Fancy Stone Gully, approximately 10 km west of Rubyvale on the Anakie Gem Fields, Queensland. The 162.26-ct bicolor measures 33.00 × 29.50 × 16.80 mm.

Kanchanaburi sapphires. The Kanchanaburi area of Thailand is currently a significant producer of blue sapphires. These stones, like those from a number of other localities, are often heat treated. The resulting color is somewhat reminiscent of heat-treated Sri Lankan sapphires, although in general the darker colors tend to be "sleepier," while the less saturated colors have more of a grayish component. Evidence of heat treatment in a number of these sapphires was revealed by an interesting internal feature: a series of small dark blue pinpoint-like inclusions resembling ink drops.

Recently, the inclusions in untreated Kanchanaburi sapphires were described to one of the Gem News editors by Mr. Tom Ba Ross, of S. P. Color Stones Co. in Bangkok. These include silk, which may be in a fine, dust-like form similar to that seen in some Burmese sapphires, or as longer, acicular crystals reminiscent of those seen in stones from Sri Lanka. In general, the Kanchanaburi stones lack liquid feathers or other solid inclusions, with the exception of what appear to be boehmite needles and silver-gray apatite crystals of typical habit.

Figure 7. This 162.26-ct bicolored sapphire from Australia is unusual for both its large size and the sharp demarcation between the two zones. Photo by Shane McClure.

Figure 6. Although the fracture in this Santa Terezinha emerald is visible where it breaks the surface, the Opticon filling makes it less apparent within the stone. Photomicrograph by John I. Koivula; magnified 35×.



Underwater treasure hunt in Thailand. *Bangkok Gems & Jewellery* reports that the government of Thailand is working with the United Nations Department of Technical Cooperation for Development (DTCD) to search for valuable metals and gems off Thailand's east coast in the Gulf of Thailand. Experts working out of Rayong, southeast of Bangkok, hope to find titanium, zirconium, and gold, as well as rubies and sapphires. They believe that the producing corundum deposits on shore extend under the waters of the gulf.

Thailand's Department of Mineral Resources has worked with the DTCD since 1978. They first collaborated on exploration of the Andaman Sea, which yielded a promising tin deposit.

Unusual tourmalines from Brazil. Stanley Brainin of Brainin & Davenport, Malibu, California, reports that

Figure 8. The new tourmaline deposit at Paraíba is producing fine stones in a variety of unusual colors. These stones, 0.42–0.71 ct, are courtesy of Julius Petsch; photo by Robert Weldon.

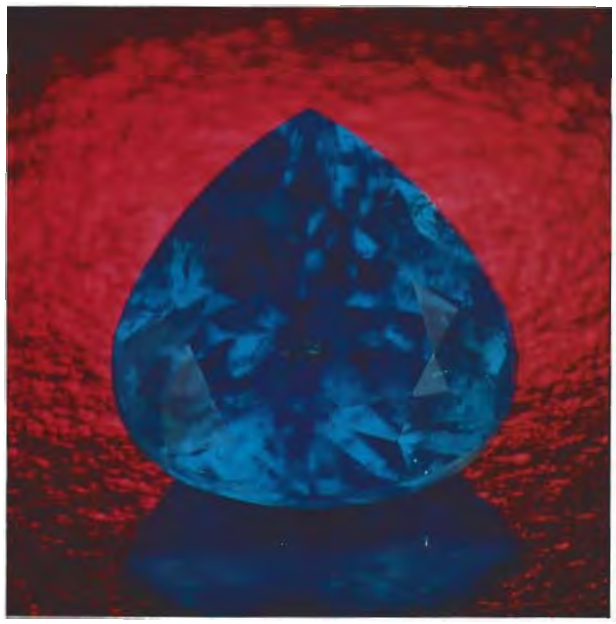


Figure 9. This fine blue 1.15-ct tourmaline from the new deposit at Paraíba, Brazil, resembles tanzanite in color. Stone courtesy of Brainin & Davenport; photo by Robert Weldon.

tourmaline of unusual colors is being recovered from a new mine in Paraíba, Brazil. The stones examined by the Gem News editors ranged in color from a highly saturated medium bluish green to medium dark blue-green to a dark blue to violetish blue (figure 8). Some of the blue-green stones had the saturation and depth of color associated with emeralds but with a much stronger blue component. The blue stones were reminiscent of fine sapphires of a color often associated with material from Sri Lanka; a few stones – those with the strongest violet component – were very similar in color to tanzanite (figure 9). Mr. Brainin and others report that the material is available in limited quantities and sizes, with most of the rough less than 3 grams and most of the cut stones less than 1 ct. David Epstein, of Teófilo Otoni, has seen a specimen-quality crystal of 100 grams and a cuttable piece of 12 grams from this locality. The largest faceted stone he had seen as of September 1989 is a 15.18-ct blue oval in the collection of K. Elawar of Teófilo Otoni. According to Daniel Sauer of Rio de Janeiro, the name of the mine is São José da Batalha and it is privately owned.

PEARLS

Interesting cultured blister pearl. Experiments in pearl culturing date back to 13th-century China, when a native of Hou-Tcheon-Fou reportedly first inserted objects between the shell and the mantle of pearl-producing mollusks, thereby stimulating the mollusk to coat the insert with nacre. The Chinese have continued this practice over the centuries, often placing metal figures of Buddha in the indigenous freshwater mussel, *Cristaria plicata*. One of these shells, with multiple nacre-coated Buddha images, is illustrated on page 523 of Webster's *Gems* (4th ed., 1983).

On a recent trip to Guangzhou, in southern China, one of the Gem News editors purchased an interesting cultured shell that contains a large (13.5 × 9.1 cm) blister pearl in the form of the goddess Kwan Yin (figure 10). X-radiography of the shell by Robert E. Kane, of the GIA Gem Trade Laboratory, revealed that the blister pearl image had essentially the same X-ray transparency as the surrounding shell, thereby ruling out a metal insert. The insert may be a piece of carved shell or other substance, such as plastic, with a similar X-ray transparency.

SYNTHETICS AND SIMULANTS

Chinese "jade" update. A number of translucent to opaque green ornamental materials have long been used as simulants for jadeite and nephrite. These simulants are often sold as jade varieties under such place names as "Korean jade" (bowenite serpentine), "Fukien jade" (soapstone), "Indian jade" (aventurine quartz), "African jade" (hydrogrossular garnet), and "California jade" (californite idocrase).

Recently, one of the Gem News editors had an

Figure 10. A 13.5 × 9.1 cm figure of Kwan Yin has been cultured on this Chinese freshwater mussel shell. Photo by Robert Weldon.

opportunity to visit the Guangzhou South Jade Crafts Factory in Guangzhou (formerly Canton), China. According to a promotional brochure provided in the showroom, this factory is the exclusive producer of "jade carving balls," a series of concentric spheres carved from a single piece of rough. This same brochure also stated that the "jade carving balls manufactured by this factory are of Burmese Jadeite and Chinese Jade."

The editor thus found it interesting that the vast majority of the material he saw being fashioned appeared to be bowenite serpentine (figure 11), with a much smaller amount of lower-quality jadeite also being worked. No nephrite jade, which is known to occur in western China, was seen. A number of workers were asked about the identity of the material being carved, and all stated that it was jade. This is in keeping with published reports that in the Chinese language, "jade" refers to a much broader category of materials than is recognized by Western gemologists.

Imitation opalized shells. Opalized shells – more correctly called opal pseudomorphs after shell – make unusual and interesting collectors' items. These specimens

Figure 11. This Chinese artisan uses a lathe drill to fashion a "jade carving ball" that had the appearance of serpentine. Photo by Robert C. Kammerling.

are recovered from time to time in the opal fields of Australia and result from the replacement of shells by opal through the action of silica-rich groundwaters.

Susan B. Johnson, assistant director of education at GIA, recently showed the Gem News editors three unusual imitations of opalized shell she obtained in Australia from an individual who believed them to be genuine. One resembled a clam shell, another had the outward form of a mussel shell, and the third looked like a turban snail shell (figure 12).

The specimens immediately caused suspicion because they appeared to be composed of dark yellow-

Figure 12. These three imitation opalized shells are composed of opal and matrix fragments in a plastic binder. The clam shell measures 4.5 cm × 3.5 cm. Photo by Robert Weldon.

brown brecciated boulder opal. It would be difficult to explain how comparatively large pieces of breccia could replace the original shells while allowing them to maintain their outward shape. Magnification revealed that all three "opalized shells" consisted of numerous chips of white opal, boulder opal, and matrix rock held together with a transparent, colorless binder. Additional testing for hardness, thermal reaction, hydrophobic/hydrophilic reaction, refractive index, and ultraviolet fluorescence revealed that the binding agent was a plastic.

Acknowledgment: The Gem News editors would like to thank Jennifer Rowland, GIA public information assistant, for her help in preparing this column.

ANNOUNCEMENTS

The Tucson Gem and Mineral Show will be held February 7–11, 1989 at the Tucson Community Center. The featured mineral for the show is wulfenite. For more information, contact the Tucson Gem and Mineral Society, P.O. Box 42543, Tucson, AZ 85733.

The Gemological Institute of America will present various lectures and seminars in Tucson February 3–11. For information, call (800) 421-7250, ext. 227, or write GIA, P.O. Box 2110, 1660 Stewart St., Santa Monica, CA 90406.

The American Gem Trade Association will be in Tucson February 3–9 at the Convention Center. They will announce the winners of the Spectrum Awards (a jewelry contest aimed at the effective use of colored stones) at that time. For information, contact the AGTA headquarters at the World Trade Center #181, P.O. Box 581043, Dallas, TX 75258, (214) 742-4367; for reservations call (800) 972-1163.

The Bangkok International Jewelry Fair will be held March 12–14, 1990. At the fair will be hundreds of Thai and international exhibitors. For information contact Headway Trade Fairs Ltd., 9/F Sing-Ho Finance Building, 168 Gloucester Road, Hong Kong. Call 5-8335121 or fax 5-8345164.

Israel's annual Showcase '90 will be held January 9–11, 1990, at the Jerusalem Convention Center, Jerusalem. Contact Israel Export Institute, Jewellery Centre, 29 Hamered St., Tel-Aviv, 68125, Israel. Telephone (03) 630830.

Bijorhca will be held January 11–15, 1990 at Ville Pinte, Paris Nord, France. Contact BOCI, 26 Rue de Renard, 7500r Paris, France. Telephone (42) 773296.

Inhorgenta 90 will be held February 9–13, 1990, at the Munich Trade Fair Centre, Munich, West Germany. Contact Münchener Messe- und Ausstellungsgesellschaft mbH, Messegelande, Postfach 121009, D-8000 München 12, West Germany. Telephone (089) 51070.

Metal Media, a juried exhibition showcasing artistic approaches to the medium of metal, including jewelry, pewterwork, flatware, and enameling, is now soliciting entries. Any U.S. resident may submit slides of up to three works. Prizes from $100 to $500 will be awarded. Chuck Evans, author of *Jewelry: Contemporary Design and Technique,* will serve as judge. The entry deadline is March 15. Send your entries to the Sawtooth Associated Artists Gallery, 226 N. Marshall St., Winston-Salem, NC 27101. Telephone (919) 723-7395.

BOOK REVIEWS

Elise B. Misiorowski and Loretta B. Loeb, Editors

JEWELRY ON DISPLAY, 3rd edition

*By MariAnn Coutchie, 107 pp., illus., publ. by ST Publications, Cincinnati, OH, 1989. US$23.95**

Jewelry on Display is an excellent reference that will help every jeweler create displays that are both attractive and sell merchandise. In this book, Coutchie clearly and thoroughly presents information on designing a display. She covers the composition of symmetric and asymmetric displays and why these standard arrangements are effective. She also points out that a designer works not only with the individual pieces of jewelry, the presentation displayers, and the props, but also with the space or area of the display.

The most important information that this "handbook" provides is the psychology behind creating a display. The book clarifies aspects of a display that one may not have been conscious of before. For example, just as planned lighting can direct the customer to shop in certain areas of the store, it can also cause a viewer's eye to focus on a particular area of a display. In addition, the use of certain color combinations can produce a balance in the color scheme, and can influence one's emotions when viewing the display. The author warns that if some of these factors are overlooked when designing a display, it could reduce the display's overall effectiveness.

Coutchie discusses signage as well, and provides many excellent guidelines on size, layout, lettering, and typefaces to help make signs more noticeable, legible, and informative. Also mentioned here is the value of exterior signs.

Another section gives necessary and descriptive information on window and showcase dimensions, and on how to cover and keep presentation displayers and flooring in good condition. Included, too, are discussions of basic store planning, security, and photographing window displays.

Many black-and-white photographs, along with a section of color photographs, visually clarify some of the items discussed in the chapters, making this book a treat to the eye. One may find several useful ideas in the chapters on "Themes," "Special Promotions," and "Christmas."

A helpful addition might have been examples of displays that didn't work and a critique of why they were not effective selling tools. However, this is a small caveat given the considerable amount of information included in this useful book. *Jewelry on Display* is a "must" for every retail jeweler.

HOLLI LUTHER
Jewelry Display
Home Study Instructor
GIA, Santa Monica

WORLD MAP OF GEMSTONE DEPOSITS

*By Dr. Edward Gübelin, publ. by the Swiss Gemmological Society, Lucerne, Switzerland, 1988. US$24.00 (paper), US$59.95 (laminated)**

At last we have a definitive world map that gives the locations of nearly all major gemstone deposits. The 36 in. × 51 in. (91 cm × 125 cm) map follows a conformed Mercator projection colored with light blue seas and soft green land surfaces. Two formats are available: a flat "frameable" version and a convenient fold-out. Brightly colored symbols depicting the particular gemstones found at each mine location stand out in good relief. To maximize its usefulness, all text is provided in English, German, French, Italian, Spanish, and Portuguese.

The legend at the bottom of the map identifies the individual gem species or groups to which the 34 coded symbols refer; of necessity the symbols are small (3 mm in diameter). The various gems are separated into four sections: precious gems, collectors' gems, ornamental gems, and rare ornamental gems. Each gem species is awarded a particular color or group of colors. On the map itself, different exterior configurations are given to each gem symbol to indicate the type of geologic deposit that produced the gem. Confusing? A little, but with a few moments of study the system begins to unfold into a clever plan that places considerable data into a relatively small area—a factor to be appreciated by the reader.

The reverse side of the map contains attractive full-color photos of 240 cut gems and carvings. Accompanying the gems are 40 color photos that beautifully illustrate gem mines and mining activities from around the world. Again, the descriptive text is provided in six languages. The gem materials and photographs are from the fabulous private collection of Dr. Gübelin. It is a pity that the back of the map cannot be seen easily without flipping it over, but the wise jeweler/gemologist can solve this problem by displaying *two* maps.

The *World Map of Gemstone Deposits* can be a valuable tool for the jeweler who wants to "ready a customer to buy." In fact, it is a welcome source of information for all gemologists, as well as for those travelers who seek the unusual.

DR. PETER BANCROFT
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GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Australian colour-changing sapphire. G. Brown and S. M. B. Kelly, *Australian Gemmologist*, Vol. 17, No. 2, 1989, pp. 47–48.

This brief Gemmology Study Club Report covers an interesting sapphire from the central Queensland sapphire fields. Most of the stone exhibited a bluish coloration and strong angular color zoning, but one small area was a distinct orange. Because of this unusual color patterning, the stone appeared bluish when viewed in daylight or illuminated through the major bluish component, but appeared reddish blue or dark purplish blue when viewed in incandescent light or when deliberately illuminated through the orange color zone.

In spite of the article's title, the authors correctly state that the stone does not display a "true alexandrite effect." The report includes a list of the stone's gemological properties and a good discussion of its inclusions.

RCK

Colour of natural spinels, gahnospinels and gahnites. K. Schmetzer, C. Haxel, and G. Amthauer, *Neues Jahrbuch für Mineralogie Abhandlungen*, Vol. 160, No. 2, 1989, pp. 159–180.

The authors systematically investigated the cause of color in spinel, gahnospinel, and gahnite using ultraviolet-visible, near-infrared, and Mössbauer spectroscopy. All colors are attributed to metal ions. In the more than 300 stones investigated, the great variability in color was found to be due to the superposition of absorption features produced by different metal ions.

The authors define four color "poles" as follows. Pole A: Spinels with mostly Cr^{3+} and V^{3+} in octahedral sites are pink to red. If the V^{3+} concentration is high, the color shifts toward orange. Pole B: Spinels with mostly Fe^{2+} in a tetrahedral coordination and variable amounts of Fe^{3+} in an octahedral site tend to be purplish blue. Pole C: If Fe^{2+}-Fe^{3+} charge transfers are superimposed on the preceding case, the color is bluish green. Pole D: Stones containing even very small amounts of Co^{2+} (1 to 6

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ppm) in tetrahedral coordination display a bright "cobalt-blue" color.

Various combinations of these "color poles" can be observed in nature. Four "color lines" are identified, which represent the possible combinations of two "color poles" found in natural spinels. These are between poles A and B, B and D, B and C, and C and A. In the last two lines, the intermediate colors have a distinct gray component. In the unusual case of green gahnite from Brazil, the color is mostly due to Fe^{2+} in octahedral sites. Minor amounts of Mn^{3+} also in octahedral sites have been identified but do not seem to affect the coloration significantly. *EF*

Coupled substitutions involving REEs and Na and Si in apatites in alkaline rocks from the Ilímaussaq intrusion, South Greenland, and the petrological implications. J. G. Rønsbo, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 896–901.

To understand the causes of some gemological properties, such as color and luminescence, it is necessary to understand the composition variation in gem minerals. Of particular importance in this regard are the rare-earth elements that are often found in apatites. The Ilímaussaq intrusion in southern Greenland consists of highly undersaturated and differentiated alkaline rocks that are enriched in incompatible elements such as Zr, Nb, Ce, La, U, and Th. As a result, the augite syenites and nepheline syenites of the intrusion contain a variety of either unusual minerals or common minerals with unusual compositions. Apatite is an important mineral for understanding the geologic processes that formed these rocks because it is one of the minerals in which rare-earth elements (La to Lu + Y) concentrate.

Apatites from the intrusion contain up to 16 wt.% REE_2O_3, as determined by microprobe analysis. The rare-earth elements are incorporated in the apatite crystal structure as a result of two coupled substitutions. The geologic implications of these reactions for the petrogenesis of both the apatites and their host rocks are discussed. *JES*

Eskimo staples. J. C. Zeitner, *Lapidary Journal*, Vol. 43, No. 5, August 1989, pp. 59–65.

This article describes many of the tools, weapons, and art objects created by Eskimo peoples from ivory, bone, and stone. Some of the more obscure materials used include amber from Point Barrow, pectolite and magnetite, and several varieties of chalcedony.

Most of these materials were sought primarily for their usefulness in helping the Eskimo survive Arctic conditions, but much fine artwork using walrus ivory, mastodon tusk, whalebone, soapstone, and nephrite, among others, has been produced. Practical applications and artwork alike are described in this article, as well as localities for most of the raw materials. *WRV*

Gems of the Mud Tank carbonatites. G. Brown, H. Bracewell, and J. Snow, *Australian Gemmologist*, Vol. 17, No. 2, 1989, pp. 52–57.

The Mud Tank carbonatites, a series of explosively intruded, carbonate-rich magmatic pipes located in central Australia, consist primarily of calcite, apatite, zircon, magnetite altered to martite, and minor phlogopite mica that also has altered to martite. The main gem diggings are located north of the line of carbonatites at a site called Zircon Hill.

Zircon fragments and rare crystals which are capable of yielding transparent cut stones up to 10 ct have been recovered. Colors include pink, purple, brown, and orange-yellow; some stones will heat treat to colorless. Additional properties of these high zircons are as follows: Mohs hardness of 7 to 7½; S.G. of 4.66–4.69; R.I. of o = 1.923, e = 1.982; birefringence of 0.059; uniaxial positive; sub-adamantine luster; weak pleochroism as slight variants of the body color; yellow fluorescence to long-wave U.V. radiation, inert to short-wave U.V. (except brownish stones with no visible absorption lines, which fluoresced yellow, and heat-treated colorless specimens, which fluoresced weak pale blue). A number of inclusions were observed: short, prismatic, high-relief crystals with strain halos; lathe-like brownish minerals; rounded crystals surrounded by a shrinkage feature or a decrepitation halo; and partially healed fractures.

Also recovered at Zircon Hill are highly fractured masses of yellowish green to greenish yellow apatite which yield transparent to translucent cabochons of under 2 ct. Properties include a hardness of 5; S.G. of 3.21; R.I. of o = 1.640, e = 1.645 (1.64 spot R.I.); birefringence of 0.005; vitreous luster; weak pleochroism (golden yellow/greenish yellow); no fluorescence to long- or short-wave U.V. radiation; and an absorption spectrum of two weak bands of fine lines at 520 nm and 580 nm. Inclusions noted were multiple partially healed fractures, epigenetically stained fractures, and bluish green "tubes" of hexagonal cross-section parallel to the c-axis.

Nineteen macro photos and photomicrographs accompany the article. *RCK*

Growth structure and crystal symmetry of grossular garnets from the Jeffrey mine, Asbestos, Quebec, Canada. M. Akizuki, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 859–864.

Orange, green, and colorless grossular garnets from the Jeffrey mine were examined to account for their anisotropic optical character. Along certain crystallographic planes, there is a noncubic, ordered arrangement of Al^{3+}, Fe^{3+}, and/or OH ions in the orange garnets. This leads to a monoclinic symmetry. Striations seen on some crystal faces are due to unequal growth along competing directions in the crystal. Surface patterns on crystal faces of the green and colorless garnets,

however, suggest orthorhombic symmetry. Details of the relationship between crystal structure and nature of crystal growth for these garnets are discussed. *JES*

Siliciophite: Australian 'cat's-eye opal.' G. Brown, *Australian Gemmologist*, Vol. 17, No. 2, 1989, pp. 48–51.

Siliciophite, a gem material recovered from various localities in southern Australia, Western Australia, and Tasmania, is described as "chrysotile asbestos impregnated with common opaline silica." When properly oriented and fashioned *en cabochon*, the material yields stones that range from being distinctly chatoyant to having broad, diffuse silky "flashes."

The color of Western Australian siliciophite varies from yellowish green to yellowish brown to brown. It has a Mohs hardness of 6; an S.G. of 2.13; an R.I. of 1.455 (singly refractive); a diaphaneity ranging from semitransparent to translucent; a resinous luster superimposed with a strong chatoyancy; is inert to both long- and short-wave U.V. radiation; and shows no diagnostic absorption spectrum, displaying only complete absorption below 480 nm.

Microscopic examination of specimens revealed parallel oriented fibers of chrysotile asbestos completely surrounded by an opaline matrix, fractures that had been completely healed by an inflow of common opal, partially healed fractures containing two-phase inclusions, black octahedra (possibly chromite), and greenish brown flakes (possibly chlorite). Also noted was the broad range in diameter of the chrysotile fibers.

This article is well illustrated, with five macro photos and seven photomicrographs. *RCK*

DIAMONDS

$^{40}Ar/^{39}Ar$ laser-probe dating of diamond inclusions from the Premier kimberlite. D. Phillips, T. C. Onstott, and J. W. Harris, *Nature*, Vol. 340, August 10, 1989, pp. 460–462.

Because of their chemical inertness and high temperature/pressure stability, diamonds provide a host setting for mineral inclusions that shields them from interaction with the surrounding environment. Consequently, diamonds and their inclusions offer a unique opportunity to study the chemistry of the earth's mantle at the time of diamond formation. This investigation involved determination of the ages of some eclogitic-suite clinopyroxene inclusions in diamonds from the Premier kimberlite in South Africa.

Clinopyroxene contains small amounts of potassium, which decays over geologic time to argon. Measurement of the concentrations of several isotopes of argon using a laser microprobe allows a determination of the date of inclusion formation. Apparent ages for seven clinopyroxene inclusions studied range from $1,111 \pm 35$ to $1,254 \pm 38$ million years, with an average of $1,185 \pm 94$ million years. These values agree well with the ages determined by other isotope-dating methods. They are also indistinguishable from the inferred time of emplacement of the host kimberlite (1,150–1,230 million years). This implies that diamond formation was essentially synchronous with kimberlite generation. The paper concludes with a brief discussion of the assumed chemistry of the mantle from which the diamonds and their inclusions formed. *JES*

Black diamonds of type IIb. S. Scandella, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 411.

Mr. Scandella reports on the observation of two type IIb diamonds in a parcel of five—two rough and three faceted—black diamonds recently examined at the Gübelin Gemmological Laboratory. The absence of dark green irradiation spots led to the conclusion that they were of natural color. They were determined to be type IIb stones based on the fact that they showed electrical conductivity of 220 volts. *CMS*

Discovery of ancient source rocks of Venezuela diamonds. P. H. Nixon, G. R. Davies, E. Condliffe, R. Baker, and R. B. Brown, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 73–75.

This article summarizes information on the discovery in 1982 of source rocks of the alluvial diamonds that have long been mined in Venezuela. The rocks, in the Guaniamo district of Bolivar province, consist of yellow-green smectites, which are the weathered products of the original diamond-bearing kimberlite. The rocks occur as dikes and sills that have been exposed over a distance of 7 km. Details of the composition and mineral chemistry of these unusual rocks are presented. *JES*

Famous diamonds of the world XXXV: Cleveland. I. Balfour, *Indiaqua*, Vol. 50, No. 2, 1988, pp. 139–140.

The Cleveland diamond was at one time the largest diamond ever cut in the United States. The 100+-ct rough that produced the Cleveland was purchased in London in 1884 by David Dessau and his son Simon. It yielded the 50-ct cushion-shaped diamond that was subsequently named after Grover Cleveland, the 22nd president of the United States.

The stone eventually came into the possession of Minnie Palmer, "a musical comedy star of the time," possibly a gift from Simon Dessau himself. The whereabouts of the Cleveland is unknown today, despite the 1966 announcement by Simon Dessau's grandson that he wanted to buy it back. *JLC*

Famous diamonds of the world XXXVI: Punch Jones. I. Balfour, *Indiaqua*, Vol. 50, No. 2, 1988, pp. 140–141.

The 34.46-ct Punch Jones, a "greenish grey octahedron" with "peculiar surface markings," is one of the largest

diamonds ever found in the United States. As of its sale at auction in 1984, it had never been faceted. The Punch Jones diamond was discovered in April 1928 in West Virginia. Balfour first describes its discovery in relation to the geology of other diamond localities in the United States. Next, he tells the story of how the diamond was found while William P. (Punch) Jones and his father were playing horseshoes in a vacant lot. For this reason the Punch Jones is sometimes called the "Horseshoe." Various explanations, repeated here by Balfour, have been proposed to explain the occurrence of this diamond in West Virginia, including the most likely theory that it was transported by a stream from an unknown region. *JLC*

The four optical attributes of a diamond. J. B. Nelson, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 434–447.

Dr. Nelson discusses at length the nature of luster, brilliance, fire, and "sparkliness" of diamond. He also describes an optical device that traces ray paths two-dimensionally through various cut proportions and demonstrates the different optical effects that occur in a gem. The author concludes with an appeal for standardization of the terminology used to describe the optical attributes of diamond. He recommends three terms of compound definition—*brilliancy*, *scintillation*, and *liveliness*—for qualitative description in English. Ten black-and-white illustrations accompany the article. *CMS*

History of the New York diamond industry. *New York Diamonds*, No. 5, 1989, pp. 62–68.

Although New York's diamond-cutting industry is much younger than that of Europe, it is still full of innovation and tradition. Less than 100 years ago, diamond cutting was a very small industry in New York, New Jersey, and Boston, with no labor pool from which to draw cutters. Just after World War I, one company brought in 20 boys from a Jewish orphanage to begin their training. In the early 1920s, these boys became the core of a very strong union that remained powerful for the next two decades.

World War II, however, brought great changes. Since no cutting was being done in Europe, De Beers focused on the U.S. As apprentices were drafted to fight in the war, however, women were hired to fill these positions. The union called a strike to fight this violation of their rules, but the higher wages the New York manufacturers could afford to pay brought the cutters back to work and essentially broke the union.

By the mid-1940s, much of the diamond industry had moved uptown to its present location on 47th Street. Cutters were now being paid by the piece, rather than by the hour. To this day, it is too difficult and expensive to train American youths to cut diamonds in New York. Therefore, the trade looks to labor coming from outside the country, now from Israel and Puerto Rico.

Phil Yurkiewicz

Inclusions in diamond from Chinese kimberlites. Z. Andi and H. O. A. Meyer, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 1–3.

The authors investigated the chemistry of mineral inclusions in diamonds from kimberlites in the provinces of Shandong and Liaoning. In Shandong, diamonds from the Chang-ma, Xi-Yu, and Poli kimberlites in the Mengyin district were studied. In Liaoning, the diamonds came from the Fuxian, Tieling, and Huan Ren kimberlite groups.

The majority of the inclusions belong to the ultramafic (or peridotitic) suite, but several eclogitic-suite inclusions were also identified. Chemical composition data are presented for olivine, pyroxene, garnet, and chromite inclusions. These inclusions are similar in both morphology and chemical composition to inclusions in diamonds from kimberlites on other continents. Thus, the authors conclude that the conditions of diamond formation in China are comparable to those in other parts of the world. *JES*

Infrared topography and carbon and nitrogen isotope distribution in natural and synthetic diamonds in relation to mantle processes. H. J. Milledge, M. J. Mendelssohn, S. R. Boyd, C. T. Pillinger, and M. Seal, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 55–60.

Infrared absorption spectroscopy is now being used to topographically map the distribution of light elements (N, H, O) in diamond. This paper reviews current work using micro-sampling spectroscopy techniques refined by the authors. For example, coated diamonds from many localities are found to have very similar nitrogen and carbon isotope compositions, whereas the composition of the cores varies widely both within and between localities. Type IIa diamonds also vary significantly in carbon isotope composition. Diamond type (IaA, IaB, Ib) can differ considerably on a micro-scale even within an individual diamond crystal. Studies of this kind have added significant new insights to the understanding of the chemical and physical structure of diamond. *JES*

Lamproitic diamonds and their inclusions: New insights from the West Australian deposits. A. L. Jaques, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 36–39.

This paper summarizes current observations on the occurrence of diamonds in lamproites in Western Australia. About 5% of the stones from the Argyle mine are gem quality (including the highly prized pinks). The diamonds are predominantly small (mean size less than

0.1 ct/stone), brown, frosted, strongly resorbed dodecahedra that have been plastically deformed and commonly contain graphite inclusions. In contrast, diamonds from the Ellendale mine are typically yellow, resorbed, rounded dodecahedra with smooth surfaces; a high proportion (60%–90%) are of gem quality. Data are presented on the isotopic composition of the diamonds and on the composition of their mineral inclusions. Some ideas on the geologic environment of diamond formation in this area are also summarized. *JES*

Optical properties of one type of natural diamonds with high hydrogen content. E. Fritsch and K. V. G. Scarratt, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 21–22.

This paper describes a correlation that can be made between the optical properties of a certain group of natural diamonds with a high hydrogen content. Diamonds belonging to this group (referred to as the "563 type" because of a prominent band in their visible-range absorption spectrum at 563 nm) always have a prominent gray component, unless the stone has been irradiated and annealed to modify the color. Many show a distinct color zonation, often with yellowish and grayish zones; the latter are cloudy due to the presence of numerous pinpoint inclusions. In polarized light, these diamonds exhibit an anomalous birefringence that has a sectional distribution which matches the color zonation. When the color zoning is particularly pronounced, the long-wave U.V. luminescence is also zoned: The yellow parts of the stone fluoresce blue, while the gray parts phosphoresce yellow. In addition to the 563-nm band, the absorption spectrum of these diamonds exhibits weak bands at 525 and 555 nm and a stronger band at 545 nm. Other absorption bands may be present, and in combination they give rise to the gray coloration. Infrared absorption spectra indicate that these are type Ia diamonds. The authors correlate these features with a high hydrogen content, and suggest that hydrogen-related defects might be responsible for some of the optical absorption features related to the gray coloration. *JES*

Variations in the physical and chemical properties of natural diamonds. J. W. Harris, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 29–31.

Statistical data are now becoming available on the physical and chemical properties of diamond, and how these properties vary with geographic locality and as a function of diamond size. Within the major mines in southern Africa, there is a general similarity between morphology and color of diamond from the six groups of kimberlites. Octahedra and dodecahedra dominate crystal morphology, with macles and polycrystalline aggregates being of lesser significance. Almost all (90%) of the diamonds are colorless, yellow, or brown. In contrast, at the Jwaneng and Orapa mines in Botswana, polycrystalline diamonds predominate, and there is a significant percentage of transparent, green-coated diamonds. Observations on the occurrence of various inclusions and plastic deformation, which is thought to cause a brown coloration in these diamonds, are also presented. Further studies of this kind are in progress. *JES*

GEM LOCALITIES

Diamond in Brazil. J. P. Cassedanne, *Mineralogical Record*, Vol. 20, No. 5, 1989, pp. 325–336.

This article reviews the occurrence and mining of diamonds in Brazil, which has been a producer of high-quality stones intermittently since the early 1700s. No economic, primary deposits of diamond-bearing kimberlite are known; those deposits that have proved so productive are secondary occurrences where the diamonds are found in various sedimentary rocks. For the most part, recovery of diamonds is accomplished by individuals using hand tools and limited mechanical equipment. The authors also present data on the crystal morphology of diamonds from this area. The most interesting portion of the article, however, is the description of the major diamond-producing regions of the country. Sixteen illustrations accompany the text. *JES*

Further evidence for the controls on the growth of vanadium grossular garnets in Kenya. R. M. Key and P. G. Hill, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 412–422.

This is perhaps the most complete report in the gemological literature on the geologic conditions in which tsavorite forms. The authors first review previous reports on the vanadium grossular deposits of East Africa. Quantitative XRF and microprobe analyses of host graphitic gneisses and associated vanadium grossular samples confirm that the host rock is the source of the vanadium, which is present in unusually high amounts in all the graphitic gneisses examined from various regions of Kenya. The study also confirms that the tsavorites of Kenya formed under granulite facies conditions. Color photos, electron micrographs, and geologic maps accompany the text. *CMS*

Un grenat vert: La tsavorite (A green garnet: Tsavorite). S. Heppe, *Revue de Gemmologie a.f.g.*, No. 99, 1989, pp. 5–7.

This article briefly sketches the history of green grossular garnet, tsavorite, through the discovery of its main deposits (Lelatema Mountains, Tanzania; Mount Tsavo and Lualenyi Mine, Kenya), with a short description of the relevant geology. The common inclusions are listed,

although they are considered noncharacteristic. The chemical composition is given in detail, and a correlation between the amount of vanadium and chromium, the index of refraction, and the coloration is established. Physical and gemological properties are thoroughly listed, and the Raman spectrum of tsavorite is briefly discussed. Four photos and two figures illustrate the article. *EF*

Inter-agate. A. Frazier and S. Frazier, *Lapidary Journal*, Vol. 43, No. 5, August 1989, pp. 28–42.

This is one of the better short articles on the agate deposits of the Idar-Oberstein area. Extensively referenced and with an old map of mining localities, the article includes a list of 22 minerals associated with the agates. The authors offer several theories as to the formation of these famous and historic deposits, and even suggest a number of collecting areas where a visitor may have some luck in recovering various chalcedonies. The section dealing with associated minerals is particularly enlightening.

This article is technically concise, with three color photos and one line drawing in addition to the map. *WRV*

Medium-dark blue aquamarines from Tongafeno, Madagascar, with high physical and optical properties, and showing three-phase inclusions. J. M. Duroc-Danner, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 423–430.

The author studied seven faceted aquamarines, as well as a number of rough crystals, from the Tongafeno pegmatite, Madagascar, and found unusually high R.I. and S.G. values similar to those of beryl from Zambia, Elba, and Brazil (Maxixe-type). A hand spectroscope revealed strong absorptions at 400–410 and 640–700 nm, and lines at 430, 620, and 630 nm. EDXRF chemical analysis revealed iron to be the likely chromogen as well as the cause of the 430-nm absorption line. The author concludes that, since the color is apparently due to iron and is stable under normal conditions, these beryls are true aquamarines despite their lack of a greenish component and their similarity in color to Maxixe-type beryl. *CMS*

Vanadian garnets in calcareous metapelites and skarns at Coat-an-Noz, Belle-Isle-en-Terre (Côtes du Nord), France. C. Benkerrou and M. Fonteilles, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 852–858.

Some unusual vanadium-rich calcic garnets occur at this locality on the Brittany peninsula. These garnets belong to the solid-solution series grossular ($Ca_3Al_2Si_3O_{12}$)–goldmanite ($Ca_3V_2Si_3O_{12}$), and extend up to about 68 mol.% goldmanite component. The garnets occur in metamorphosed calcareous sediments as small, sector-zoned crystals. V-rich sectors are described as being green, and V-poor sectors as yellow, in optical thin section. In skarns developed in these sedimentary rocks, the garnet crystals consist of a goldmanite core surrounded by a grossular overgrowth. The genesis of these unusual garnets is also discussed. *JES*

Thailande – Kanchanaburi Bo Phloi: Une page se tourne (Thailand – Kanchanaburi Bo Phloi: A page is turned). Ph. Moncorge, *Revue de Gemmologie a.f.g.*, No. 99, 1989, pp. 3–4.

Bo Phloi, literally translated, means "shafts' town." This short article explains that since early 1988 this sapphire field has been exploited with modern, heavy equipment by the Sap mine and that the traditional shafts are rapidly disappearing. The geologic setting and former mining techniques of this deposit are also briefly described. *EF*

INSTRUMENTS AND TECHNIQUES

Electrical properties of opal. M. Y. Xu, H. Jain, and M. R. Notis, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 821–825.

The authors investigated differences in electrical properties of natural and synthetic opals, using one natural white opal from South Australia and two synthetic plate-like opals manufactured by Nakazumi Crystal Laboratory, Japan. The electrical conductivity is lower for the synthetic opal presumably because of the lower content of Na^+ charge carriers (in comparison to natural opals). The dielectric constant of the synthetic opal is variable, and depends on sample orientation and water content.

This article suggests that it may be possible to construct an instrument capable of separating natural from synthetic opal on the basis of electrical behavior. *JES*

La perle au microscope électronique (Pearls seen with an electron microscope). J.-P. Gauthier and J.-M. Ajacques, *Revue de Gemmologie a.f.g.*, No. 99, 1989, pp. 12–17.

After a very brief historical perspective on microscopy, the authors describe features visible on the surface of a pearl with an optical microscope. A thin section of a cultured pearl shows the nucleus, covered by a thin black deposit on which grows a layer of radial structure, followed by the classic concentric aragonite layers. Observation with a scanning electron microscope allows one to see the step-like border of each aragonite layer as well as its structure, a coalescence of polygonal (mostly hexagonal) platelets. The transmission electron microscope is the only instrument that provides an image of the organic matter between the aragonite layers. Actually, there are two pericrystalline membranes around the crystals and a more elusive, sometimes pinched, interlamellar membrane that bridges the

two layers. Information on the relative orientation of the aragonite crystals can be derived from electron diffraction patterns. The average thickness of an aragonite layer is 250 to 300 nm. Seventeen excellent micrographs illustrate the article. *EF*

Vector representation of tourmaline compositions. D. M. Burt, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 826–839.

The tourmaline group consists of a chemically complex suite of minerals, several of which are of gemological importance. The group comprises a number of end-member compositions, represented by mineral species such as elbaite and liddicoatite. Other tourmaline end members have been synthesized in the laboratory, but have not yet been found in nature.

This article presents a method of depicting the relationships between the compositions of tourmaline-group minerals by using a graphic vector representation. Examples are cited where this method can be used to plot a number of compositions that, for instance, fall along the solid-solution series between end members. This method is more convenient to use than traditional triangular diagrams in illustrating such chemical relationships. Details of constructing these vector composition diagrams are presented. *JES*

JEWELRY ARTS

A fourteenth century crown. A. Gray, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 431–432.

Ms. Gray describes the 14th-century "English crown" recently displayed at the Royal Academy, London, for the first time since 1401, when it left England as part of the dowry that Blanche, daughter of Edward IV, took with her on her marriage to Ludwig III of Bavaria. Made of floral gold tracery work set with light blue sapphires, pale "rubies," and pearls, the crown is more of historic interest than gemological value, due to the poor quality of the gems. Prior to its cataloging as one of Henry IV's possessions in 1399, the history of the crown is unknown. The enameling and gold work suggest French craftsmanship. A color photograph of the crown accompanies this note. *CMS*

SYNTHETICS AND SIMULANTS

Chemical vapor deposition of diamond. J. E. Butler, *Extended Abstracts of the Workshop on Diamonds—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 11–13.

This brief paper reviews the methods of chemical deposition of synthetic diamond from low-pressure gases. A number of techniques have now been developed to grow a thin layer of synthetic diamond, and this result poses some interesting questions about the conditions of diamond growth. This particular study involved characterizing the chemical species present in the gaseous environment from which diamond growth occurs. A theoretical model is presented to explain the mechanism of diamond growth. *JES*

Diamond growth at low and high pressure. I. Sunagawa, *Extended Abstracts of the Workshop on Diamond—28th International Geological Congress*, Carnegie Institution, Washington, DC, 1989, pp. 109–112.

In this paper, the author rationalizes many of the features of natural and synthetic diamonds in terms of their conditions of crystal growth. In each of the instances of natural and synthetic growth, differences in crystal morphology, perfection, and homogeneity can be understood in terms of growth conditions and growth kinetics.

Natural diamonds grow in silicate solutions under stable conditions; during their transport to the earth's surface, they experience dissolution, annealing, and plastic deformation. Single-crystal, combined-type, and polycrystalline diamonds grow under conditions of differing driving force. Because they undergo dissolution, the external forms of natural crystals are more or less rounded. Growth occurs parallel to the {111} octahedral faces, but never on a planar surface parallel to the {100} cube face, in accord with analysis of the crystal structure of diamond.

In contrast, synthetic diamonds are grown at high pressures from metal solutions under stable conditions. Their crystal morphology is significantly different. The cube face {100} is a major growth plane, and the relative dominance of the {100} versus {111} depends on the driving force of crystallization. In addition, {110} and {113} faces can also be present. The composition of the metal solution is just one of the factors that influences crystal growth.

Synthetic diamond can also be grown metastably at low pressures. Polycrystalline diamond films are now being grown by the chemical vapor crystallization method for many industrial applications. *JES*

TREATMENTS

Heat treatment of geuda stones—spectral investigation. R. N. Ediriweera and S. I. Perera, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 403–404.

This study contributes to the understanding of how blue color is produced when geuda sapphires are heat treated. On the basis of before-and-after spectra taken from 50 samples, the authors conclude that the color is due to the formation of $(Fe\text{-}Ti)^{6+}$ biparticles from pre-existing Ti^{3+} and Fe^{3+}. The color developed at temperatures exceeding 1500°C and darkened at higher temperatures, up to 1900°C. In conjunction with the blue color, a broad

band beyond 560 nm developed, while an original weak 540 nm absorption disappeared. No comparison with spectra for natural-color blue sapphires is provided.

CMS

MISCELLANEOUS

Availability of a library of infrared (2.1–25.0 μm) mineral spectra. J. W. Salisbury, L. S. Walter, and N. Vergo, *American Mineralogist*, Vol. 74, No. 7/8, 1989, pp. 938–939.

This note announces the availability of a new library of mid-infrared spectra for a number of common minerals through an open file report (#87-263) of the U.S. Geological Survey. The spectra were recorded by the reflectance method from carefully prepared (powdered) samples of the chosen minerals.

Plans to continue building the spectrum library are reported. Gem minerals included in the current library are andalusite, garnet, beryl, cordierite (iolite), olivine (peridot), quartz, spodumene, and tourmaline. The article provides the information necessary to obtain a copy of this library in digital (computer) or hard-copy form.

JES

The Muslim lapidary—Some aspects of the gem folkways in Sri Lanka. M. M. M. Mahroof, *Journal of Gemmology*, Vol. 21, No. 7, 1989, pp. 405–409.

Mr. Mahroof provides insight into the Muslim community of gem cutters in Sri Lanka. Descendants of Arab sea-faring traders, the Muslim lapidaries of Sri Lanka have been, and still are, an important part of the gem trade of that nation. This article traces the history of this professional community to the present day, and describes the largely traditional methods used in cutting the gems that have brought fame to Sri Lanka. This article should be of particular interest to the retail jeweler who seeks to add "color" to sales knowledge.

CMS

The preservation of type mineral specimens. P. Dunn and J. Mandarino, *Mineralogical Record*, Vol. 19, No. 4, 1988, pp. 226–227.

In this editorial, Drs. Dunn and Mandarino take a strong stand on the dealing in, and collection of, "type" mineral specimens by private collectors. "Type" mineral specimens are those used in the original scientific study and description of a mineral species. The authors express their firm belief that such specimens should be collected only by mineral scientists and professional curators who can house them in public institutions where they will be safeguarded, studied, and their authenticity ensured. They suggest that certain specimens should be "off limits" to collectors, and that purported "type" specimens in the hands of private collectors be considered tainted and of little or no scientific use. The authors do recognize the debt of gratitude that public collections owe private mineral collectors, and they don't wish to discourage their collecting of most specimens. But they feel that in the search for the rare and unusual, the private collector should not let himself jeopardize these few critical and important specimens and the significant scientific information they may hold. This editorial is followed by two pages presenting formal definitions for "type" mineral specimens.

Christopher P. Smith

Letters: Type specimens. *Mineralogical Record*, Vol. 20, No. 4, 1989, pp. 301–303.

In response to Drs. Dunn and Mandarino's 1988 editorial on the preservation of "type" mineral specimens, letters from two dealers (Forrest and Barbara Cureton) and a private collector (Dr. Mark Feinglos) were published. Both letters were very critical of the statements made in the original piece, agreeing in basic principle with the editorial but also feeling that the point was taken too far. Their strongest objection was to the use of the term *tainted* in reference to type mineral specimens held in private collections: They felt that Drs. Dunn and Mandarino were unfairly implying that scientists by virtue of their degrees are more careful and trustworthy in the handling of type specimens than dealers or collectors.

Never wavering on their stance, Drs. Dunn and Mandarino replied to the letters' poignant questions and accusations while trying not to simply reiterate their editorial. In doing so, they made a final appeal to the collecting community at large to hold these very few and rare specimens sacred and entrusted to the scientific community alone for proper research and safeguarding.

Christopher P. Smith

Spotlight on Scripps. B. Wiersema, *Lapidary Journal*, Vol. 43, No. 5, August 1989, pp. 20–26.

The San Diego Museum of Natural History, as part of a three-year, $12 million expansion project, recently opened the Josephine L. Scripps Hall of Mineralogy, part of which is the Bruder Family Gem Gallery. The new mineralogy hall includes 12 interactive exhibits that demonstrate mineral properties and some principles of physics.

Among the interactive exhibits is one on crystal growing, where participants can rapidly grow brightly colored crystals. A recreated mine tunnel, complete with a typical San Diego County pegmatite dyke and gem pocket, is scheduled to open in 1991.

The article also includes information on the psychology of exhibits, the influence of the jewelry market, and the major personalities involved. Josephine Scripps' long relationship with protégé Bill Larson is colorfully recounted. One would have liked to read more, however, about the Bruder Family Gem Gallery, especially since the opening of this hall was timed to take full advantage of the increased public interest in crystals and the jewelry trade.

Loretta B. Loeb