

VOLUME XLIII

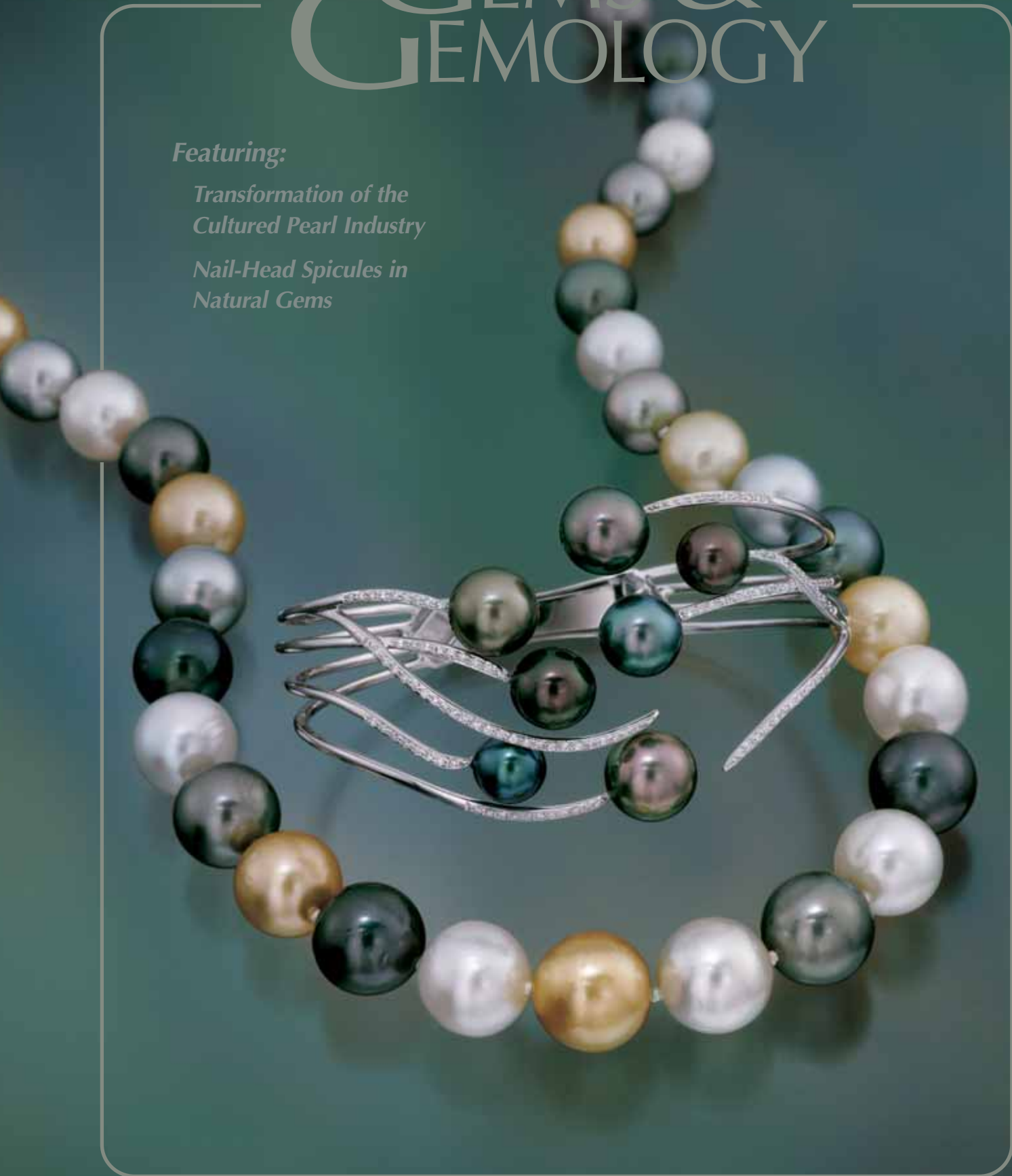
GEMS & GEMOLOGY

FALL 2007

Featuring:

*Transformation of the
Cultured Pearl Industry*

*Nail-Head Spicules in
Natural Gems*



THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA



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Alice S. Keller
akeller@gia.edu

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tom.overton@gia.edu

Technical Editor

Sally Magaña
sally.magaña@gia.edu

Consulting Editor

Carol M. Stockton

Contributing Editor

James E. Shigley

Editor

Brendan M. Laurs
GIA, The Robert Mouawad Campus
5345 Armada Drive
Carlsbad, CA 92008
(760) 603-4503
blaurs@gia.edu

Associate Editor

Stuart Overlin
soverlin@gia.edu

Circulation Coordinator

Debbie Ortiz
(760) 603-4000, ext. 7142
dortiz@gia.edu

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DATABASE COVERAGE

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ABOUT THE COVER

The cultured pearl market, long dominated by the Japanese akoya, has expanded to include a wide variety of goods produced throughout the Pacific region. In this issue, Russell Shor reviews the economic and environmental forces that have changed the cultured pearl industry over the past 15 years. Shown here are two examples of modern cultured pearl jewelry: a strand of 10–14 mm Tahitian and South Sea cultured pearls, and a bracelet set with Tahitian cultured pearls (8–10 mm) and diamonds. Courtesy of Mastoloni, New York. Photo by Harold & Erica Van Pelt.

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Save the Date *for the* 2009 Gemological Research Conference

Last year, more than 700 participants from 32 countries came to GIA's first-ever Gemological Research Conference (GRC), in San Diego, California. Those who attended the two-day conference or read the coverage of it in our Fall 2006 issue understand the caliber of this international event.

At this time, I am delighted to announce that the second Gemological Research Conference is set for August 21–23, 2009. This event, which is again being co-chaired by *Gems & Gemology* editor Brendan Laurs and GIA distinguished research fellow Dr. James Shigley, will also take place in San Diego, at the Town & Country Resort and Convention Center. Participants will learn about new technical developments and have the opportunity to discuss the critical issues facing gemology with speakers and attendees from around the world.

For 2009, the GRC has been expanded to a three-day event. It will again feature a compelling lineup of keynote speakers and oral and poster presentations. Among the new additions to the program are panel discussions and a gem photography competition and workshop. We are pleased to welcome the collaboration of the Mineralogical Society of America in organizing one of the conference sessions. A major goal of the GRC is to promote interest in gemology among scientists from a variety of disciplines, and to share problems and potential solutions as we address the increasingly complex challenges in gem identification and characterization. We look forward to the involvement of our colleagues in the mineralogical community, as well as that of the myriad academics, researchers, and experts from other fields who appreciate the complexity and beauty of diamonds and other gems.

The dual-track program will address a number of important research topics. Track 1 will focus on gem treatments, synthetics and simulants, gem localities, the geology of gem

deposits, diamond characterization, colored stone identification, inclusions, new technologies, and more. Track 2 will explore areas such as pearls and organic gems, color description, jewelry manufacturing technology, market research and analysis, gem pricing, gems in objects of cultural heritage, and jewelry history, among others.

Rounding out the 2009 GRC program are educational field trips to the gem pegmatite mines in San Diego County and evening social events, including *Gems & Gemology's* 75th anniversary party.

Travel grants will again be available to selected presenters who demonstrate appropriate need. The GRC travel grant fund provides financial assistance to worthy scientists who otherwise would not be able to participate. In 2006, grants were given to 20 deserving presenters from 12 countries. Please contact editor Brendan Laurs (blaurs@gia.edu) or myself if you are interested in contributing to this fund. Information

on applying for a grant will be released with the formal call for abstracts next year.

Now is the time to make plans to participate in the 2009 GRC—block out the dates, select your research topic, and invite friends and colleagues to join you for the single most important event in the global gemological community. For more information, please visit www.grc2009.gia.edu or e-mail grc2009@gia.edu. All of us at *Gems & Gemology* look forward to seeing you there.



Alice S. Keller
Editor-in-Chief
akeller@gia.edu



Letters

MORE ON POLYMER-IMPREGNATED TURQUOISE

In the Summer 2007 issue, K. S. Moe et al. ("Polymer-impregnated turquoise," pp. 149–151) documented the spectroscopic properties of a turquoise cabochon and concluded that it had been impregnated with an ultraviolet (UV) radiation-hardened polymer. Comparing the spectroscopic properties of the "filler" with that of Norland Optical Adhesive 65 (a known photopolymer for various technical applications), the authors further concluded that this type of material, which was previously known in gemology only for emerald fracture filling, is also now being used for turquoise.

It should be noted, however, that the radiation polymerization of impregnated turquoise has been known for more than 25 years. H. Breault and A. E. Witt (*Turquoise-Plastic-Composite*, U.S. patent 4,075,365, issued Feb. 21, 1978) described the impregnation of natural turquoise with a liquid monomer in which polymerization is possible through catalytic, thermal, or radiation initiation. In particular, a monomer consisting of the dimethacrylate of triethylene ether glycol is used for the impregnation, and polymerization is carried out by ^{60}Co gamma irradiation.

In addition, it is known from another U.S. patent (E. Proksch and H. Eschweiler, *Porous, Heat-Sensitive Substrates Coated with Synthetic Resins*, U.S. patent 3,935,364, issued Jan. 27, 1976) that natural porous stone material can be coated with a liquid synthetic resin (of different components) that is then polymerized and hardened by UV or electron irradiation. Further details, especially the compounds used with these processes, can be found in the patent documents.

Based on information obtained from the trade (H. Zimmermann, pers. comm. 2006, 2007), it appears that several different companies are now engaged in the impregnation and polymerization of turquoise. To assist impregnation of the rough with the liquid monomer, the untreated material is sometimes placed in an autoclave. The exact chemical composition of the monomer is pro-

prietary, but copper sulfate is sometimes added to intensify the color (H. Zimmermann, pers. comm., 2006, 2007). The polymerization is performed mainly by ^{60}Co gamma or electron irradiation.

Over the last few years, BCS Stones GmbH, Harxheim, Germany, has treated several thousand kilos of rough per year by polymerization via electron irradiation. Production figures of other companies are not available at the moment.

Karl Schmetzer
Petershausen, Germany

RAMAN PEAKS IN CORAL

The article "Pink to Red Coral: A Guide to Determining Origin of Color" in the Spring 2007 issue (pp. 4–15) is very informative, and the analysis is very detailed and systematic. However, the article also states that there is a Raman peak at 1123 cm^{-1} (see figures 14 and 15). Recently, I performed Raman analysis on the same type of natural red coral but observed a peak at 1132 cm^{-1} , not 1123 cm^{-1} . This result also matched well with the Renishaw Raman Library. I would appreciate it if the authors could clarify if the peak value they report is an error or a variance in data.

C. G. Zeng
Nan Yang Gemological Institute
Singapore

REPLY

We want to thank Mr. Zeng for pointing out a typographical error made early in our data record that was carried throughout the text of our article. The last two numbers for the position of this peak were inadvertently reversed. The correct identification of the peak position should indeed be 1132 cm^{-1} and not 1123 cm^{-1} .

Christopher P. Smith, Shane F. McClure,
and David M. Kondo

FROM SINGLE SOURCE TO GLOBAL FREE MARKET: THE TRANSFORMATION OF THE CULTURED PEARL INDUSTRY

Russell Shor

Over the past 15 years a combination of market forces, environmental events, and scientific research has radically changed the cultured pearl industry from a single commodity dominated by one producer to a highly diverse industry operating throughout the Pacific region. The new products, consistent quality, and broader marketing programs in turn led major designers and retailers in the United States and Europe to take a much greater interest in cultured pearls. During this period, consumer interest has expanded from the traditional small and medium white round Japanese akoya cultured pearl to the larger South Sea and Tahitian goods, as well as numerous previously “undesirable” shapes and colors.

Environmental and economic forces have transformed the cultured pearl industry (figure 1) since the early 1990s, when Japanese akoyas constituted more than 70% of global pearl production by value. (*Note: Because the recovery of natural pearls is now negligible, all uses of the term pearl in this report will refer to cultured pearls unless otherwise indicated.*) At that time, Japanese firms and individual farmers kept a tight hold on the grafting techniques they had pioneered decades earlier. Both black pearls from French Polynesia and South Sea pearls from Australia, Indonesia, and the Philippines were rising in popularity, but these were generally sold through long-established Japanese firms that purchased entire crops and marketed them worldwide. Freshwater pearl culturing in China was still in its infancy as far as higher-quality goods were concerned.

By the mid-1990s, infectious diseases had killed an estimated three-fourths of the oysters being operated in Japanese waters, while the best Chinese freshwater cultured pearls (FWCPs) began to rival the mid-range akoyas in quality. As the Japanese pearl producers struggled to recover, a severe economic

downturn hit other parts of Asia, pressuring Japanese banks to tighten the credit they had been giving local distributors to purchase large quantities of South Sea and black pearls. As a result, large pearl farms throughout the Pacific region broke out of their role as “contract” producers for the Japanese firms and began conducting auctions under their own auspices.

These larger producers also sought to differentiate their goods through marketing and branding initiatives, particularly for the top qualities. Eventually, new grafting techniques led to an entirely new array of products for a category that had been known for nearly a century for its sameness and simplicity—round and white. These new pearls included fancy colors such as pastel pinks, violets, “golds,” and browns, and featured previously less desirable shapes such as baroques and ringed goods (“circles”).

See end of article for About the Author and Acknowledgments.
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Figure 1. Since the early 1990s, the pearl industry has seen dramatic change, as new types of pearls and new sources challenge the former domination of Japanese farms and dealers. The traditional 6–7 mm akoya product (bottom two rows) has been joined by new ones from French Polynesia (top two rows), China (third row), and the South Seas. Some of the newer producers and distributors are focusing on higher-end products, such as the diamond and Tahitian cultured pearl earrings shown here. Earrings courtesy of Mastoloni, New York; South Sea strand (9–12 mm) courtesy of The Collector Fine Jewelry, Fallbrook, Calif. Photo by Harold & Erica Van Pelt.

Yet these developments have not been without new challenges, as the greater number of pearl farms throughout the Pacific (figure 2) has led to overproduction and precipitous price fluctuations in some sectors of the market.

This article will chart how a combination of diversified production, economic and ecological events, and intensive branding and marketing efforts transformed the pearl industry. Once defined by a single basic product with a staid fashion image, it now embraces an array of colors and shapes that have captured the interest of contemporary jewelry designers and major retailers.

BACKGROUND

Japan Dominates 20th Century Pearl Culturing. The cultured pearl industry began in Japan in the first years of the 20th century, after Tatsuhei Mise and Tokichi Nishikawa developed the basic technique still used today for bead-nucleated pearls (a bead inserted into the gonad of the mollusk along with a piece of mantle tissue). Over the ensuing decades, their innovations were parlayed into a major commercial enterprise by pearl entrepreneur Kokichi Mikimoto (figure 3). Few of the early products resembled the round, lustrous gems associated with Japanese cultured pearls today; most were small and irregular or mabe (half) pearls. By the 1920s, howev-

er, round pearls 2–3 mm in diameter had become more common and helped fuel a worldwide fashion boom (figure 4). In addition, limited numbers of South Sea pearls were being cultured by Japanese firms operating primarily out of Indonesia and the Philippines.

In 1931, a total of 51 Japanese farms produced over one million pearls. During that decade, farmers began experimenting with collecting spat (embryonic oysters) and raising them in tanks so they would not have to rely on oysters collected from the wild. This change contributed to a major increase in production: Within seven years, 289 farms cultured 11 million pearls, nearly all for export (Muller, 1997b).

In the 1940s, World War II devastated the pearling industry along with the rest of the Japanese economy, with only one-third of the farms able to remain in business at even a subsistence level. During the post-war reconstruction, however, Mikimoto's internationally renowned brand helped the nation recover (Strack, 2006). Pearl production exploded through the 1950s, reaching 300 million shells in operation by 1962, with another 100 million added by 1966, when official production peaked at an all-time high of 39,522 *kan*, or 148.2 metric tons (tonnes). Some estimates placed this number much higher, in the neighborhood of 65,000 *kan*, or 243.8 tonnes, largely because of a 47-fold increase in



Figure 2. Originally confined to a few areas in Japan, cultured pearl production has now spread across the Pacific region. This map indicates the approximate areas where major pearl farming now takes place. The *Pinctada maxima* oyster produces white and golden pearls, and the *P. margaritifera* produces black pearls.

the number of pearl farms between 1951 and 1966 (Strack, 2006). (Most pearl production is still reported in traditional Japanese weight measures: 1 *kan* equals 1,000 *momme*; 1 *momme* equals 3.75 grams, or 0.13 oz.)

During the 1950s and '60s, Japanese companies established the basic sales and distribution procedures that most saltwater pearl producers use to this day: Farmers divide their goods by quality and sell them at competitive auctions conducted by one of the several producers' organizations (Muller, 1997). Back then, the buyers at these auctions were large Japanese wholesalers who sent the goods for processing (technically treatments—see Box A), which included tumbling to improve luster, bleach-

ing to remove some blemishes, and the coloring agent cosin to create the valued pink overtone (Muller, 1997; Strack, 2006).

As demand increased in the United States and elsewhere, Japanese exporters established close ties with pearl dealers in many regions (figure 5). These included Mastoloni, Honora, Albert Asher, and Imperial-Delta in the U.S., and Schoeffel and Golay Buchel in Europe, then the two major consumer markets. By the time sales peaked in the mid-1960s, the pearl industry had established deeply entrenched distribution channels (many of which remain in existence today), even through a severe decline in sales and production at the end of that decade (Muller, 1997b).



Figure 3. Japanese pioneer Kokichi Mikimoto revolutionized the pearl industry by launching its first internationally recognized brand. Mikimoto drew on the efforts of his son-in-law, zoologist Tokichi Nishikawa, and carpenter Tatsuhei Mise to develop the pink-to-white round akoya cultured pearls with which the Mikimoto name became synonymous. Photo © Horace Bristol/Corbis.

Because the pearl industry was so vital to Japan's post-war economy, Kokichi Mikimoto spearheaded an effort to keep pearl culturing technology and marketing in the hands of his countrymen (Strack, 2006). The result was the so-called Three Principles enacted by Japan's Administrator of the Fisheries Agency based on the Foreign Exchange Act. These principles were:

1. The technology of pearl culturing and manufacturing should not be given to foreign countries.
2. All pearls cultured in foreign farms should be exported to Japan, regardless of the country in which they were produced.
3. Any Japanese company that plans to culture pearls in foreign countries should submit to the Fisheries Agency their plans as to the oyster species, number of oysters to be operated,

and culturing areas. The culturing of akoya pearls in foreign countries is prohibited (S. Akamatsu, pers. comm., 2007).

These principles had a profound effect on pearl production worldwide. Although culturing operations would emerge in Australia, Indonesia, the Philippines, French Polynesia, and China, their production and especially distribution were largely controlled by Japanese firms (Muller, 1998). And there was no real challenge to Japanese supremacy until the mid-1990s, when economic and natural forces would combine to create a free market and diversified industry throughout the Pacific region. These forces would affect pearl production in much the same way that world events have diminished the once-dominant role of the De Beers Diamond Trading Company (Shor, 2005). As with the diamond industry, the trend toward globalization, free markets, and resource producers seizing greater

Figure 4. Aggressive marketing by Mikimoto helped return pearls to fashion in the 1920s. Famed silent film actress Louise Brooks is shown here wearing a dramatic pearl rope. Photo © Sunset Boulevard/Corbis.



BOX A: PEARL TREATMENTS

Like many gem materials, akoya cultured pearls have a long history of “accepted” treatments. In the early years of the 20th century, Japanese producers developed a number of processes to improve the appearance of their pearls before placing them on the market. None of these were disclosed, and they remain undisclosed to this day. In recent years, however, some of these processes have grown more sophisticated, blurring the boundary between an “acceptable process” and a “treatment”—as foreign substances are employed in some cases to improve or change color or add luster.

The first step in traditional akoya processing, called *maeshori*, involves immersing the pearls in a solvent, usually methyl alcohol, for cleaning. Originally performed before bleaching to make that process more effective, it is now used alone on virtually all cultured pearls to improve their luster (Akamatsu, 2007). In some cases, however, luster-enhancing coatings are applied. Typically, such coatings are considered a treatment.

The next step in the traditional process is bleaching (figure A-1), which removes dark organic compounds and creates a purer white. This usually involves immersing the cultured pearls in dilute hydrogen peroxide under low heat in controlled lighting conditions. After bleaching, some are treated with an additive to create the slightly pinkish overtone seen in many akoyas. In the 1920s and 1930s, the Japanese producers used cosin, a vegetable dye; today, they employ a variety of coloring agents (Strack, 2006).

The final step in traditional processing is tumbling, which improves luster. CIBJO does not require that the steps in the traditional process be disclosed (CIBJO, 2006).

However, dyeing and irradiation have been used for many years to alter pearl color (figure A-2). Typically, the bright, obvious colors that result from most dyes do not resemble anything found in nature. Yet some dyes can simulate attractive natural colors. One of the most common agents is silver nitrate, which has been used on both saltwater and freshwater cultured pearls to chemically darken the nacre and imitate naturally colored black pearls (Crowningshield, 1988) as well as fancy colors (Hurwit, 1998). This treatment is detectable by X-ray fluorescence analysis (Komatsu and Akamatsu, 1978). Irradiation of both freshwater and saltwater cultured pearls is also used to simulate black pearls and, in some cases, enhance the appearance of orient (Crowningshield, 1988; Li, 2001).

In the late 1990s, increasing amounts of dyed “golden” South Sea pearls began appearing in the market, which also caused alarm within the trade (“Treatments cause concern in industry,” 1997; Strack, 2006). Some companies used heat treatment to create this color. Still other such pearls were found to be both heat treated



Figure A-1. Virtually all akoya cultured pearls are bleached to improve whiteness. The process involves immersion in a heated hydrogen peroxide solution combined with fluorescent illumination. Photo by Niels Ruddy Hansen.

and dyed (Elen 2001, 2002). Most recently, bleaching of some black Tahitian cultured pearls is believed to create fancy colors, such as the popular “chocolate pearls” currently in the marketplace (Wang et al., 2006), though dyed pearls of that color are in the market as well.

As with all gem treatments, some methods of enhancing poor-quality material to improve appearance and increase value remain a challenge for identification and disclosure.

Figure A-2. Large quantities of inexpensive freshwater cultured pearls are dyed to achieve different appearances and sometimes unnatural colors, such as the broad spectrum of products shown here at a trade show. Photo by Robert Weldon.



control over distribution proved the catalyst to unraveling a century-old system.

The Mid-1990s: A Turning Point for Japan. Into the 1990s, Japanese-produced akoya cultured pearls (from the *Pinctada martensii* oyster) remained the industry mainstay. In 1993, for example, the total production value of Japanese akoyas was estimated at \$600 million, while the white South Sea goods totaled \$120 million and French Polynesian black cultured pearls totaled \$75 million (Muller, 1998).

Consumer demand for pearls had revived from a lull in the United States and Europe during the 1980s, and was further stimulated by growing Asian economies. While prices for akoyas rose strongly as a result, production from Japanese farms was actually declining: By 1993, it had fallen to about 35% of 1962 levels. To accommodate demand, some producers began rushing their goods to market in as little as six months after implantation. Although Japanese akoyas had historically been cultivated to a nacre thickness of 1 mm on average, complaints of nacre peeling from pearls with coatings less than 0.2 mm thick began to surface, largely in Japan (Shor, 1994a). The Japanese government's Pearl Inspection Office did not permit export of akoyas with such thin nacre, but there were no corresponding restrictions on domestic sales.

Also in the mid-1990s, with prices reaching record highs, Japanese pearl farmers began facing their first significant competition in lower price ranges—from Chinese freshwater cultured pearls. Once predominantly small and irregularly shaped, these were now being produced as semi-rounds in sizes similar to those of medium akoyas (6–7 mm). Japanese farmers were also facing increasing land and labor costs, as well as stronger pollution-control measures. At the same time, a fluctuating yen caused prices of better-quality pearls to increase fourfold for U.S. consumers—their primary market—in less than a decade.

To deal with these challenges, many Japanese producers and distributors decided to focus on the higher-quality market (figure 6) by increasing minimum nacre thickness and concentrating on pearls larger than 7 mm, which prior to 1990 had constituted only 5% of Japanese goods. Consequently, by the early 1990s, 8–9 mm akoyas accounted for about 25–30% of Japan's total production (Shor, 1994a; Strack, 2006).

Soon, however, Japanese domination of the cultured pearl industry would be assaulted by three

forces: cataclysmic natural events, the Asian financial crisis, and the growing independence of non-Japanese producers.

Natural Forces. In November 1994, pearl dealers and producers assembled in Kobe, Japan, where many of the large Japanese pearling companies are headquartered. The primary aim of this convention was to establish a fund to support global advertising and marketing for pearls and pearl jewelry. Tragically, less than two months later, while participants still mulled over the proposal, a large earthquake (7.3 on the Richter scale) destroyed much of the city and killed more than 6,400 people. Although the earthquake did not affect the pearl farms, it did cause delays in the *ham-age* (unprocessed akoya pearl) auctions ("Kobe earthquake," 1995).

Figure 5. Collaboration between Japanese producers and pearl dealers in the U.S. and Europe helped make akoya cultured pearl necklaces and earrings a classic jewelry staple by the middle of the 20th century. Photo courtesy of Mikimoto & Co.





Figure 6. Faced with challenges from Chinese and other producers, many Japanese akoya farmers reoriented their businesses to concentrate on the higher end of the market. These 7 mm akoya cultured pearls have a tsavorite and diamond clasp designed by Ilka Bahn. Courtesy of The Collector Fine Jewelry; photo by Harold © Erica Van Pelt.

In addition, unusually warm ocean temperatures, which can affect luster, and attempts to increase production by operating too many shells in areas too small to properly nurture them (Muller, 1997a) resulted in a poor 1995 harvest. While the Japanese industry spoke of recovery (“Earthquake, strong yen slow sales,” 1995), further disasters awaited—events from which the industry has not yet recovered.

In the summer of 1996, a sudden and mysterious malady began killing pearl oysters in farms near Shikoku, a small island off southern Honshu. Within a few weeks, mortality was running at one million mollusks per day. By fall, the illness had spread to the primary pearling area of Mie, eventually killing two-thirds of the 300 million shells in operation there. No one in the Japanese pearl industry or government could agree on a concrete reason for the mass deaths. Some blamed ocean pollution caused by other industries, or weather conditions that diminished the pearl oysters’ chief food source, plankton. “Red tides”—massive invasions of plankton that smothered the mollusks by depleting oxygen levels in the water—were cited in some circles. Still others speculated that overreliance on hatchery-bred oysters had left crops less resistant to disease and pollution. However, nearly everyone noted that the high cultivation density was the catalyst for the widespread devastation (Federman, 1997; Strack, 2006). By 2001, production from Japanese farms had fallen to \$120 million (Strack, 2006), a

mere 20% of 1993 levels. Ultimately, the National Research Institute of Aquaculture in Japan concluded that the massive mortality of the akoya oyster was caused by an infectious disease (S. Akamatsu, pers. comm., 2007).

By the early 2000s, the mortality rate had decreased to a (still high) 20–30% and production appeared to have stabilized, partly because a significant percentage of the cultured pearls represented as “Japanese” were actually imported from South Korea and China, primarily Hainan Island (R. Torrey, pers. comm., 2007). Japanese production, or akoya cultured pearls from the *P. martensii* mollusk that are marketed as Japanese, has stabilized at a level of about 25 tonnes, a far cry from the almost 150 tonnes reported for 1966.

A Financial Crisis. With the collapse of Japan’s 1980s “bubble” economy beginning in 1990, most of the country’s large banks had to cope with billions of dollars in nonperforming loans. This caused the nation’s economy to stagnate, although the national government averted a full-blown depression by subsidizing some of the banks’ losses. The rest of Asia continued to boom through the 1990s, allowing many Japanese banks to reap returns from outside the country’s borders. Then, in 1997, the Asian boom ended abruptly after several very large corporations in Indonesia and Thailand defaulted on loans, touching off runs on those nations’ stock markets. Within three months, the currencies of

Thailand, Indonesia, South Korea, and several other nations collapsed, leaving many Japanese banks—which had financed major infrastructure projects in those countries—caught in the middle. The banks had no choice but to cut their credit facilities to many Japanese industries, including pearl producers and distributors (N. Paspaley, pers. comm., 2007). As a result, producers outside the country lost some of their biggest customers—who no longer had the financial resources to buy up entire harvests—and were forced to develop their own distribution channels.

Emerging Producers. All of these developments meant that by the end of the 1990s the Japanese distributors, though still significant buyers, no longer held direct control over a large majority of the world's pearl production (R. Torrey, pers. comm., 2007). The once-dominant akoya pearl was now sharing the market with competitors, as the late 1990s also saw increased production of other types of pearls. Today, the main types of cultured pearls on the market, besides akoyas and akoya-like goods, are:

- South Sea cultured pearls from the *Pinctada maxima*, a large saltwater oyster primarily found and cultivated in Australia, Indonesia, the Philippines, and Myanmar (Burma). These cultured pearls range from silvery white (predominantly Australia and Myanmar) to creamy white (Indonesia and the Philippines). Typically, they are much larger (routinely over 10 mm in diameter) and significantly more costly than akoyas.
- “Black” cultured pearls from the *Pinctada margaritifera*, an oyster primarily cultivated in the waters around French Polynesia. While the most costly appear black with high iridescence, they actually vary greatly in color, shape, and size, and thus have a wide price range.
- Freshwater cultured pearls, primarily from *Hyriopsis cumingii* mussels native to China. These generally are much less expensive than the other types, because the pearling operations in China are so prolific. The vast majority of FWCPs are white or off-white, though recently some farms have cultivated fancy colors and many are dyed or irradiated. Unlike producers elsewhere, most of the Chinese cultivators do not implant the mollusks with

beads, but only with pieces of mantle tissue, which yield primarily baroque pearls—and occasionally rounds.

Most recently, “golden” pearls from the gold-lipped *P. maxima* are being cultivated in the Philippines, with some coming from Australia, Indonesia, and Myanmar. Like the South Sea goods, these are sold in the luxury market.

SOUTH SEA WHITE CULTURED PEARLS

For the purposes of this article, all pearls cultivated in the *P. maxima* oyster are referred to as *South Sea pearls*. There are two major types of *P. maxima*: the white lipped, found mainly around Australia, Myanmar, and parts of Indonesia; and the gold lipped, found farther north, primarily around the Philippines, though some also occur around Indonesia.

By some accounts, pearl culturing in Australia predates culturing in Japan. An Australian, Queensland fisheries commissioner William Saville Kent, has been credited with culturing mabe and even spherical pearls as early as 1890, but he did not document his techniques before his death in 1906, and there are no records of his farm after a 1910 *Journal of Science* reference to the purchaser succeeding “in growing spherical pearls using techniques bought with the farm” (O’Sullivan, 1998).

What is known is that, in 1917, shortly after Mikimoto started mass production of cultured akoyas with the Mise-Nishikawa method, the Mitsubishi company of Japan established a *P. maxima* pearl farm in the Philippines. Others followed, and several survived until the outbreak of World War II. Although these farms were abandoned during hostilities, the decade following the end of the war brought a revival of *P. maxima* pearl culturing activity.

Australia. Pearling in this region dates back more than 400 years, when aboriginal populations harvested *P. maxima* shells and natural pearls, which were sold to Indian traders and ultimately ended up in Persia (present-day Iran). After the Europeans arrived in Australia, pearling fleets went to the western and northwestern coasts to harvest the shells for mother-of-pearl, then an important material for creating decorative objects, buttons, and inlay. The natural pearls themselves were a serendipitous by-product. The fleets were also active around Indonesia, the Philippines, and Burma (now Myanmar).

In 1954, a joint pearl culturing venture between Tokuichi Kuribayashi (founder of Pearl Shell Fishing Co., which harvested *P. maxima* shells along Australia's coast in pre-war years) and Alan Gerdau of the Otto Gerdau Co. (an Australian-owned firm in New York) began operation in what is now Kuri (after Kuribayashi) Bay in Western Australia. Called Pearls Pty., it was headquartered in Broome, some 386 km (240 miles) south of Kuri Bay. Kuribayashi also established a Tokyo branch called Nippo Pearl Co. (Muller, 1997b).

The technical team at Kuri Bay was led by Junichi Hamaguchi, who perfected a method of creating substantially bigger pearls by inserting a larger nucleus into the oyster without rejection. This enabled the Kuri Bay pearls to be harvested after

only 18 months of cultivation (N. Paspaley, pers. comm., 2007). As a result, Kuri Bay became very profitable, and Nippo Pearl Co. dominated production and supply of South Sea pearls until the mid-1980s.

A number of other pearl farms followed soon afterward in Western Australia, where oysters were more plentiful; among the operators were Paspaley, Broome Pearls, Arrow Pearls, and Roebuck Deep Pearls. Through most of the 1960s, Australian producers sold their entire output in bulk lots to Japanese wholesalers (N. Paspaley, pers. comm., 2007).

The first highly publicized "branding" opportunity for the Australian product came in 1964, when Van Cleef & Arpels sold the Duchess of Windsor a necklace featuring 29 Australian cultured pearls, graduated in size from 11 to 15 mm (Sotheby's, 1987; figure 7). Twenty-three years later, the necklace brought \$198,000 at the Sotheby's auction of her jewels (Strack, 2006).

During the early years of Australia's industry, Japanese grafters, many of whom worked for or owned pearling firms, traveled there to implant the nuclei into the local mollusks (figure 8), as they did in other pearl-producing countries. They usually brought their own nuclei, made from the Mississippi River freshwater mussel. For their work, the technicians received a portion of the resulting crop. In accordance with Japanese code (discussed above) that forbade the transfer of pearling techniques to non-Japanese—and their desire to protect their own livelihoods—the technicians refused to train Australians (Strack, 2006).

In the 1970s, a number of Australian farms experienced severe problems with mollusk mortality and declining pearl quality. Although the situation had stabilized by the end of the decade, mortality rates remained very high—60% to 70% through the 1980s—primarily due to neglect during the implantation operations and outmoded grafting and harvesting practices. In 1984, for example, the entire harvest from all producers totaled only 40 *kan*, or 150 kg (Strack, 2006).

A 1988 study of the pearling industry by the Western Australian government, which noted the problems with overharvesting (Shor, 1995b), resulted in a licensing system that imposed limits on the number of firms permitted to collect wild oysters and quotas on the numbers of mollusks that could be collected and operated. As part of this 1990 industry regulation package, the Western Australian government issued permits to 16 firms that limited

Figure 7. The Duchess of Windsor, who was known for her stylish jewelry, helped establish South Sea cultured pearls as a fashion item when she purchased the necklace shown here (center strand) in this photo with the Duke of Windsor that was taken in the 1960s. Photo by Maurice Tabard, Camera Press Ltd., London.



their catch quotas and—to prevent rapid spread of disease and blight—restricted the number of oysters operated from hatchery stocks. The legal limit was 570,000 for wild oysters under operation, plus an additional 320,000 from hatcheries, with the result that some 700,000–770,000 shells were in operation at any particular time (Tisdell and Poirine, 2000), or approximately one-thousandth the estimated number of akoya oysters that were under cultivation in Japan in 1988. Another reason for favoring wild oysters is that they tend to produce the extremes in quality, while pearls cultured from hatchery oysters tend to be more uniformly medium quality (N. Paspaley, pers. comm., 2007).

In cooperation with Hamaguchi, Paspaley's farms had introduced new pearl culture technologies during the 1970s and '80s, including techniques that allowed the use of young pearl oysters and the insertion of a second nucleus into a pearl sac produced by harvesting of the first pearl. Although initially there were some problems with these second insertions in terms of oyster mortality and the quality of the pearls, these were overcome by making the incision to extract the first pearl in a different area of the mollusk, and changing the mantle tissue used in the second grafting (N. Paspaley, pers. comm., 2007). With current methods, the initial grafting yields pearls averaging 11–12 mm and has a success rate (with the oyster surviving to yield a commercially viable pearl) generally over 90%, comparable to akoya. For the second grafting, a shell bead the size of the just-extracted pearl is inserted, yielding a pearl that ranges from 14 to 16 mm. However, the yield is lower, 65% on average, and the quality of color and luster is not always as high as the first pearl. Some oysters are operated a third time to yield 17–20 mm pearls, but the quality and success rate are often lower still (Strack, 2006).

By 1989, Australian production had climbed to 140 *kan* and was poised for a sharp increase. In October of that same year, Paspaley purchased Pearls Pty. and its Australian parent, the Otto Gerdau Co., to become the dominant producer in Australia. That same month, Paspaley conducted the first auction of South Sea pearls outside Japan. The sale of 24 *kan* at the Darwin, Australia, event brought \$35 million, with prices for the top qualities surpassing their estimates by 40–100%. For the first time, Japanese buyers faced major competition from firms in other countries, including Hong Kong and the United States (Torrey, 2005; Strack, 2006).



Figure 8. The skill of Japanese technicians was instrumental in establishing the South Sea cultured pearl industry in Australia. Here, the technician is preparing to implant a bead in the oyster. Photo by R. Shor.

Extreme top qualities of South Sea pearls over 15 mm are estimated to be a tiny minority of production (figure 9), which accounts for their value. Round and nearly round pearls below 15 mm account for about 20% of Australian production, less in Indonesia and the Philippines. Symmetrical shapes (primarily drops) account for about 50% of Australian production, 20% in Indonesia and the Philippines. Baroque shapes account for about 30% of Australian production and as much as 70% of Indonesian and Philippine production (Strack, 2006; Branellac, 2007).

In the 1980s, the Australian government had expanded the number of pearling licenses, which attracted a number of new operations—including Clipper Pearls and Blue Seas Pearling. Following the slump in demand from Japanese buyers after the Asian financial crisis in the late 1990s, most of these new Australian pearl farms (which accounted for 20% of the country's production) decided to



Figure 9. Large, top-quality South Sea cultured pearls such as these are very rare. Courtesy of Paspaley.

market their pearls through Australian wholesale agents (N. Paspaley, pers. comm., 2007). Since the mid-1990s, Australian production has increased in measured steps; by 2005, total output had reached 850 *kan* (3.19 tonnes), six times the amount recorded for 1989 (Muller, 2005).

Indonesia. Although Japanese firms started culturing pearls in Indonesia during the 1920s, it was not until the early 1970s that an industry took shape—again with Japanese involvement. During the 1980s, a number of Japanese and Australian companies began operations in the island nation with *P. maxima* oysters. Indonesia's pearling operations are located on small islands throughout the archipelago. In 2006, there were 107 documented farms; Japanese and Australian companies operated nearly half of them; the remainder were locally owned, the most dominant being Concorde Pearls (Sertori, 2006; N. Paspaley, pers. comm., 2007). Yet there were, and still are today, many undocumented farms, some encroaching on areas claimed by established operations (Sertori, 2006). Since the government's ban on harvesting wild *P. maximas* in 1997, all pearls are cultured from hatchery-bred oysters. These pearls tend to be more uniform in quality and smaller in size—8–12 mm on average, though they can be as large as 16 mm. In addition, the colors tend to be warmer than the Australian goods, at their best showing tints of yellow, pink, and "gold" (Muller, 1999).

Indonesia's pearl production has fluctuated dramatically over the past 15 years. Violent storms and a catastrophic earthquake in December 1992 devastated much of the oyster population (Muller, 2005), causing production to fall from an estimated 600 *kan* in 1991 to 300 *kan* in 1994. It continued to slide over the next four years to 200–250 *kan*. By 2000 output had rebounded to 600 *kan*, but an earthquake again brought disaster and the following year's crop amounted to about 400 *kan*. Some observers believed the earthquakes altered the nutrients in the water, while others maintained that El Niño cycles changed the water temperature around the islands. Still others blamed the overpopulation of prime pearling areas (Muller, 2005), since Indonesia—unlike Australia—does not impose limits on the number of shells in operation or the number of farms in any specific area.

By 2005, however, output had jumped to 1,022 *kan* (3.83 tonnes) worth \$85 million (Muller, 2005; Strack, 2006), with qualities from established farms rivaling the best Australian goods. While substantially higher by weight than Australia's production of 850 *kan*, this was still well below Australia in value (\$123 million). Most of Indonesia's output is marketed generically by dealers from Australia, Europe, Hong Kong, and Japan.

Serious challenges remain, however. Theft has become a significant problem, as most of the farms are located in remote areas with no law enforcement and are difficult to guard effectively. In addition, most of the illicit pearls are stolen before the culturing process is complete, then sold as Indonesian goods, which gives buyers a poor impression of Indonesian pearls (Sertori, 2006).

Myanmar. Burma was once known as the source for the best South Sea cultured pearls because of their large size (17+ mm), subtle color, and high luster (figure 10). That was before neglect, disease, and government seizures all but halted production by the end of the 1980s.

During the 1950s, a Japanese firm, the South Seas Pearl Co., began a joint venture to produce Burmese pearls. With the expulsion of Japanese businesses following a military coup in 1962, the Burmese government assumed control of the industry and employed local Australian and Japanese technicians to keep the farms running. The first commercial harvest under the new regime, in 1969, yielded 3,485 cultured pearls weighing just over 1.92 *kan* (7.20 kg). During the 1970s and '80s, the

country continued to produce relatively small quantities of pearls, but of extraordinary quality. Production peaked in 1983 at just over 17 *kan* (63.75 kg; Myanmar Pearl Enterprise, 2003). All the pearls were sold at government-sponsored auctions in the capital Rangoon (now Yangon).

Explanations for the exceptional quality of these Burmese cultured pearls vary. The most common is that very small nuclei were used to prevent nucleus rejection, and the beads were left in the oyster for four years. Hence, the resulting pearls had very thick pearl nacre and closely resembled natural South Sea pearls.

The industry suffered, however, after another military coup in 1988 (as a result of which the country was renamed Myanmar in 1989) and a failed 1990 attempt to restore democracy brought waves of social and economic upheaval. The pearl farms fell into neglect, and the mollusks suffered from bacterial infection. By the early 1990s, production was negligible.

Later that decade, however, the Japanese firm S. Tasaki Shinju and an Australian joint venture with the government, Myanmar Atlantic Ltd., established new operations. These and other enterprises have since revived production to some degree, but the newer Burmese cultured pearls have not achieved the extraordinary quality of the earlier goods (Strack, 2006). Myanmar's production totaled 179 *kan* in 2005, 102 *kan* of which was produced by the S. Tasaki Shinju operations ("Myanmar expected to produce 220 *kan* in 2006," 2006).

Philippines. Like other Pacific locales, the Philippine pearl industry has its roots in the *P. maxima* mother-of-pearl fishing industry that flourished during the 19th century. Attempts to establish operations date back to 1914, but pearl culturing in the Philippines did not begin in earnest until the South Seas Pearl Co. became involved there in 1962. Several non-Japanese companies launched operations in the nation's southern islands during the late 1970s, and by 1994 the Philippines' 120 *kan* production ranked third behind Australia and Indonesia, with 20 large and medium-sized farms (Strack, 2006). Unlike Australia, where most of the culturing is done with wild oysters, the vast majority of Philippine pearls are cultured from hatchery stock (Torrey, 2005).

In 2005, there were 37 farms that produced an estimated 450 *kan*, valued at \$25 million. Although Philippine farms produce many fine-quality goods,



Figure 10. Although their total production has never been great, Burmese South Sea cultured pearls are renowned for their size, luster, and color. The loose pearl is approximately 16.5 mm in diameter. Courtesy of The Collector Fine Jewelry; photo by Harold © Erica Van Pelt.

the average per-*momme* value of Philippine production (\$55) that year was about one-third that of Australia's producers (Muller, 2005). It is important to reiterate, however, that the *P. maxima* found in Philippine waters, mainly around the southern islands, has a gold-lipped shell, as opposed to the white or silvery lip of the Australian or Indonesian variety, which imparts a warmer, creamy character to the resulting white pearl. However, at least one major farmer used the gold-lipped *P. maxima* to consistently produced bright "golden" pearls, which will be discussed below.

BLACK PEARLS

Natural black pearls from the black-lipped *P. margaritifera* oyster were part of Polynesian culture and legend long before European explorers first arrived in the 16th century (see, e.g., Goebel and Dirlam, 1989). After the Marquesas Islands became a French protectorate in 1842, a mother-of-pearl fishing industry flourished under the colonial government through the rest of the 19th century. Natural pearls were a valued by-product of this industry, though it was estimated that only one oyster in 15,000 would yield a pearl of any size (Tisdell and Poirine, 2000). The only other major source of black pearls was several

thousand miles across the Pacific—along Mexico's Baja California peninsula around La Paz (Goebel and Dirlam, 1989), where the Spanish commenced pearl fishing from the *Pteria sterna* oyster in the 16th century (Cariño and Monteforte, 1995).

In 1961, the Fisheries Service of the French Polynesian government began a trial culturing project in conjunction with two Japanese firms: Nippo Pearl Co., which had provided technical assistance to Australia's early producers, and Tayio Gyogo Ltd., which also operated in Australia. That pilot project on Bora Bora, approximately 240 km (150 miles) northeast of Papeete, the French Polynesian capital on the island of Tahiti, produced a number of good-quality black pearls, but there was no commercial follow-up (Tisdell and Poirine, 2000).

In the early years of culturing with *P. margaritifera*, the public's lack of familiarity with black pearls led to rumors that they were dyed. In addition, there was widespread belief that colors other than white were simply not marketable (Tisdell and Poirine, 2000; Strack, 2006). One pearl farmer, Jean Claude Brouillet, carried an array of black pearls to top jewelers in London, Paris, New York, and Tokyo in the early 1970s, and later described how the president of Cartier in Paris "used them as playthings" during their meeting (Tisdell and Poirine, 2000).

A turning point came after Robert Crowningshield (1970) reported on his examination of a black cultured pearl in *Gems & Gemology*, finding the color to be natural. GIA's decision in the mid-'70s to offer identification reports stating the origin of color gave these pearls much-needed credibility (Moses and Shigley, 2003).

The French Polynesian government, seeing potential employment for people on the outlying islands, aggressively encouraged the development of new pearl farms. Two entrepreneurs stepped in: Robert Wan, a French Polynesian resident of Chinese descent; and Salvador Assael, a New York importer born in Italy. Wan purchased and enlarged Tahiti Perles, an operation begun by Australian William Reed, while Assael worked with Brouillet to expand his concern by building infrastructure and hiring expert Japanese technicians. By 1976, the Wan farm was on its way to becoming one of French Polynesia's largest producers (figure 11), acquiring Brouillet's farm nine years later.

Assael began marketing his pearls in the U.S. in 1973 and soon became one of the largest distributors for a number of producers, including Wan. This

marked the first measurable success of a producer and distributor of any type of pearl who had no Japanese affiliation (Goebel and Dirlam, 1989).

Then, in 1979, the smaller farms grouped together in a cooperative called Groupement d'Intérêt Economique (GIE) Poe Rava Nui, under an initiative by the government's Fisheries Service (Luke, 2005). The GIE provided economic support for small pearl farmers and organized a central auction of its members' harvests in Papeete that continues to the present day (Strack, 2006).

All this progress came at a price, however. The market's growing acceptance of black cultured pearls and the high prices realized for top-quality goods, coupled with government incentives to develop the industry, launched a "pearl rush" that saw hundreds of new farms start up during the early 1980s. The overexploitation of the waters around certain atolls caused massive mortality—an estimated 50% of the seven million oysters under operation in 1985–1986. Inspectors found no specific bacteria or disease and concluded that overpopulation and slow currents were responsible. In those two years, there were 69 cooperative units and 20 larger private farms located across 18 islands—and this was only a fraction of what would come in the 1990s (Tisdell and Poirine, 2000).

As Australian and French Polynesian pearl production increased to sustainable levels, the next step would be to establish these goods in the marketplace.

BREAKING AWAY—FROM JAPAN AND "GRANDMOTHER"

With other transitions in the 1990s, South Sea and French Polynesian pearl producers accelerated their efforts to cultivate and market their goods independently of the Japanese. They also worked to dispel the conservative fashion image of pearls.

By the middle of the decade, these producers were selling nearly all of their pearls worldwide through competitive auctions held in Hong Kong and Kobe, in a variety of currencies. Unlike akoya auctions, where the only significant buyers were Japanese, buyers at these auctions came from every corner of the globe (Shor, 1995b; M. Coeroli, pers. comm., 2007). Now that they had largely separated themselves from the distribution channels for akoyas, the next step for South Sea and French Polynesian pearl farmers was to establish unique brands for their products.

Global advertising was a central issue at another



Figure 11. After overcoming a variety of economic and technical challenges, pearl farms in French Polynesia were producing commercial quantities of black pearls by the late 1970s. Shown here is a pearl boat working a Robert Wan farm on the island of Marutea Sud, approximately 1,850 km (1,000 nautical miles) east of Tahiti. The workers are cleaning marine life from the oysters prior to returning them to the water for further growth. Photo by Amanda Luke.

landmark pearling convention in 1994. Although this Honolulu conference, “Pearls 94,” was boycotted by Japanese producers, dealers, and researchers, it was truly an international gathering, with 645 participants from 38 countries (Strack, 2006), and provided a unique opportunity for the exchange of technical and market information.

The main proposal to emerge from Honolulu was a \$2 million program to educate consumers about the different types of pearls and stimulate demand to offset the increased yield anticipated from China (discussed below) and other producers (Shor, 1994b). It would have been funded by a “tax” from each producer on the value of their exports.

While that proposal was never adopted, producer organizations embraced the need to inform consumers, and many soon developed educational and promotional efforts of their own. Specifically, in 1995 Australian producers established the South Sea Pearl Consortium to promote their product as a luxury pearl cultured in Australian waters. At the same time, French Polynesian producers, with government support, began marketing programs through their own organization, Perles de Tahiti, to heighten awareness of black pearls. Implicit in the messages of both organizations was the fact that their products were distinct from the Japanese akoya: the Australians’ by size and limited production, the Tahitians’ by color.

South Sea Pearl Consortium. This group began as an alliance of Australian producers (Paspaley and Broome Pearls) and international wholesalers (Nippo Pearl Co. and Hamaguchi Pearling Co. of Japan, Cogent Trading of Hong Kong, and Assael International of the United States). Seeded with an initial contribution of \$2 million from its members, the consortium began a consumer advertising campaign that stressed the luxury aspects (large size and top color) of South Sea pearls. Later in 1995, the members of the Pearl Producers Association of Western Australia joined the consortium and agreed to fund its ongoing promotions with a contribution of 1% of all proceeds from their pearl auctions (Shor, 1995a). The consortium, which opened membership to Indonesian and Burmese pearling firms after 2000, also worked to improve grafting techniques and to safeguard quality by prohibiting its members from treating their pearls (Strack, 2006).

Perles de Tahiti. Unlike the early Australian pearling industry, producers in French Polynesia for the most part did not operate under direct Japanese ownership, though they relied on Japanese expertise for grafting and maintenance of the oysters. For a time, French Polynesia sold the vast majority of its production to Japanese distributors. Once again, however, independence had a price, which was to be paid in the 1990s.

The French Polynesian government, anxious to increase employment and gain critical foreign trade, had maintained a very liberal policy toward granting pearl farming licenses. As a result, the number of farms—most of them small and undercapitalized—multiplied tenfold, from 69 in 1986 to more than 700 in 1994. However, many of these did not employ skilled technicians or follow the culturing process long enough—some less than 18 months (Tisdell and Poirine, 2000)—to produce a good-quality pearl (e.g., figure 12). Thus, production climbed dramatically from 575 kg (153.3 *kan*) in 1990 to 11,364 kg (3,030.4 *kan*) in 2000, while the average price per gram declined from \$42 to \$13.65 over the same period and continued sliding to a low of \$9.58 in 2003 (Coeroli and Galenon, 2006).

In the mid-1990s, however, Perles de Tahiti launched a campaign to promote “black” pearls as a product distinct from Japanese or South Sea pearls. The initial budget of US\$650,000, financed by a 2.5% “tax” levied on producers, went toward cooperative advertising with luxury retailers in the United States, France, Italy, and Japan. As part of the branding process, Perles de Tahiti named their product “Tahitian” cultured pearls, despite the fact they were cultivated on islands throughout the French Polynesian archipelago (again, see figure 2). Around the world, the name *Tahiti* conjured up favorable images of a pleasant, exotic locale (M. Coeroli, pers. comm., 2007).

A key step in establishing the Perles de Tahiti brand was to impose quality standards. In 1999, the

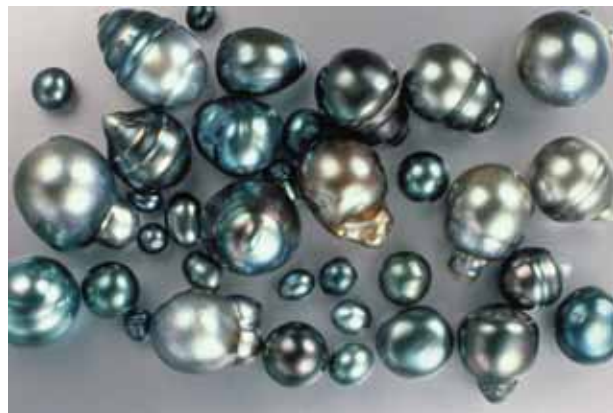
government introduced a minimum quality standard for exports: a nacre layer at least 0.6 mm thick (to take effect September 1, 2001), to be increased to 0.8 mm (effective July 1, 2002). At least 80% of the shell bead nucleus had to be covered and heavy blemishes could affect no more than 20% of the surface (M. Coeroli, pers. comm., 2007). Roundness and color were not addressed. The government also restricted the number of producers through a licensing system that limited the number of operations in a particular area, as well as the number of shells that could be operated (Tisdell and Poirine, 2000).

Results were slow to come, however, since there was considerable excess inventory, and initially the government did not have sufficient resources for comprehensive inspection. Not until 2004 did the French Polynesian government fully enforce the quality control measures it had enacted in 1999. Production declined to just over 8,000 kg (2,133 *kan*) that year, and it has remained fairly stable since then, while the average price began to increase substantially (M. Coeroli, pers. comm., 2007). At least 35% of the pearls produced during this period were not cleared for export (Strack, 2006).

The second step in the Perles de Tahiti marketing plan was to work with jewelry designers and manufacturers to create fashion-forward products that would update the image of cultured pearls (e.g., figure 13). The global jewelry design competition it launched in 1999 represented a sharp break from previous pearl marketing efforts, which concentrated on strands because they made the most extensive use of the product. By 2006, the annual contest was attracting 6,000 entries from 39 countries (Coeroli and Galenon, 2006). Perles de Tahiti also believed that showing celebrities wearing fashionable pearl pieces would dispel the “grandmotherly” image of pearls. In 2007, Perles de Tahiti budgeted \$6.4 million for marketing: \$2 million in the United States, \$2 million in Japan, and the remainder divided between Europe and emerging markets such as Brazil, India, China, and the Middle East.

The efforts of producers to market their goods independently of Japan, coupled with the disasters besetting the Japanese pearl farms, showed tellingly in U.S. pearl imports. In 1996, Japan was the source of 62% of all pearls imported into the United States. By 1999, that portion had fallen to 45%, and by 2001 it had dropped to 35%. Over the same period, direct imports from Australia increased from 12% to 20% and imports from French Polynesia rose from 5% to 9%.

Figure 12. Overproduction and lax controls caused a flood of poor-quality black cultured pearls on the market in the 1990s, hurting prices and forcing the government to impose quotas and quality standards. Photo by Robert Weldon.



CHINESE CULTURED PEARLS

Freshwater. During the first century of pearl culturing, nearly all of the product came from saltwater mollusks. In the 1930s, freshwater cultured pearls became a relatively small segment, consisting primarily of small, irregularly shaped Japanese goods from Lake Biwa near Kyoto and Lake Kasumigaura near Tokyo (Strack, 2006). In the early 1990s, however, round and semi-round freshwater cultured pearls from Chinese producers emerged as a low-cost alternative to akoyas and, by the end of the decade, to South Sea pearls. One important distinction was that unlike the saltwater products, which were grown with a bead and a piece of mantle tissue, Chinese FWCPs were grown using only mantle-tissue implants, with no beads. Another was that dozens of pearls could be cultured in a single freshwater mussel—as opposed to typically one or two pearls per oyster for saltwater pearls.

Chinese FWCP production began in the early 1960s under the auspices of Shanghai University and the Fisheries Institute of Zhanjiang, in Guangdong Province. Typically these pearls, which were cultured using the *Cristaria plicata* mussel, were small, irregularly shaped goods (commonly referred to in the trade as “rice krispies,” because of their resemblance to the breakfast cereal; figure 14). At first, Japanese dealers purchased the entire production, mixing them into Biwa goods and marketing them as such, even as output soared from an estimated 155 *kan* (581.3 kg) in 1974 to 3,109 *kan* (11,659 kg) in 1979 (Strack, 2006).

However, Chinese production continued to skyrocket, reaching approximately 80 tonnes during the mid-1980s, a level the Japanese dealers could no longer absorb. The unfettered flow of pearls sent prices plummeting, particularly as millions deemed unsuitable for fine jewelry use were dyed various colors and fashioned into costume jewelry (Akamatsu et al., 2001). Still, these “rice krispie” pearls were a vastly different product from the traditional akoya spheres that had been the mainstay of the pearl industry, so the oversupply from China had little effect on the traditional market. That would soon change.

A number of farms (e.g., figure 15), now financed by large Hong Kong traders and several major Japanese producers, began to experiment with the *Hyriopsis cumingii* (triangle) mussel, which could produce a semi-round to round, akoya-like piece (Akamatsu et al., 2001). The first crops of “potato” pearls (so called because of their off-round shape and



Figure 13. In an attempt to raise the profile of black cultured pearls and broaden their appeal beyond traditional strands, Perles de Tahiti sponsored a series of design contests that led to innovative black pearl jewelry. The suite shown here (8.0–11.0 mm), designed by Mari Saki of Nagahori Corp., Tokyo, was an award-winning submission in 2006. Courtesy of GIE Perles de Tahiti.

Figure 14. The flat baroque shape of early Chinese freshwater cultured pearls led to the moniker “rice krispie” pearls. Advances in culturing technology and a change to a different species of mussel brought about dramatic improvements in quality in the 1990s. Photo by Maha Calderon.





Figure 15. Chinese freshwater pearls are produced from pond farms large and small across the country, such as the one shown here in Zhuji, Zhejiang Province. Photo by Valerie Power.

the fact their color resembled that of a peeled potato) were approximately 3–6 mm in diameter, with a fairly dull luster. They appeared in the market in 1992, the same year the Chinese government removed export controls on all pearls.

This development caused great concern in the Japanese industry. A strand of round Chinese FWCPs cost 10–30% of a similar-size akoya necklace, and the quality was improving with each harvest. In addition, as with the *C. plicata* mussel, several tissue insertions could be made in a single mollusk (figure 16), which resulted in multiple pearls from each mussel. A delegation of Japanese pearl producers journeyed to China in late 1993 to seek that government's help in imposing production limits and export restrictions on both freshwater and saltwater (see below) pearls. A key member of the delegation said that while the Chinese government did promise to impose export limits (Shor, 1994a),

the mission was ultimately unsuccessful because exports continued to climb.

Round Chinese FWCPs made their major U.S. debut in 1995, at the JCK Las Vegas trade show (Torrey, 1995; Shor, 1995b). Estimates of Chinese FWCP production ran as high as 500 tonnes that year, and doubled again by 1997 (Strack, 2006). As larger (7+ mm) goods appeared in the market, controversy erupted after claims began circulating in the trade that these pearls were nucleated with reject FWCPs rather than being formed by tissue implants only. However, a comprehensive study by Scarratt et al. (2000) found no evidence of such nuclei. In recent years, though, some Chinese pearl farmers have had considerable success with shell bead nucleation of hybrid (*H. cumingii* and *H. schlegelii*) mussels to better control shape (Fiske and Shepherd, 2007).

By the end of the decade, Chinese FWCPs had improved significantly in shape, size, and surface

Figure 16. Much of the enormous production of Chinese freshwater cultured pearls is due to the fact that the mussels used can produce dozens of pearls at a time (left); akoya oysters (right) typically produce no more than one or two pearls each. Photos by Doug Fiske (left) and Valerie Power (right).



quality, with substantial advances in grafting and cultivation techniques. Although the culturing of 7–8 mm pearls could take anywhere from five to seven years (and larger pearls required the use of fewer implants), the sheer volume that could be produced from a single mussel meant that the quantities of such goods would remain high.

Investors from Hong Kong began organizing producers, especially those that turned out finer-quality goods, into a centralized distribution operation. One of the largest of these firms, founded in 1983, was Man Sang Holdings. Man Sang invested heavily in building a pearl-processing infrastructure within China, particularly in Shenzhen, approximately 160 km (100 miles) north of Hong Kong. In 2006, Man Sang reported sales of \$48.5 million (Man Sang annual report, 2006).

Since 2004, when output exceeded 1,500 tonnes, many Chinese FWCP producers have strived for innovations at the top end (figure 17). Some examples are pastel-colored and South Sea-sized (12–14 mm) products with high luster that command exceptional prices (“HKPA enhances freshwater pearl promotion,” 2007).

At an average weight of 0.7 g per cultured pearl, that 1,500 tonnes equates to 2.14 billion pieces. However, production estimates note that only about half of these are suitable for adornment (many poor-quality pearls are crushed and used in cosmetics and other products). About 2% are round and near-round, regardless of other value factors such as color or blemishes. Very high quality, truly round goods over 8 mm that can compete in appearance with akoyas or even South Sea pearls are a minute percentage, about 0.0025% of the total. Only one in 500,000 is of exceptional quality (Shou Tian Guang, pers. comm., 2007).

Saltwater. The Chinese saltwater cultured pearl (SWCP) industry dates back to 1958, when the Zhanjiang Fisheries Institute began an experimental project near Hainan Island in the South China Sea. Employing the *P. chemnitzii*, a slightly different variety of oyster from the Japanese *P. martensii*, the project reportedly had a small but consistent output through the 1960s, though production statistics were never released. Japanese dealers purchased entire harvests and marketed them as akoyas from Japan (Strack, 2006).

In the late 1980s, as the Chinese economy began to liberalize, entrepreneurs started farms all along the country’s southern coast. By 1993, China’s



Figure 17. After years of quality improvements, the best Chinese freshwater cultured pearls are capable of competing with top products from Japan and other areas. This necklace (4–8.5 mm) and pendant (8.5 and 11 mm) were designed by Cornelis Hollander Designs, Scottsdale, Arizona. Photo by Robert Weldon; courtesy of the American Gem Trade Association.

annual production of SWCPs—some with a nacre thickness of 2 mm, more than three times that of most Japanese goods—had reached 5–10 tonnes, compared to Japan’s production of 80–90 tonnes (Strack, 2006). Because of the long cultivation periods (two to three years), a large percentage of these goods were irregularly shaped.

When the oyster mortality crisis struck akoya pearl farms in the mid-1990s, Japanese importers became even more dependent on Chinese farms to augment their supplies. Chinese SWCPs were similar in size (4–6 mm) to the average Japanese akoya pearl and very similar in appearance. Also during the mid-1990s, Chinese farmers began using *P.*

martensii to produce true akoyas and became a major supplier of oyster stocks after the destruction caused by infectious disease ("Japan buys oysters in China," 1997). However, bad weather and disease created problems in China as well, eventually forcing as many as one-fourth of the 3,000–4,000 farms out of business.

By the late 1990s, Chinese SWCP production, now more than 20 tonnes a year, was approaching that of Japan, which had continued to fall (from 40 tonnes in 1997 to 25 the following year). The more advanced farms were routinely producing goods as large as 8.5 mm, but quality remained an issue. The locally produced nuclei tended to be more blemished and more difficult to fashion into near-perfect spheres than the beads from the American *Unio* mussel that the Japanese preferred. In addition, the Chinese farmers now rushed the pearls to market much more quickly than in previous years, and the often thin nacre (under 0.4 mm) tended to make Chinese pearls less lustrous (Strack, 2006). As with the FWCP producers, however, the more sophisticated SWCP operations worked to improve the overall quality of their product. Hong Kong firms, later joined by the Japanese, began establishing large processing centers in the SWCP centers as well—and sharing many Japanese quality-enhancing techniques (Strack, 2006).

OTHER PRODUCERS

Pacific Rim. South Sea pearls are produced in other Pacific nations such as Thailand, New Zealand, and Papua New Guinea, some as government-sponsored pilot projects and others under the aegis of large corporations such as Man Sang, Golay Buchel, Tasaki, and several large Australian firms.

During the 1990s, the Cook Islands began to steadily increase production of black pearls, the vast majority of which were irregular in shape and bore a distinctive ribbed pattern. The main pearling island of Manihiki was home to about 75 pearl farms (some 60% of the total), most of them selling to Australian dealers through local cooperatives (Strack, 2006). However, many believe that the Cook Islands' industry is actually much more extensive, as large quantities of pearls are smuggled out of the country each year to avoid customs duties (Stanley, 2003).

Note, too, that Okinawa has produced small quantities of black cultured pearls intermittently since the 1920s (Muller, 1997b). The Ryukyu Pearl



Figure 18. American entrepreneur John Latendresse was successful in producing freshwater cultured pearls (fancy shapes, for the most part) in the U.S. during the 1980s and 1990s, but the last substantial harvest was in 2002. This freshwater cultured pearl fish pin set with sapphires and rubies was designed by Glen J. Engelbrecht. Courtesy of the American Pearl Co., Nashville, Tennessee.

Co., founded in the 1960s, is still cultivating high-quality black pearls in that area (S. Akamatsu, pers. comm., 2007).

Since 1999, small quantities of akoya-like pearls have been produced in Vietnam by several locally owned firms, as well as Japanese and Australian companies (Strack, 2006). South Korea also supports a relatively small akoya production, largely under Japanese ownership (R. Torrey, pers. comm., 2007).

North America. Black pearls have been found along the Gulf of California (also known as the Sea of Cortez) since pre-Columbian times, and were noted by Spanish explorer Fortún Jiménez as early as 1533. Natural pearls were a major export from Baja California until the oyster beds were nearly depleted at the beginning of the 20th century. Although several attempts were made to culture pearls in the Gulf of California, not until the 1990s did an operation yield commercial quantities of round cultured pearls from the native *P. sterna* oyster. In 2006, Perlas del Mar de Cortez produced about 5,000 cultured pearls in a wide variety of darker colors. The firm markets half of its production to local jewelry manufacturers and the remainder to wholesalers, primarily in the U.S. (Kiefert et al., 2004).

Freshwater cultured pearls from Tennessee have received a great deal of press attention over the years—far more than actual production would normally warrant. After many years of experimenting

with different grafting methods and mussel species, American Pearl Company founder John Latendresse succeeded in creating a wide variety of pearls with fancy shapes—bars, buttons, drops, and coins—determined mainly by the shape of the bead nucleus (figure 18). Since Latendresse's death in 2000, the company has undergone many changes. The farm's last substantial harvest was in 2002, resulting in 87,294 cultured pearls from approximately 75,000 mollusks, the smallest harvest in 15 years. During the 20 years of production, Latendresse kept about 15–20% of the harvest for "rainy days," leaving the firm with considerable inventory (G. Latendresse, pers. comm., 2007). Today, the pearl farm in Camden, Tennessee, is primarily a tourist attraction.

CULTURING IS NO LONGER A BLACK-AND-WHITE ISSUE

"Golden" Pearls. It has long been known that the gold-lipped *P. maxima* in Philippine waters creates, on rare occasions, bright yellow or "golden" pearls. Before the 1990s, these colors were not considered desirable in many markets, particularly Asian ones, and most farmers tried to develop grafting methods that would avoid them (R. Torrey, pers. comm., 2007). Nevertheless, Jewelmer, a partnership between French-born pearl farmer Jacques Branellac and Manila businessmen Eduardo and Manuel Cojuangco, spent most of the 1980s breeding *P. maxima* in a hatchery in Bugsuk on Palawan Island to develop an oyster that would consistently yield golden pearls and result in a brandable product very different from other South Sea pearls (Torrey, 2004).

Once researchers found the best combination of nutrients and other factors to increase the likelihood of creating golden pearls (figure 19), they began breeding large numbers of spat in hatcheries, then raised them in sea beds. Jewelmer's golden pearls averaged 11–13 mm after 18–24 months of culturing (Torrey, 2001, 2003). Although the company's production figures are proprietary, its 2006 production has been estimated at 70% of the total Philippine production of 450 *kan* (R. Torrey, pers. comm., 2007). A 2007 report stated 30% of the pearls Jewelmer produced were golden, but less than 10% were "deep golden" in color (Parels-AEL, 2007).

Beginning in 1999, Jewelmer started marketing golden pearls as a glamour item by staging lavish fashion shows annually at the mid-September Hong Kong Jewelry and Watch Fair—chosen because it

attracts most of the world's key pearl buyers, who attend the major pearl auctions held in conjunction with the fair (Torrey, 2004). The company also advertises extensively (its marketing budget is confidential) in trade publications and some consumer magazines around the world, again stressing the golden pearl as a fashionable luxury item. Jewelmer was one of the first producers to launch a major effort to brand and sell its pearls downstream to jewelry designers and retailers through world trade shows instead of marketing them all generically to wholesalers through auctions (Torrey, 2001).

The push to create trade and consumer acceptance of golden pearls (figure 20) served as a catalyst for the entry of other fancy colors that had once been regarded as undesirable. These new colors

Figure 19. Once an undesirable oddity in many markets, golden cultured pearls became an important product during the early 2000s. Courtesy of Jewelmer.





Figure 20. As dealers and consumers began to appreciate the beauty and fashion possibilities of golden cultured pearls such as these (~12 mm), the door was opened to a variety of other fancy colors. Necklace courtesy of Baumell Pearl Co., San Francisco; photo by Robert Weldon.

would help thrust pearls into the center of the fashion world (Honasan, 2001).

Other Fancy-Colored Pearls. Although Tahitian pearls are typically called “black,” the majority are actually shades of green or gray. On occasion, other colors—including yellow-green, “bronze,” and light blue—show up in production. Like their white pearl-producing counterparts, French Polynesian farmers initially deemed these colors undesirable to the point that many chose not to market them at all (R. Torrey, pers. comm., 2007).

In 1996, however, a number of companies began selling fancy-colored goods. One of these was Swiss pearl wholesaler Golay Buchel, which ran an ad in U.S. magazines touting a yellow-green Tahitian pearl necklace as “pistachio pearls,” shown next to luxury-priced golden and white pearls. The company reported that coupling the yellow-green necklace

with more familiar white and “black” colors helped build rapid acceptance and consumer demand (Federman, 1998a).

About the same time, naturally colored violet, lavender, “apricot,” “copper,” and even purplish red Chinese FWCPs began filtering into the market. As a result, pearl wholesalers such as Schoeffel, Golay Buchel, and others began the hitherto unheard-of practice of mixing saltwater and freshwater pearls together in the same pieces to achieve multi-colored looks (Federman, 1998b; figure 21).

As these colors gained favor in the market, producers began studying how to achieve them more predictably. On the Fiji Islands, J. Hunter Pearls launched a specialty line of fancy colors cultured from the *P. margaritifera* that included various shades of green, blue, gold, and “rose.” The compa-

Figure 21. Improvements in culturing and production led to greater numbers of fancy-colored pearls entering the market. Designers soon began mixing colors to achieve attractive combinations, sometimes even combining salt- and freshwater cultured pearls (~10 mm). Necklace courtesy of Albert Asher Pearl Co., New York; photo by Robert Weldon.



ny, founded in 1999, also specializes in larger sizes, averaging 11 mm (J. Hunter Pearls Fiji, 2007).

BRANDING AND MARKETING

The cultured pearl is the only segment of the jewelry industry that grew from a branded product, thus setting a precedent for others to follow. Kokichi Mikimoto's relentless efforts to popularize cultured pearls were instrumental in creating the Mikimoto brand. In 1899, just three years after the first culturing successes (at that time, primarily mabe pearls), Mikimoto established a retail store in Tokyo's premier shopping district, Ginza. The first overseas Mikimoto store opened in London in 1913, followed by Shanghai, Bombay (now Mumbai), New York, Los Angeles, Chicago, and Paris, all by 1929. Today, Mikimoto remains one of the most recognizable names in the jewelry industry.

In the ensuing years, cultured pearls outside the Mikimoto brand became generic, albeit precious, items, much like diamonds and colored stones. The pearl crises of the 1990s—the loss of most of Japan's akoya crops, overproduction and quality problems with Tahitian goods, and the Asian banking crisis—forced producers to seek large new clients outside Japan and, in many cases, assume the costly burden of holding inventory (N. Paspaley, pers. comm., 2007). As a result, some of these producers, too, faced the need to establish a brand identity.

Fearing a commoditization that would lead to a destructive discounting cycle, and determined to keep inventories from accumulating, large, well-financed producers such as Perles de Tahiti and Paspaley turned to designer jewelry to give their products individuality and shore up demand for the higher end (M. Coeroli, pers. comm., 2007; N. Paspaley, pers. comm., 2007; figure 22). A number of these efforts were successful, drawing attention from the fashion press, and mainstream fashion designers and retailers in the United States and Europe began featuring pearls (figure 23). Pearl specialists such as Heinz and Tove Gellner of Wiernsheim, Germany, and Christianne Douglas of London created innovative pieces, which received substantial fashion press coverage, from necklaces and brooches to long "body wraps" using a mixture of pearl varieties. Robert Wan, the largest producer of Tahitian pearls, commissioned his own designer lines of jewelry, which were displayed at major trade shows around the world (M. Coeroli, pers. comm., 2007).

In Europe, an Italian pearl importer created



Figure 22. The necklace and matching earrings shown here were part of the White Magic collection commissioned by Paspaley in 2005 to showcase the design possibilities of its South Sea cultured pearls. Jewelry by Gisèle Moore, London; photo courtesy of Paspaley and the South Sea Pearl Consortium.

Utopia, a branded fashionable jewelry line, from South Sea pearls (figure 24). The company launched the brand in 1997 because confusion over different types of pearls and publicity surrounding treatments had begun to undermine consumer confidence (P. Gaia, pers. comm., 2007). It kept custody of the supply chain from farm to inventory, and guaranteed that each pearl was untreated (Johnson et al., 1999). Backed by international marketing, Utopia expanded from a local operation serving Italian retailers to one with a presence in most major world markets within a decade (A. Gaia, pers. comm., 2007).

David Yurman, who in 2004 had more than 200 retail locations, was one of the first to enthusiastically embrace pastel-colored pearls. That year he introduced an extensive pearl line that employed all major varieties and mixed various colors (Zimbalist,



Figure 23. In response to price fluctuations and problems with production quality, black-pearl producers moved to protect demand for high-end goods by working with designers and retailers to create a variety of fashionable designs. Shown here is a suite by J. Grahl Design, Balboa Island, California. Photo by Sylvia Bissonette; © J. Grahl Design.

2004). Such mixing proved difficult because of optical effects. For example, a black pearl placed next to a white one should be 10–15% larger because, side by side, the white appears larger. Yurman continued to feature cultured pearls heavily in 2007 (figure 25), with 69 pieces. He commented on his website that pearls “have become the focus of my collections this year” (David Yurman, 2007).

Pearl retailing also underwent a revolution. In 2004, Tiffany & Co. launched a major pearls-only retail chain operation, Iridesse. While there still was no well-defined or documented consumer rush toward pearl jewelry, Tiffany believed there was substantial unrealized commercial potential for this product, based on a number of factors:

- Advances in pearl farming and culturing techniques were sufficient to guarantee a stable supply of all types of pearls, particularly higher qualities.
- The varied colors, shapes, and sizes of pearls lent themselves to a versatility of design and purpose that was underrealized in the marketplace.
- The wide variation in prices among pearl types allowed development of both distinctive, contemporary jewelry pieces and traditional strands. As a result, Iridesse offers pearl jewelry ranging from \$80 to \$40,000.

Iridesse commissioned several designers, including Christian Tse of Pasadena, California, and Coleman Douglas of London, to create unique pieces and help the chain establish a completely separate identity

Figure 24. Utopia has built its brand on the guarantee that its pearls are untreated. Aimed at fashion-conscious consumers, Utopia uses unconventional designs such as the necklace shown here, which combines white and golden South Sea pearls, fancy-color sapphires, and diamonds. Courtesy of Utopia, Milan.



from its parent company, which historically has offered few pearl pieces (R. Cepek, pers. comm., 2007).

Iridesse had opened six stores by the end of 2005, and nine more followed in 2006. The firm opened its 16th store—in the Century City Shopping Center in Los Angeles—in May 2007, making Iridesse a mid-sized chain in its own right (“State of the majors,” 2007).

The newfound diversity of pearls, coupled with the creations of jewelry designers and the expansion of major retailers into this arena, has widened the public’s perception of this gem beyond the strand of white spheres once worn only on formal occasions. Indeed, keshis, baroque shapes, and ringed pearls, which were traditionally difficult to sell, are increasingly in demand as more designers work with them (Gomelsky, 2007). Today, the no-longer-traditional strand of cultured pearls has assumed an important role in the wardrobe of the strong female professional (figure 26). By late 2006, suppliers of all types of pearls reported that business in the U.S. had increased by as much as 40% in one year on the strength of all the factors mentioned above (Henricus, 2006).

FUTURE

The past 15 years have provided the world’s pearling industry with strong lessons on the benefits and pitfalls of a free market and the challenges that nature can present.

On the demand side of the market—if trends in diamond and colored stone consumption can be used as a reliable guide—it is likely that emerging economies such as India, China, and Turkey will show substantially higher demand for cultured pearls in coming years. Indeed, Asian nations have a strong cultural affinity for them. On the production side, it is certain that new ventures will enter the market, because start-up costs are relatively low. For instance, a saltwater farm with 25,000–30,000 mollusks can be launched for as little as \$200,000, with a break-even point of less than five years (Fong et al., 2005).

This low barrier to entry makes pearl farming attractive to entrepreneurs and governments in countries with long coastlines and high unemployment. A number of nations, primarily in the Pacific Rim, are currently engaged in start-up pearl projects. These include New Zealand (cultured abalone pearls), the Marshall Islands (black cultured pearls), Vietnam (freshwater as well as akoya-like), and



Figure 25. Designer David Yurman has made a significant move into pearl jewelry with products such as this diamond, blue topaz, and cultured pearl necklace. Photo © David Yurman.

Figure 26. Speaker of the House of Representatives Nancy Pelosi, one of the most powerful women in the United States, is known for her attractive pearl necklaces. Photo © Mike Theiler/Reuters/Corbis.





Figure 27. The world pearl market will likely see continued innovations and new products in the years ahead. The diamond and mother-of-pearl pendant shown here is highlighted by an 11 mm carved black pearl that was cultured over an amethyst bead. Jewelry courtesy of Galatea, San Dimas, California; photo by Robert Weldon.

New Guinea (South Sea). However, China's vast production and low operating costs will likely thwart any start-ups that do not attempt to differentiate their products.

One new venture is returning to the area where pearling began some 3,000 years ago: the Persian Gulf. Although natural pearl production there all but ended by the 1960s as oil became the economic focal point, the region retains an intense historical affinity for pearls. In early 2007, the Dubai Multi Commodities Centre formed a joint venture with Arrow Pearls of Australia to culture akoya pearls in the region. The Dubai government granted the venture, Pearls of Dubai, five concession areas to establish pearl farms. In the summer of 2007, the enterprise began a pilot project of 100,000 oysters that will be harvested early in 2009. Ultimately, it seeks to produce a branded

"Dubai" line of cultured pearls, 8–9 mm goods marketed through local jewelers (N. Haddock, pers. comm., 2007). Several ventures in other emirates along the Gulf are in the planning stages.

Moreover, new types of cultured pearl products will certainly enter the market. Faceted pearls were in vogue during the early part of this decade, and in June 2007, a jewelry designer from California introduced black pearls with gemstone bead nuclei, cultivated in Vietnam. The designer, Chi Huynh of San Dimas, uses beads made from amethyst, citrine, and turquoise, then carves the resulting pearl to reveal portions of the stone beneath (Roskin, 2007; figure 27).

Nature, of course, will continue to impact pearl production worldwide. The effects of disease and overexploitation are well documented, as is the damage caused by earthquakes and typhoons. Pearl farms in Asia escaped the devastation of the December 2004 Sumatra-Andaman tsunami ("Tsunami reported to have little impact on industry," 2005). In China, though, a powerful August 2007 typhoon reportedly destroyed nearly half the akoya stocks under operation ("Chinese akoya production plummets after typhoon," 2007). Still other environmental concerns remain. In particular, pearl producers Jacques Branellac and Nicholas Paspaley addressed the issue of global warming at the GIA GemFest seminar held April 14 of this year in Basel, Switzerland (Paspaley, 2007; Branellac, 2007). They expressed their concerns that the future might see an increase in the number of catastrophic storms, rising sea levels, saltwater intrusion into freshwater cultivation areas, a greater incidence of disease and parasite proliferation, and higher water temperatures.

The unpredictability of nature, coupled with the proliferation of producers around the world, will probably result in more supply booms and busts in coming years. Despite the intensive, sophisticated branding efforts of some major producers, pearling remains a highly fragmented industry. However, it is also likely that the popularity of pearls in world markets will grow even more rapidly as the product continues to improve, and pearl farmers, jewelry designers, and retailers promote it to traditional and emerging consumer populations.

CONCLUSION

While Japanese producers, technicians, and distributors remain an integral part of the trade they created more than a century ago, the past 15 years

have seen sweeping transformations in the cultured pearl industry. After decades of Japanese domination with a single product—the akoya strand—two major producers, both with vastly different products, entered the market simultaneously: Australians with large white South Sea pearls and French Polynesians with their exotic black pearls. Early on, both positioned their products as a luxury alternative to the akoya, creating major marketing campaigns to establish distinct identities for their pearls. And both sought control over production and distribution of their own goods.

Meanwhile, producers in other nations—such as Indonesia and the Philippines—began penetrating the market in earnest. The behemoth, however, was China. Drawing from literally thousands of freshwater pearl farms, China first challenged Japan’s traditional dominance at the low end of the market with its huge, largely unregulated flow of freshwater “rice krispie” pearls. In time, the Chinese began producing an array of new products

that offered a more affordable alternative to the akoya. Toward the end of the 1990s and into the 21st century, the global industry introduced new colors, new technical innovations, and branded pearls, while encouraging designers to transform cultured pearls into a much more contemporary fashion product than before.

Yet there have been significant challenges as well. Severe banking problems crippled much of the Japanese industry in the 1990s, as natural forces were inflicting difficult lessons on pearl farmers in Japan, French Polynesia, and Indonesia. Virtually every producer has had to deal with problems inherent in overtaxing local resources, while climatic fluctuations will continue to be a concern for products dependent on a fragile ecology. In recent years, however, most major producers appear to have learned how to balance sustainable growth with attention to the market. And this has contributed enormously to the increasing popularity of cultured pearls worldwide.

ABOUT THE AUTHOR

Mr. Shor (russell.shor@gia.edu) is senior industry analyst at the Gemological Institute of America in Carlsbad, California.

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A STUDY OF NAIL-HEAD SPICULE INCLUSIONS IN NATURAL GEMSTONES

Gagan Choudhary and Chaman Golecha

Nail-head spicules are inclusions that have traditionally been associated with hydrothermal synthetic quartz and emerald. They are caused primarily by rapid growth conditions and disturbances during crystallization of their host. However, these or similar-looking inclusions have also been found in natural gems. The authors examined a natural emerald and blue sapphire showing true nail-head spicules, and a yellow sapphire, spinel, diamond, and rock crystal quartz with inclusions that strongly resembled them. Nail-head spicules remain a notable feature of rapid and disturbed growth, but they do not confirm a stone's natural or synthetic origin without further examination.

Although the identification of any gem material requires testing with a variety of instruments, in most cases the stone's natural or synthetic origin can be determined conclusively by features seen with magnification. For example, curved lines/bands (flame fusion), "hounds tooth" patterns (hydrothermal), and "wispy veil" inclusions (flux) are all classically associated with synthetics.

Nail-head spicules are typically associated with synthetic hydrothermal (and occasionally flux-grown) emerald (figure 1) and synthetic quartz (figure 2). However, such inclusions have been reported in a number of natural and other synthetic gem materials (table 1), including natural emerald (DelRe, 1992; Rockwell, 2003). Similar-appearing features have been observed in photomicrographs of natural sapphires from Madagascar (Kiefert et al.,

1996; Milisenda and Henn, 1996), though they have not been described in detail.

This article documents nail-head spicules and similar-appearing features in a variety of natural gem materials, which could potentially lead to their misidentification as synthetics.

NAIL-HEAD SPICULES AND THEIR FORMATION

Nail-head spicules are wedge-shaped two-phase (liquid and gas) inclusions capped by crystals that act as growth obstacles. In synthetic materials, they may occur in numerous places throughout the sample, but they mainly appear near the seed plate. According to Gübelin and Koivula (1986), since the fluid component is in direct contact with the crystal cap, an inclusion of this kind is technically a *three-phase* inclusion.

Relatively disturbed growth is the primary cause of nail-head spicules. During growth of the host crystal, a small crystal or platelet is deposited on its surface. As the crystal continues to grow past the inclusion, a tapered void is created, which traps the hydrothermal growth medium such that, upon cooling, it becomes two phases consisting of liquid and a gas bubble. In flux-grown synthetics, such voids may contain flux (Schmetzer et al., 1999). In the case of synthetic emeralds, the crystal cap is usually phenakite, beryl, or chrysoberyl, and may even be gold from the crucible (again, see table 1).

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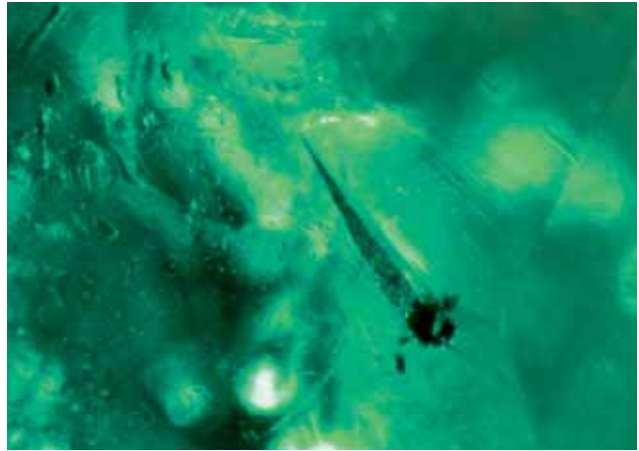


Figure 1. At left is a classic nail-head spicule in a hydrothermally grown synthetic emerald. On the right is a spicule breaking the surface of a flux-grown synthetic emerald. Note the black material at the surface break. Photomicrographs by John I. Koivula (left, magnified 80 \times) and G. Choudhary (right, magnified 60 \times).

These flat platelets/crystals are not always easily resolved with a standard gemological microscope.

In synthetic emeralds, nail-head spicules develop most readily when growth occurs on a seed plate inclined at an angle to the crystallographic axes, as in the case of Biron material (Kane and Liddicoat, 1985). To the best of the authors' knowledge, no detailed research has been performed on the formation of nail-head spicules in synthetic gem materials, and further correlation with the growth conditions is beyond the scope of this article.

MATERIALS AND METHODS

Six stones are documented in this report: two sapphires, an emerald, a spinel, a diamond, and a sample of rock crystal quartz. All were faceted except the spinel (a pebble), and all were submitted for testing at the Gem Testing Laboratory, Jaipur, India. The emerald was brought in by a gemologist who had purchased it as a natural specimen of Sandawana (Zimbabwe) origin but was concerned about its identity due to the presence of nail-head spicules along some planes. The remaining stones were submitted for routine identification reports.

Standard gemological tests were conducted on all six stones; however, we could not determine the refractive index of the spinel as it was water-worn. We examined the internal features of the samples with both a binocular gemological microscope, with fiber-optic and other forms of lighting, and a horizontal microscope. Infrared spectra (in the 6000–400 cm^{-1} range for all stones, with particular attention in the 3800–3000 cm^{-1} range for the quartz) were recorded using a Nicolet Avatar 360

Fourier-transform infrared (FTIR) spectrometer at room temperature with a transmission accessory. Multiple infrared spectra were collected to find the

Figure 2. Nail-head spicules are also seen in synthetic quartz, where they are commonly situated along the seed plate, as in this synthetic citrine. Photomicrograph by C. Golecha; magnified 30 \times .

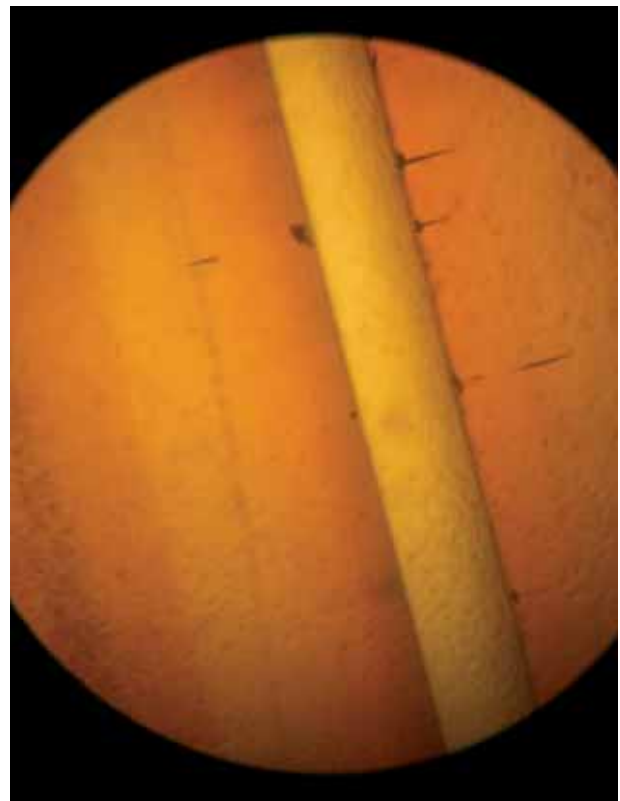


TABLE 1. Selected reports of nail-head spicules and similar inclusions in natural and synthetic gem materials.

Gem material	Inclusions	References
Natural		
Emerald	Tapered voids with flat platelets, filled with two-phase inclusions Spicule-like inclusion capped by a yellowish crystal (calcite)	Rockwell (2003) DelRe (1992)
Diamond	Hexagonal columnar indented natural Etched out needle-like crystals	Smith (1991) Chapman (1992)
Sapphire	Rounded apatite crystals accompanied by growth tubes Apatite crystals at the ends of hollow tubes	Kiefert et al. (1996) Milisenda and Henn (1996)
Pezzottaite	Fine growth tubes emanating from crystals of tourmaline	Laurs et al. (2003)
Synthetic		
Hydrothermal emerald (Biron)	Short "needle" emanating from a tiny cluster of euhedral phenakite crystals Cone-shaped void filled with a fluid and a gas bubble, with a phenakite crystal at its base; nail-head spicules at the edge of gold inclusions	Sechos (1997) Kane and Liddicoat (1985)
Hydrothermal emerald (Chinese)	Needle-like tubes with one or two phases associated with beryl or chrysoberyl crystals at broader ends.	Schmetzer et al. (1997)
Hydrothermal emerald (Linde)	Phenakite crystals with wedge-shaped voids extending from them	Liddicoat (1993)
Hydrothermal emerald (Russian)	Growth tubes filled with liquid or two phases, associated with doubly refractive crystals	Schmetzer (1988)
Hydrothermal emerald (Regency)	Reddish brown crystals with pointed growth tubes containing liquid and gas	Gübelin and Koivula (1997)
Flux emerald (Chatham)	Elongated cone-shaped spicules associated with tiny birefringent "phenakite" crystals, and filled with colorless or yellowish molybdenum	Schmetzer et al. (1999)
Flux emerald (Nacken)	Cone-shaped cavities with tiny crystals (beryl), partially filled with multicomponent inclusions: V-bearing polymerized molybdate, nonpolymerized molybdate, isolated aluminous silicates Wedge-shaped nail-like inclusions with a "phenakite" crystal at the wider end, filled with flux; rarely, large dark brown tapered inclusions with a polycrystalline appearance	Schmetzer et al. (1999) Nassau (1980)
Hydrothermal red beryl	Hollow or two-phase (liquid and gas) inclusions, capped by a colorless or colored solid inclusion of unknown nature	Shigley et al. (2001)
Hydrothermal quartz (citrine)	"Breadcrumb" inclusions associated with a two-phase spicule	Gübelin and Koivula (1974)

orientation of best transmission. In the case of the quartz, spectra were taken according to the optic-axis direction as well (both parallel and perpendicular to the c-axis).

RESULTS AND DISCUSSION

The gemological properties of the six stones are summarized in table 2. In all cases, these were consistent with those reported in the gemological literature for natural samples of each material.

Sapphire (Specimen 1). Viewed with magnification, this stone exhibited many crystalline inclusions and some elongate inclusions, mainly concentrated along the wider girdle end. Also observed were elongated, somewhat conical or rectangular inclusions terminated by crystals; these appeared to be nail-head spicules.

When the specimen was immersed in methylene

iodide, the nature of the inclusions became clearer. All the nail-head spicules were oriented in a single direction parallel to the optic axis (figure 3). Each typically consisted of a cluster of crystal-like terminations connected to an elongated conical cavity; several also exhibited two-phase inclusions within the cones. Those spicules with a rectangular tube-like projection were somewhat similar to the inclusion patterns illustrated by Kiefert et al. (1996) and Milisenda and Henn (1996). Most of the spicules were situated among a group of birefringent transparent colorless crystals, many of which had highly reflective faces (figure 4). Also observed were conical apatite crystals, which are commonly associated with Sri Lankan origin (Hughes, 1997). Viewed with diffused illumination (while still in immersion), the sapphire showed strong hexagonal growth zoning with uneven patches of color.

A weak undulating chevron pattern, which indi-

TABLE 2. Gemological properties of six natural stones with nail-head spicule or similar inclusions.^a

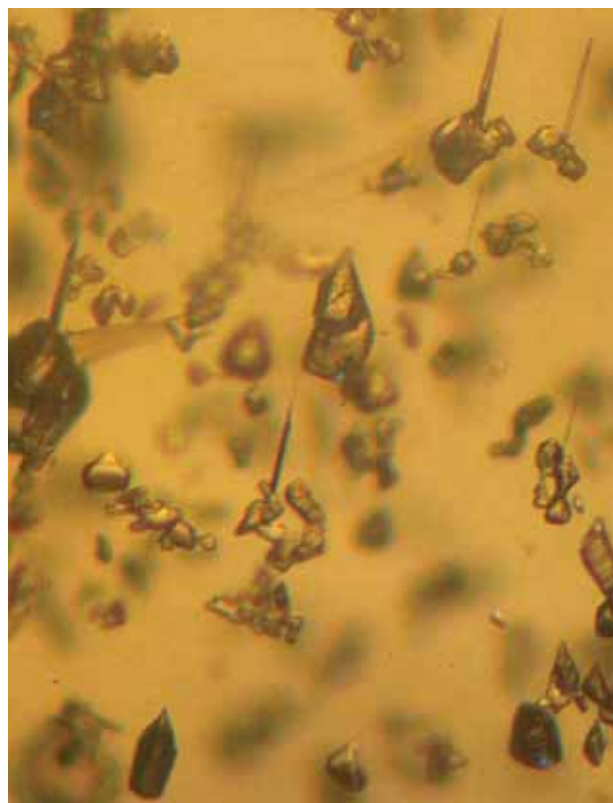
Property	Sapphire		Emerald	Spinel	Diamond	Rock crystal quartz
	Specimen 1	Specimen 2				
Color	Blue	Yellow	Yellowish green	Blue	Light yellow	Colorless
Weight (ct)	3.09	5.00	12.56	13.84	0.61	5.00
Cut style	Cushion mixed	Oval mixed	Octagonal step	Rough	Round brilliant	Oval mixed
RI	1.762–1.770	1.762–1.770	1.584–1.591	nd	OTL	1.542–1.551
SG	3.99	3.99	2.73	3.61	3.52	2.64
Absorption spectrum	nd	nd	Typical chromium spectrum ^b	Iron band at 460 nm	nd	nd
UV fluorescence						
Long-wave	Strong “apricot”	Strong “apricot”	Inert	Inert	Medium blue	Inert
Short-wave	Similar, but weaker	Similar, but weaker	Inert	Inert	Weak blue	Inert

^aAbbreviations: nd=not determined, OTL=over the limits of the standard refractometer.

^bBand at 580–625 nm, line at 640 nm, and doublet at 680 nm.

cated the rapid growth necessary for formation of nail-head spicules, was seen mainly where the spicules were concentrated. (Unfortunately, these

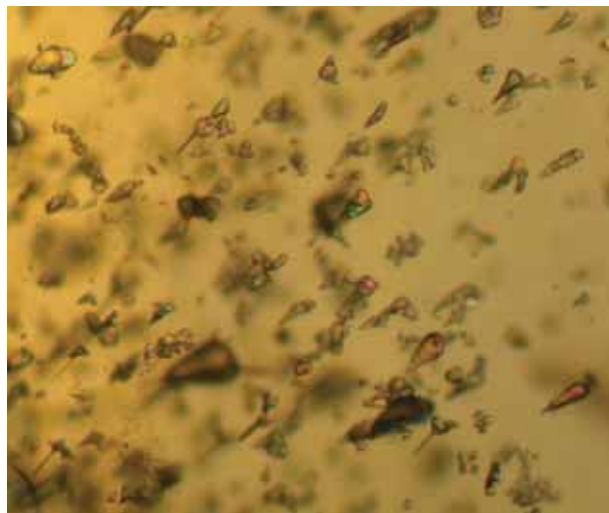
Figure 3. Nail-head spicules are oriented parallel to the optic axis in this natural blue sapphire, seen here immersed in methylene iodide. Each consists of a cluster of crystal terminations connected to a cone. Some of the cones are two-phase inclusions. Photomicrograph by C. Golecha; magnified 40×.



features could not be resolved clearly for photography.) This undulating pattern somewhat followed the hexagonal color zoning. A literature search turned up no reports of nail-head spicules in synthetic sapphires, so this stone was particularly unusual, as this chevron pattern is often seen in hydrothermal synthetics.

The natural origin of this sapphire was easily confirmed with standard instruments and the presence of other features such as zoning and fluorescence. However, another similar spicule (figure 5) was present near the pavilion, which could have led

Figure 4. Viewed with crossed polarizers, the crystal clusters in the blue sapphire proved to be birefringent. Also note the conical elongated apatite crystals, which are commonly observed in Sri Lankan sapphires. Photomicrograph by C. Golecha; immersion, magnified 25×.



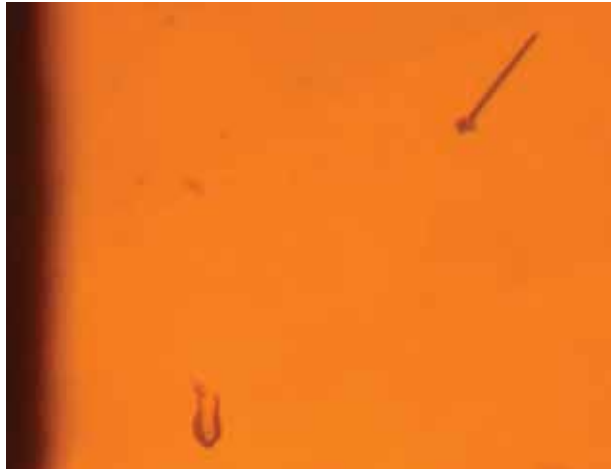


Figure 5. A single spicule (upper right) was present near the pavilion of the blue sapphire. Identification by standard techniques could be difficult if the stone was cut with this inclusion alone. Photomicrograph by C. Golecha; immersion, magnified 30 \times .

to misidentification had the stone been cut with that inclusion alone.

Sapphire (Specimen 2). This yellow sapphire contained numerous etch channels, and one of them reached a crystalline inclusion, giving the general appearance of a nail-head spicule (figure 6). The iden-

Figure 7. In this emerald, small, dark conical inclusions can be seen projecting from the parallel planes in the background, similar to nail-head spicules projecting from the seed plate in a synthetic emerald. However, the presence of abundant curved, fibrous tremolite-like inclusions indicates a natural origin: Sandawana, Zimbabwe. Photomicrograph by G. Choudhary; magnified 20 \times .

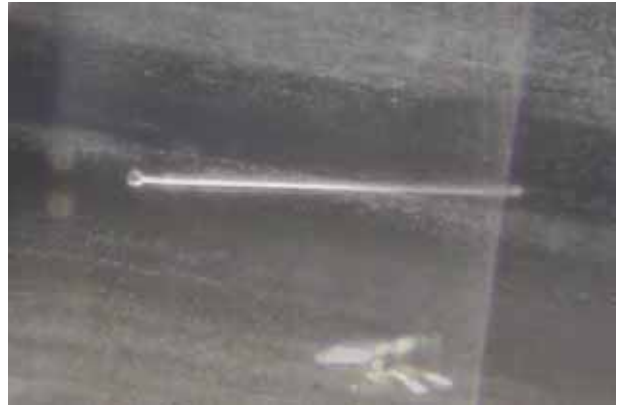
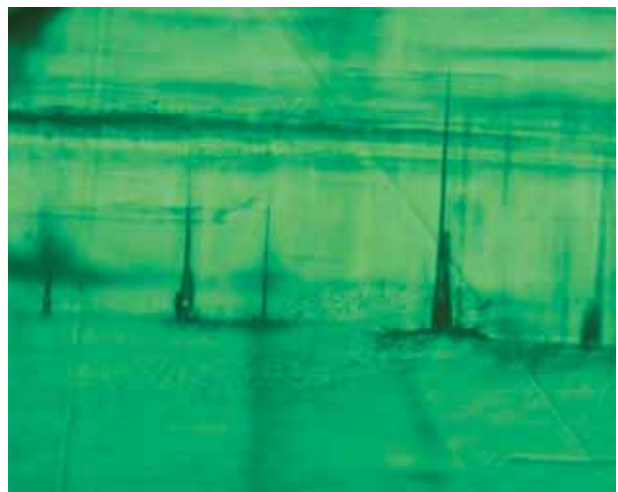


Figure 6. This etch channel in a yellow sapphire is in contact with an included crystal, resulting in a nail-head spicule-like appearance. Photomicrograph by G. Choudhary; magnified 30 \times .

tification of the stone and its natural origin was easily established; however, the inclusion could create confusion for a novice gemologist.

Emerald. This stone contained abundant curved, tremolite-like fibrous inclusions (figure 7), which proved its natural origin and indicated its source as Sandawana (Gübelin and Koivula, 1986). When it was viewed from various angles, however, numerous nail-head spicules were observed in a single direction originating from parallel planes (figures 7 and 8) that were oriented perpendicular to the optic axis. The effect was very similar to that seen in

Figure 8. At higher magnification, the parallel growth planes in figure 7 showed abundant nail-head spicules; also note the two-phase inclusions at the broader end. Photomicrograph by G. Choudhary; magnified 35 \times .



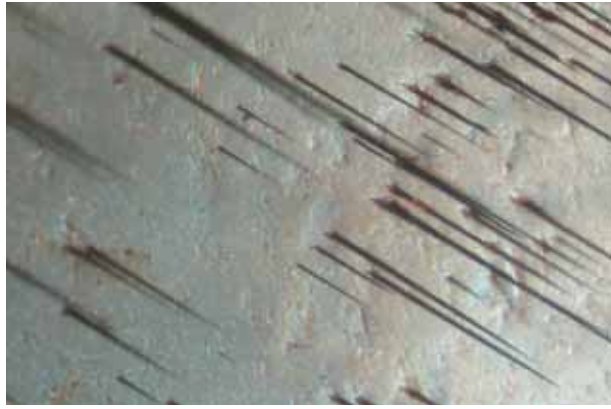


Figure 9. Near the surface of this spinel pebble, a number of long, conical etch features resemble oriented spicule inclusions. Photomicrograph by C. Golecha; magnified 30 \times .

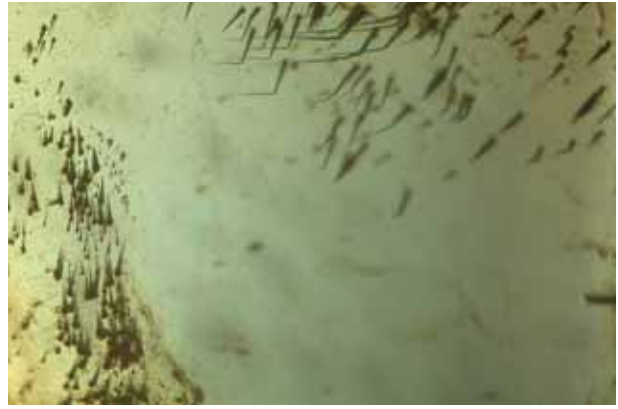


Figure 10. Spicule-like inclusions, some displaying a sharp bend, were observed in various directions pointing toward the interior of the spinel pebble. Photomicrograph by C. Golecha; magnified 20 \times .

synthetic emeralds. In this case, the crystals at the base of the spicules could not be resolved, and all the spicules appeared to originate from the plane itself.

Also present were liquid “fingerprints,” flat reflective films oriented along the basal plane, and angular zoning. Confirmation of natural origin came from FTIR spectra taken in various directions for best transmission, which showed the strong peak at 5270 cm^{-1} that is characteristic of natural emerald (e.g., Choudhary, 2005). Nail-head spicules have been previously encountered in natural emeralds (DelRe, 1992; Rockwell, 2003), so this sample served as a further reminder of the need for careful and complete examination.

Spinel. Magnification revealed numerous surface-reaching conical inclusions (figure 9) pointing toward the interior of the pebble from various directions. Some also exhibited a sharp angular bend (figure 10). Careful examination revealed that the inclusions broke the surface with rhomboid or sub-hexagonal/rounded cross sections (figure 11) that varied with the direction of entrance into the stone, which suggested that the shapes were determined by the growth orientation. Some of these inclusions were filled with a brownish epigenetic material (figure 11, right).

At certain angles, these inclusions were highly reflective, with flat surfaces intersecting each other in a pyramidal arrangement. Although their overall characteristics were indicative of etch channels, the

Figure 11. These spicule-like inclusions in spinel appear to be etch channels. Their cross sections varied from rhomboid (left) to sub-hexagonal or rounded (right). Also note the brownish epigenetic filling material (right). Photomicrographs by G. Choudhary; magnified 30 \times (left) and 45 \times (right).





Figure 12. This diamond contains some nail-head spicule-like inclusions that are actually crystals with stress cracks at one end. Given the formation conditions of diamond, true nail-head spicules are not possible. Photomicrograph by C. Golecha; magnified 30 \times .

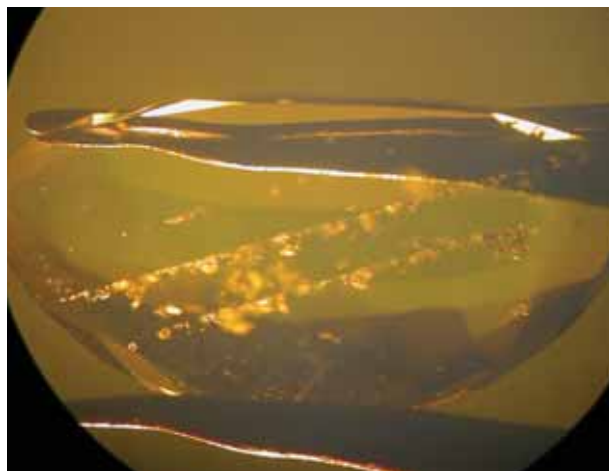


Figure 13. Inclusions are concentrated along two parallel planes in this faceted quartz. The pattern resembles a common inclusion scene in synthetic quartz: "breadcrumbs" along a seed plate. Photomicrograph by C. Golecha; magnified 15 \times .

possibility of these being elongated needles cannot be ruled out (Chapman, 1992). The authors have observed similar inclusions in a few flux-grown synthetic emeralds, where the spicules broke the surface and appeared to be filled with a black material.

Although etch channels are common in a number of natural gems, in this specimen they closely resembled nail-head spicules. Due to the absence of any other visible inclusions, this specimen could have easily confused a novice gemologist.

Diamond. Because diamonds form at conditions of very high temperature and pressure, they do not contain fluid inclusions that are resolvable with a gemological microscope. However, this diamond possessed several crystal inclusions with stress cracks (figure 12) that at certain angles appeared to be short needles associated with a crystal. The combination gave a strong resemblance to nail-head spicules. These features were mainly concentrated near the crown in random directions. The diamond's natural origin was ascertained by the presence of naturals on the girdle.

Rock Crystal Quartz. Scattered inclusions consisting of whitish aggregates were concentrated along two parallel planes in this stone (figure 13). The scene resembled the "breadcrumb" inclusions often present along the seed plate in synthetic quartz. In certain orientations, some of these whitish clusters closely resembled nail-head spicules (figure 14) and seemed to be formed by the orientation of crystal inclusions almost perpendicular to each other. At

higher magnification, the clusters proved to be aggregates of a whitish mineral (figure 15). The morphology of the clusters resembled muscovite flakes (Gübelin and Koivula, 2005), but we could not conclusively identify them due to lack of access to Raman spectroscopy.

Further analysis with FTIR spectroscopy showed absorptions in the 3600–3000 cm^{-1} region, along with a strong peak at 3483 cm^{-1} that is characteristic for natural crystalline quartz. Similar spectra were record-

Figure 14. The aggregation patterns of these inclusions in quartz strongly resemble nail-head spicules at certain orientations. Photomicrograph by C. Golecha; magnified 35 \times .



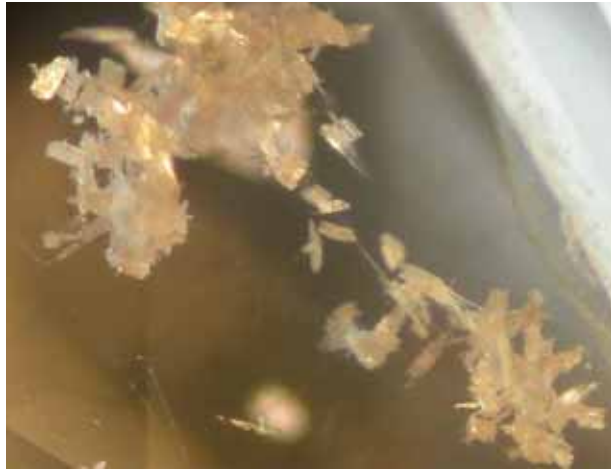


Figure 15. At higher magnification, the inclusions in figure 14 proved to be aggregates of a natural mineral, possibly muscovite. Photomicrograph by C. Golecha; magnified 45x.

ed parallel and perpendicular to the optic axis, with only minor differences in the intensity of the peaks.

Although the pattern of the whitish crystal aggregates indicated a natural specimen, the presence of spicule-like inclusions and the concentration of the inclusions along a defined plane could have led to the stone's misidentification as synthetic without careful examination.

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CONCLUSIONS

Nail-head spicule inclusions have long been associated with hydrothermally grown synthetic gem materials. Such inclusions indicate rapid, disturbed growth, which is the case for most synthetics but also for some natural gems. Similar-appearing inclusions may be produced by a combination of other features. Much like the spiral “fingerprint” inclusions that were once considered characteristic of Biron synthetic emerald (Gübelin and Koivula, 1986), the mere appearance of nail-head spicules should not be considered conclusive proof of synthetic origin. When such inclusions or similar structures are present, a more detailed examination is necessary to determine the nature of the sample. Such instances serve as reminders of the importance of not relying on any one feature for the identification of a gem material.

ABOUT THE AUTHORS

Mr. Choudhary (gtl@gjepcindia.com) is assistant director (technical and training), and Mr. Golecha is executive manager (technical and training), at the Gem Testing Laboratory, Jaipur, India.

COPPER-BEARING TOURMALINES FROM NEW DEPOSITS IN PARAÍBA STATE, BRAZIL

Masashi Furuya

Two new deposits of Cu-bearing tourmaline have been found in Paraíba State, Brazil, not far from the original source at Mina da Batalha. The Glorious mine has produced a limited amount of gem-quality material with a composition that is similar to the tourmaline from Mina da Batalha. Initial work at the second locality, known as Mineração Batalha, has not yet produced any gem-quality material.

In 2006, new finds of copper-bearing elbaite tourmaline were made at two locations in Paraíba State, near the town of Junco do Seridó. This small town is located approximately 18 km northeast of Mina da Batalha, the site of the original discovery of the now world-famous “electric-blue Paraíba” Cu-bearing tourmalines (e.g., Fritsch et al., 1990). One of the new deposits, known as the Glorious mine, has produced gem-quality Paraíba tourmaline with some colors that resemble those found at Mina da Batalha (figure 1). The other locality—the Mineração Batalha mine—has not been worked as extensively but shows potential to produce gem-quality material in the future. This report provides a preliminary description of these new tourmaline deposits.

Glorious Mine. Location. The Glorious mine is located approximately 2 km west of Junco do Seridó at the following coordinates: longitude 36°43'59"W and latitude 7°00'18"S. This new deposit falls within a zone of gem pegmatite dikes that extends from Mina da Batalha northward into neighboring Rio Grande do Norte State, where there are two similar gem-tourmaline deposits at the Alto dos Quintos (also known as Wild) and Mulungu (Terra

Branca) mines near Parelhas (Shigley et al., 2001; see figure 2). Over the years, pegmatites in the area have been mined intermittently on a small scale as sources of high-quality white kaolinite clay that is used for ceramics, with tourmaline often recovered as a byproduct.

Geology and Mining. The first report on the mining of Cu-bearing tourmaline from the Glorious deposit was published by Furuya and Furuya (2007). The nearly vertical pegmatite dike ranges from 20 cm to 2 m wide, and is partly kaolinitized. It is hosted by quartzite of the Equador Formation (again, see Shigley et al., 2001), and consists of feldspar (partially altered to kaolinite), quartz (sometimes smoky or amethyst), mica (dark reddish violet), and lesser amounts of black and colored tourmaline. The gem tourmaline is found as crystals and fragments embedded in kaolinite or in partially decomposed pegmatite. The tourmaline colors include blue, green-blue, green, and violet, with the most valuable blue material representing about 20% of the production. The violet material turns blue on heating, but the green material does not change significantly with heat treatment (H. Sakamaki, pers. comm., 2007). In some cases, the crystals are color zoned from the center outward, with a pink core, a bright blue zone, and a very dark green (almost black) exterior.

Like most gem mining in Brazil, recovery of tourmaline at the Glorious mine involves a small-scale operation. A Japanese company—Glorious Gems Co. Ltd., under the ownership of H. Sakamaki—operates the mine with a license from the Brazilian government. Approximately 25 employees work full-time at the mine; they use heavy machinery to remove as much as 20 tonnes of pegmatite material each day. Preliminary mining activities began in March 2006, with full operation three months later following the construction of a washing plant. The pegmatite is accessed by two shafts (and associated trenches), located about 100 m apart; as of March 2007, they had been excavated to a depth of 30 m (e.g., figure 3). The west shaft was 4 m wide, and the east shaft was 2 m wide. At the bottom of each shaft, tunnels extended sideways along the pegmatite.

The tourmaline is found both in cavities and “frozen” within quartz or kaolinitized feldspar. The pegmatite material is usually so decomposed that it can easily be broken

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Figure 1. These unheated Cu-bearing tourmalines are from the new Glorious mine in Paraíba State, Brazil. The faceted stones weigh 0.15–0.34 ct, and the rough material ranges from 2 to 5 mm. Most of the Glorious mine production is green and violet, and the balance contains various shades of blue. The violet material heat treats to blue. Photos by T. Komuro (left) and M. Furuya (right).

up with hand tools in the mine and then hauled to the surface in buckets. On occasion, the miners use a pneumatic drill to break up the pegmatite. All material removed from the dike is washed and hand-picked to recover the tourmaline. The largest tourmaline crystal (6.0 g, but with many cracks) was found at a depth of 10 m in December 2006. Many smaller pieces were found at ~30 m depth. The largest clean crystal recovered thus far measured 3 × 3 × 12 mm.

The total production to date of unheated blue tourmaline is approximately 500 g, with only about 200 pieces of sufficient size and quality to be faceted (~40 carats estimated after cutting). So far about 100 pieces of blue to greenish blue to violet tourmaline have been cut, each weighing around 0.20 ct.

Materials, Methods, and Results. Ten faceted stones (0.15–0.34 ct) and 15 pieces of rough tourmaline (0.08–0.60

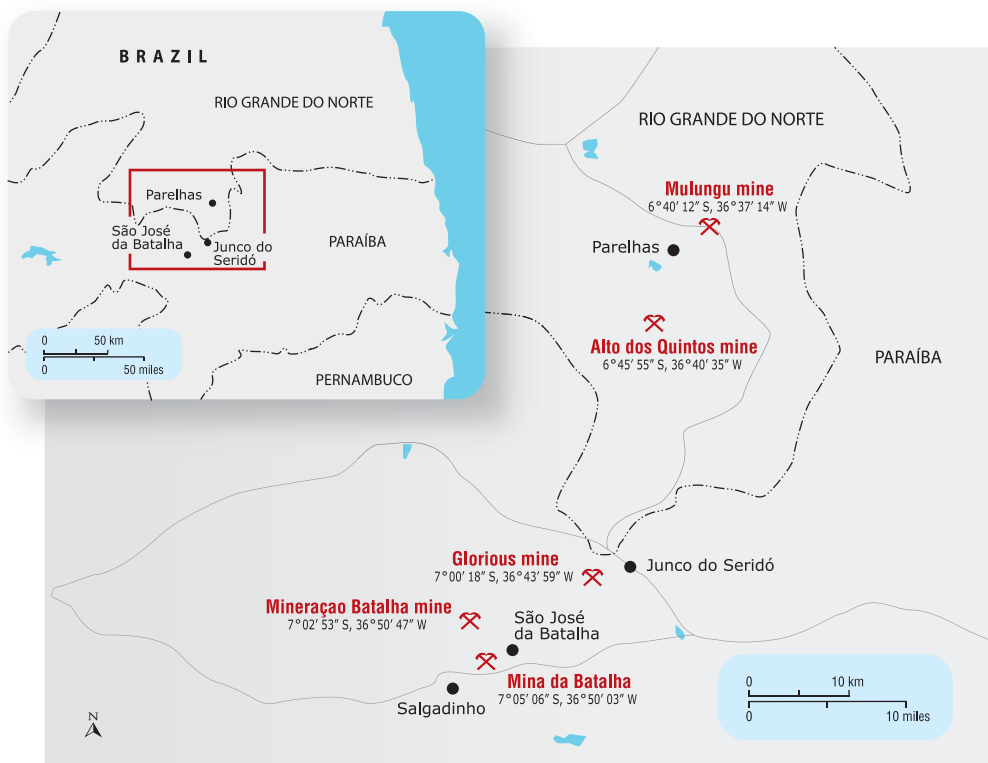


Figure 2. The new Glorious and Mineração Batalha mines are located in Paraíba State, close to the original Mina da Batalha deposit.



Figure 3. Excavation of the west shaft at the Glorious mine began in March 2006. As of March 2007, the trench and associated tunnels in this area reached a depth of 30 m. Photo by M. Furuya.

ct, average 0.30 ct) from the Glorious mine were studied for this report. The rough samples ranged from blue to green, and also included pink, violet, and brown, but only

Figure 4. Located just 4 km from the original Mina da Batalha deposit, the Mineração Batalha mine was being explored by a shaft 20 m deep in April 2007. Photo by M. Furuya.



the chemical data for the blue-to-green rough samples are reported below. Gemological properties of the faceted tourmalines were as follows: color—greenish blue to blue to violet; $RI-n_o=1.638-1.640$ and $n_e=1.618-1.620$; birefringence—0.018–0.021; SG—3.06–3.10; and fluorescence—inert to both long- and short-wave ultraviolet radiation. As is typical with other gem tourmalines, the Glorious samples contained two-phase (liquid and gas) inclusions and fluid-filled trichites. These inclusions resemble those seen in Paraíba tourmaline from Mina da Batalha.

Semiquantitative chemical data for all the samples were obtained by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy. In addition, samples from other known deposits of Cu-bearing tourmaline were analyzed by the same instrument, for comparison (table 1); the colors included blue, “neon” blue, greenish blue to bluish green, and green. The Glorious mine tourmalines had an elbaite composition, and most samples had $Cu > Mn$, as in other Brazilian Paraíba-type tourmalines. The faceted Glorious mine samples contained more Cu than the tourmalines that were analyzed from the other localities.

Mineração Batalha Mine. This deposit (figure 4) is located a short distance from the Glorious mine (about 10 minutes by vehicle), and only 4 km north of Mina da Batalha. It was first recognized by A. Campos in October 2006. Two months later, Mr. Sakamaki invested in this deposit, which is currently operated by companies run by both men. A

Figure 5. At this underground exposure (20 m depth), the Mineração Batalha pegmatite is up to 30 cm wide. It is surrounded by very hard quartzite of the Equador Formation. Photo by M. Furuya.



TABLE 1. Average semiquantitative chemical composition of some minor and trace elements (wt.% oxide) in blue-to-green Cu-bearing tourmaline from the Glorious, Mineração Batalha, and six other mining areas.^a

Property/oxide	Glorious		Mineração Batalha	Mina da Batalha	Mulungu	Alto dos Quintos	Edoukou, Nigeria	Ofiki, Nigeria	Alto Ligonha, Mozambique
	Cut	Rough	Rough	Cut	Cut	Cut	Cut	Cut	Cut
Sample type	Cut	Rough	Rough	Cut	Cut	Cut	Cut	Cut	Cut
No. samples	10	9	6	10	10	2	10	10	10
MnO	1.83	1.97	2.50	1.10	0.90	0.37	2.97	1.84	2.42
CuO	3.34	2.35	3.26	2.63	1.67	1.17	1.88	0.56	0.62
Ga ₂ O ₃	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03
Bi ₂ O ₃	0.71	0.54	0.62	0.77	0.13	0.22	0.36	0.09	0.42

^a Data collected by EDXRF using an Edax Eagle μ Probe, operated by K. Danjo, using 30 kV voltage, 1,000 mA current, and a 100 μ m spot size. Chemical data were calculated assuming 1.62 wt.% Li₂O, 10.94 wt.% B₂O₃, and 3.13 wt.% H₂O, as reported for Cu-bearing elbaite by Fritsch et al. (1990).

decomposed (partially kaolinitized) pegmatite dike that is 20–70 cm wide (figure 5) is being explored by a single shaft that was about 20 m deep in April 2007. Mining began in early 2007, with a crew of 15 workers using hand tools and a pneumatic drill. Dynamite is sometimes needed because the host quartzite is much harder here than at the Glorious mine. Miners typically remove about 5 tonnes of pegmatite material each day for washing and sorting by hand.

The copper-bearing tourmaline at Mineração Batalha is found within kaolinitized feldspar, in areas that are rich in black tourmaline, rubellite, and smoky quartz. Many of the crystals are bicolored, with a beautiful blue outer layer and a pink-to-violet core (figure 6). The larger crystals can attain weights up to 5 g, but the material recovered to date contains numerous inclusions and is too fragile for cutting; no stones had been cut at the time of this writing.

Figure 6. Tourmaline from the Mineração Batalha mine is commonly color zoned, with an “electric” blue rim and a pink-to-violet interior. Photo by M. Furuya.



EDXRF analyses of six small blue crystals of Mineração Batalha tourmaline (again, see table 1) revealed contents of Cu and Mn similar to those for blue tourmaline from Mina da Batalha. Given the close proximity of this new mine to Mina da Batalha, the owners are optimistic that it will produce good material in the future.

Conclusion. In 2006, mining began at two new Cu-bearing tourmaline deposits in Brazil’s Paraíba State: the Glorious and Mineração Batalha mines. The ongoing discovery of Cu-bearing tourmaline in this region indicates that its numerous pegmatites have not been fully explored for gem material. The bright blue coloration shown by some of the tourmalines from these two new occurrences is comparable to that of the copper-bearing tourmalines first discovered almost 20 years ago at Mina da Batalha. Given the high value of this material on the gem market, any new supply of such tourmalines is significant.

ABOUT THE AUTHOR

Mr. Furuya (jgg@sapphire.co.jp) is director of the Japan Germany Gemmological Laboratory in Kofu, Japan.

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NATURAL TYPE IA DIAMOND WITH GREEN-YELLOW COLOR DUE TO NI-RELATED DEFECTS

Wuyi Wang, Matthew Hall, and Christopher M. Breeding

Commonly seen in HPHT-grown synthetic diamonds with a green component, nickel-related defects were identified for the first time in a type Ia natural diamond with a strong green component. The 1.75 ct Fancy green-yellow diamond showed a strong peak at 1332 cm^{-1} in the IR absorption spectrum, strong absorption from the 1.40 eV center and the associated $\sim 685\text{ nm}$ band in the Vis-NIR spectrum, and extremely strong emissions from Ni-related defects in the photoluminescence spectra—all of which proved that nickel was the primary cause of the green color.

Nickel is widely used as a catalyst in high-pressure, high-temperature (HPHT) synthetic diamond growth processes. Consequently, Ni-related lattice defects are common in HPHT-grown synthetic diamonds, and can produce a green color component when the nitrogen concentration is sufficiently low (Lawson et al., 1998). The occurrence of trace amounts of Ni has also been confirmed in some natural diamonds—including, but not limited to, chameleon diamonds, yellow-orange diamonds colored by a broad absorption band at $\sim 480\text{ nm}$, H-rich diamonds, and even some colorless type IIa diamonds (Shigley et al., 2004; Hainschwang et al., 2005; and the present authors' unpublished research).

In a recent study, Wang and Moses (2007) provided the first evidence of Ni-related defects producing green color in a natural gem diamond: a 2.81 ct type IIa Fancy Intense yellowish green oval cut. However, the general role of Ni as a color-producing center in many natural diamonds remains unclear. Soon after studying the type IIa diamond noted above, GIA's New York laboratory examined a type

Ia natural diamond with a strong green color component that also proved to be the result of Ni-related defects.

Materials and Methods. A 1.75 ct cushion-cut diamond (figure 1) was submitted to the New York laboratory for a grading report and color graded Fancy green-yellow. To fully document that both the stone and the color were natural, we conducted standard gemological testing, fluorescence imaging (Diamond Trading Company [DTC] DiamondView), and detailed spectroscopic testing. Infrared absorption spectra were collected using a Thermo 6700 Fourier-transform infrared (FTIR) spectrometer ($6000\text{--}400\text{ cm}^{-1}$, 1 cm^{-1} resolution, up to 1,024 scans, at room temperature). UV-visible-near infrared (UV-Vis-NIR) spectra were collected with an Ocean Optics high-resolution spectrometer (Model HP-2000+, $250\text{--}1000\text{ nm}$, 1 nm resolution, deu-

Figure 1. This 1.75 ct cushion-cut Fancy green-yellow diamond is colored mainly by Ni-related defects. Photo by Jian Xin (Jae) Liao.



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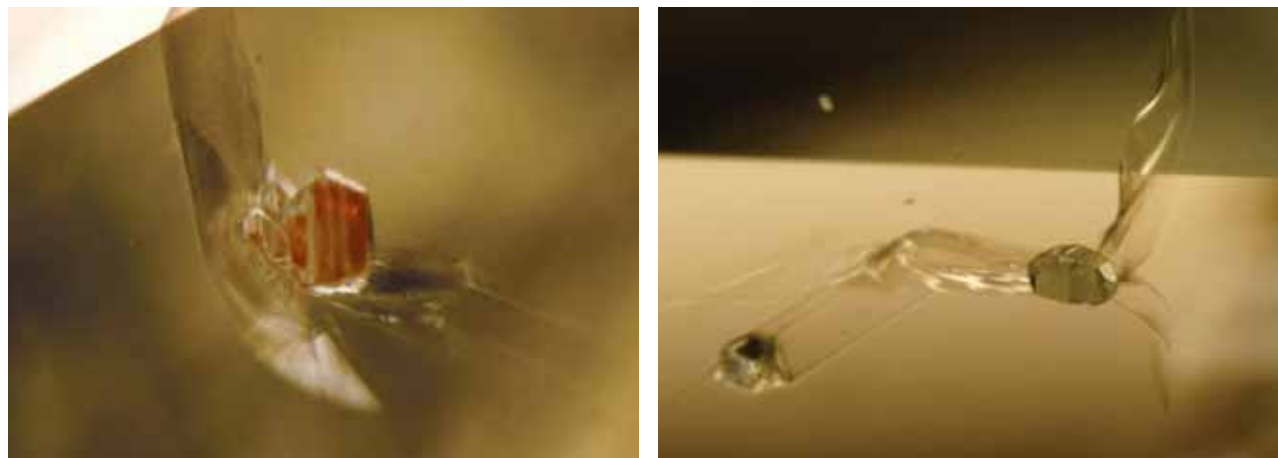


Figure 2. The presence of included crystals of reddish orange almandine-rich garnet (left, image width 0.98 mm) and pale green omphacite (right, image width 0.65 mm) demonstrates that this natural diamond crystallized in an eclogitic environment. Photomicrographs by W. Wang.

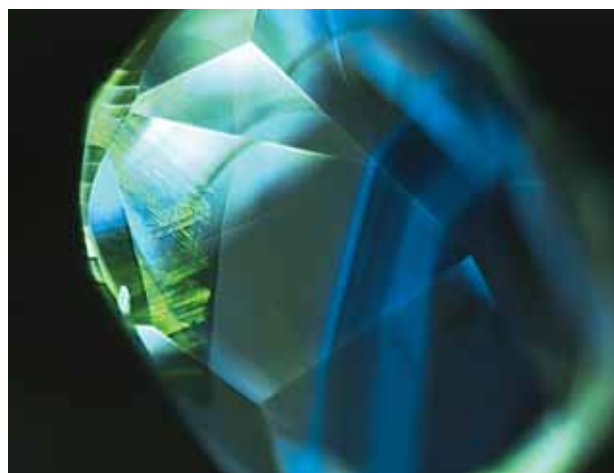
terium-tungsten-halogen source, at liquid-nitrogen temperature). Photoluminescence and Raman spectra were collected using a Renishaw inVia Raman microscope (488, 514, 633, and 830 nm laser excitations, various scan ranges, at liquid-nitrogen temperature). To test the diamond's color stability and any possible thermochromic properties, we heated it with an alcohol lamp to a temperature of $\sim 350^{\circ}\text{C}$.

Results and Discussion. Observation with a gemological microscope indicated that the green-yellow color was distributed evenly throughout the stone, with no evidence of treatment visible. Microscopy also revealed colorful euhedral mineral inclusions (100–150 μm in longest dimension) that were surrounded by small fractures. The reddish orange and pale green crystals (figure 2) were identified as almandine-rich garnet and omphacite, respectively, by Raman spectroscopy. These inclusions are typical of diamonds from eclogitic environments (Meyer, 1987; Koivula, 2000). The presence of natural mineral inclusions proved that the diamond was not synthetic. Furthermore, careful microscopic examination with various lighting configurations confirmed no coating was present.

The diamond fluoresced strong orangy yellow to long-wave UV radiation and moderate greenish yellow to short-wave UV; we observed no phosphorescence with standard handheld gemological UV lamps. When examined with the DTC DiamondView, the stone showed a large variation in fluorescence (figure 3). Some zones displayed unevenly distributed linear green luminescence features. Other regions showed moderate greenish yellow luminescence. Still other parts of the stone displayed banded blue fluorescence. Weak greenish yellow phosphorescence was also observed at the ultra-short wavelengths. The large variation in fluorescence colors and the absence of a typical HPHT-synthetic diamond growth pattern confirmed that this stone was natural.

The infrared absorption spectrum showed a clear band at 1282 cm^{-1} , indicating the diamond was type IaA; the nitrogen concentration was calculated to be about 36 ppm. Distinct absorption peaks were also noted at 3107 and 1405 cm^{-1} , showing the occurrence of hydrogen impurities. A relatively strong peak at 1332 cm^{-1} suggested that N^+ (which sometimes serves as a proxy for Ni content in diamond) might also be present. Isolated substitutional nitrogen acts as an electron donor, and some nickel-related defects are observed in the negatively charged state (Lawson et al., 1998). A strong 1332 cm^{-1} absorption is consistent with the detection of Ni-related defects in this diamond.

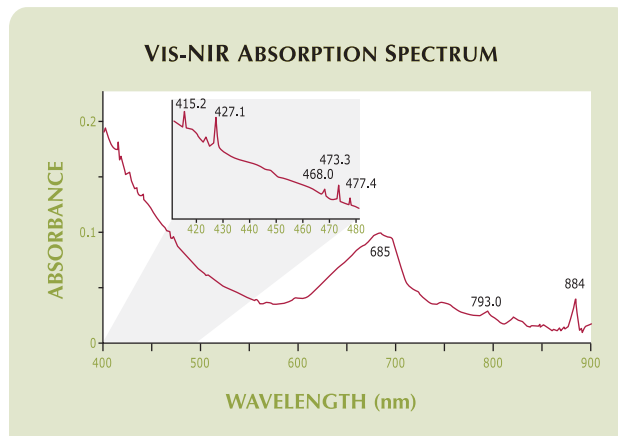
Figure 3. The green-yellow diamond showed distinctive zoned fluorescence in the DiamondView that also ruled out a synthetic origin. Areas of green, greenish yellow, and blue fluorescence occurred in different parts of the diamond. Image by W. Wang.



The Vis-NIR absorption spectrum (figure 4) showed weak but distinct absorptions between 350 and 370 nm (357.0, 360.2, 363.5, 367.0 nm; not shown in the figure due to the high UV background) and between 460 and 480 nm (468.0, 473.3, 477.4 nm). These series of peaks are known to originate from Ni-related defects (Collins and Stanley, 1985; Lawson and Kanda, 1993a; Yelisseyev et al., 1996). They are identical to those reported for the type IIa, Ni defect-colored yellowish green diamond seen previously (Wang and Moses, 2007). Unlike the type IIa diamond, however, this type Ia stone exhibited additional weak absorptions at 415.2 nm (zero-phonon line [ZPL] of the N3 center) and 427.1 nm, but it lacked features in the 600–650 nm range (608.1, 637.5, 642.5 nm). An outstanding characteristic of the Vis-NIR absorption spectrum of the type Ia green-yellow diamond was the strong absorption of the 1.40 eV center (unresolved ZPL doublet at ~884 nm) and the associated ~685 nm band; these are likely caused by interstitial Ni⁺ (Isoya et al., 1990; Lawson and Kanda, 1993b). We also observed a sharp peak at 793.0 nm, another well-known Ni-related defect, but it was much weaker than the 884 nm peak. The 685 nm band was strong and broad, extending from 585 nm to about 735 nm, and efficiently blocked the transmission of red and orange light. Combined with a gradual increase in absorption from ~555 nm to the high-energy (low-wavelength) side due to unknown causes, the 685 nm absorption generated a transmission window centered at ~555–585 nm that resulted in the observed green-yellow bodycolor.

The photoluminescence spectrum collected with 830 nm laser excitation was dominated by the 883.1/884.8 nm doublet (i.e., the 1.40 eV center; figure 5). When 514 nm

Figure 4. Strong absorption from the 1.40 eV center (ZPL at ~884 nm) and the associated ~685 nm band are the dominant features in the Vis-NIR absorption spectrum of the 1.75 ct Fancy green-yellow diamond. The 1.40 eV center, which is due to interstitial Ni⁺, is the main cause of the diamond's green component.

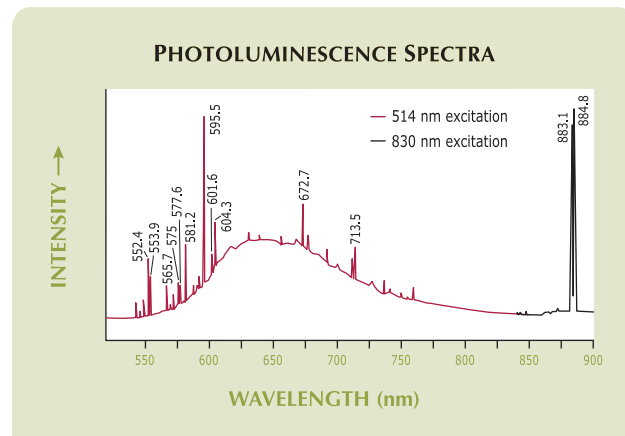


laser excitation was used, the spectrum exhibited a broad band centered at ~640 nm, with numerous sharp emissions superimposed between 560 and 760 nm. These PL features are typically associated with the broad 480 nm absorption band that occurs in some natural yellow-to-orange diamonds and all chameleon diamonds, both of which reportedly contain Ni-related defects (Collins, 2001). However, these features are not believed to correlate directly with the 1.40 eV center. Unlike the green-yellow stone presented here, those types of diamonds do not show Ni-related defects in the Vis-NIR absorption spectrum. Spectroscopy also revealed that some common defects in type Ia natural diamonds (e.g., H3, H4, N-V centers) were not detected in this diamond.

Green color in natural diamonds can be introduced by a number of known defects or defect combinations, including absorptions from GR1, H2, and some hydrogen-related defects, and/or the luminescence of the H3 defect (Collins, 1982, 2001). The absence of any of these centers and the almost exclusive occurrence of Ni-related defects (in particular the 1.40 eV center), strongly indicate that the green component of this diamond is caused by Ni.

A final interesting property of the green-yellow diamond is that when heated (~350°C), the stone changed color slightly to a more yellow (less green) hue. After approximately 15 seconds, the original color was restored when we cooled the stone at room temperature. This weak thermochromism, together with other gemological and spectro-

Figure 5. PL spectra confirmed the presence of extremely strong emissions from Ni-related defects (e.g., the 883.1/884.8 nm doublet). Numerous sharp emissions in the range 560–760 nm and a very broad luminescence band centered at ~640 nm strongly indicate an association between this diamond and natural yellow-orange and chameleon diamonds, which exhibit broad 480 nm absorption bands. The 640 nm feature is an emission band of an unknown defect that caused very weak absorption at ~480 nm.



scopic similarities between this stone and chameleon diamonds, may indicate that Ni-related defects play a role in the thermochromic and photochromic diamond properties exhibited by both of these unusual types of diamonds.

Conclusions. Spectroscopic evidence from this rare type Ia gem diamond, as well as the yellowish green type IIa stone described recently, proves that Ni-related defects are directly responsible for the green component of the bodycolor. Diamonds colored by Ni may, in fact, be more common than has been believed, as reexamination of previously collected spectra seems to indicate. Therefore, nickel-related defects may represent another important cause of green color in natural diamonds.

ABOUT THE AUTHORS

Dr. Wang is manager of research projects, and Mr. Hall is manager of Identification Services, at the GIA Laboratory in New York. Dr. Breeding is a research scientist at the GIA Laboratory in Carlsbad, California.

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Thomas M. Moses and
Shane F. McClure
GIA Laboratory

Large Cat's-Eye AQUAMARINE

The East Coast laboratory had the opportunity to examine an unusually large collector-quality specimen of cat's-eye aquamarine. The 201.18 ct stone, which measured $37.31 \times 30.38 \times 22.55$ mm, was cut as a high-domed oval cabochon and displayed a fairly sharp, straight eye (figure 1).

Chatoyancy in beryl is usually caused by tube-like inclusions or growth tubes oriented parallel to the c-axis (see, e.g., Summer 1992 Gem News, pp. 131–132; Spring 2004 Gem News International, pp. 66–67). However, emerald from the Coscuez mine



Figure 1. This unusually large (201.18 ct) aquamarine displayed a distinct chatoyant band.

in Colombia has been reported to display chatoyancy caused by “hazy linear clouds” (Winter 1996 Gem News, pp. 284–285). A case of “pseudo-chatoyancy” in a brown beryl was observed as being caused by light transmission through closely spaced twin planes (Winter 1999 Lab Notes, p. 202). Technically, this was not true chatoyancy, which by definition is caused by reflections from oriented inclusions.

The cabochon we examined was a medium greenish blue, had a spot RI of 1.58, and displayed 427 and 537 nm absorption lines in the desk-model

Figure 2. Growth zones parallel to the length of the aquamarine in figure 1 contained reflective crystals and films. Field of view 7.3 mm.



Figure 3. At low magnification, the reflective flat crystals and films in the aquamarine appeared as hazy linear clouds. Field of view 24 mm.



Figure 4. Very fine parallel reflective needles were dispersed throughout the large aquamarine, perpendicular to the growth zones. Field of view 4.1 mm.



spectroscope, all of which are consistent with aquamarine. It had oriented inclusions in two directions. Parallel to the length of the stone were regularly spaced growth zones delineated by planes of reflective flat crystals and films (figure 2), some of which were sufficiently fine to appear as hazy linear clouds under low magnification (figure 3). Perpendicular to these zones throughout the stone were very fine reflective needles (figure 4). The uniform distribution of these perpendicular sets of inclusions resulted in the straight and distinct chatoyant band.

The size, color, and well-defined chatoyancy of this cat's-eye aquamarine made it a very notable gemstone.

Donna Beaton

Dyed Blue CHALCEDONY Detected by UV-Vis-NIR Spectroscopy

The 25.87 ct blue bead in figure 5 was recently submitted to the West Coast lab. Refractive indices of 1.539–1.550, a granular fracture, and a slightly banded structure identified the bead as chalcedony. Color concentrations around the drill holes suggested the presence of dye, but there was no evidence of the absorption lines characteristic of cobalt (at 620, 657, and 690 nm) in the handheld spectroscope. The other possibility was the use of a copper solution to enhance the color.

Standard nondestructive gemological tests are often inadequate to determine the presence of a copper-based dye in blue chalcedony. To verify that the chalcedony was dyed, we

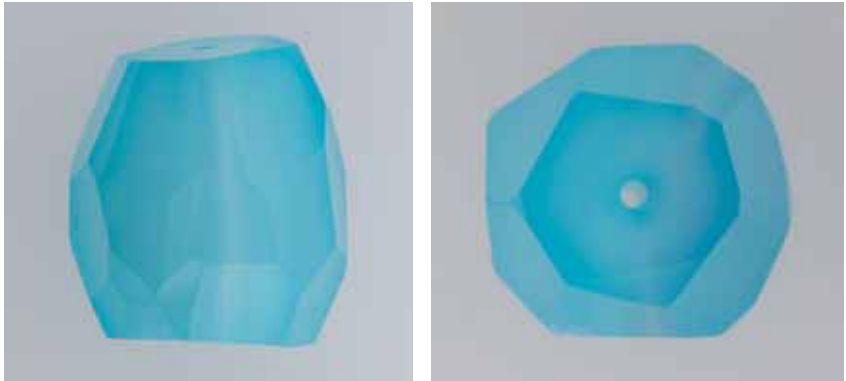


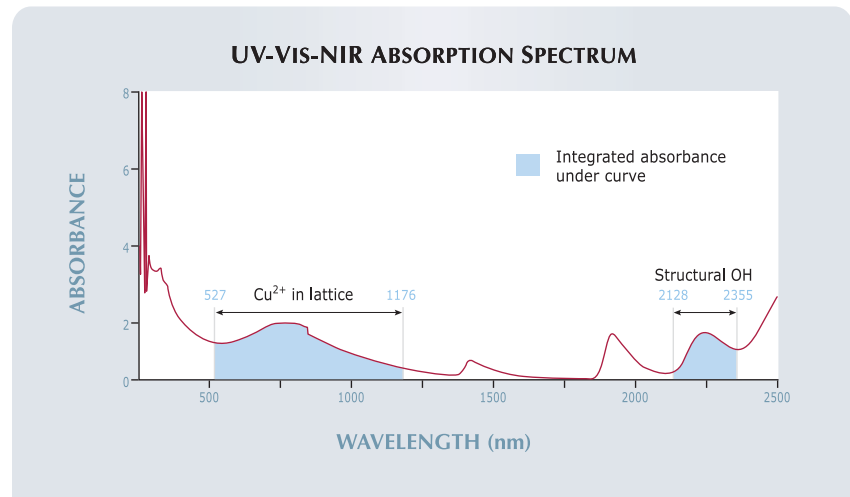
Figure 5. This 25.87 ct blue chalcedony bead proved to be colored by a copper-based dye. Note the subtle banding characteristic of chalcedony and, on the right, the suggestion of dye around the drill hole.

applied a technique developed by A. Shen et al. ("Identification of dyed chrysocolla chalcedony," Fall 2006 *Gems & Gemology*, p. 140) that uses the ultraviolet-visible-near infrared (UV-Vis-NIR) spectrum. In accordance with this technique, we calculated the ratio of the area (the integrated absorbance) under the peaks representing Cu^{2+} in the lattice vs. the integrated absorbance under the peak representing structural OH. As reported by Shen et al. (2006), for natural blue chalcedony this ratio ranges from 7 to 44; samples dyed

with copper solutions have a ratio ranging from 0.5 to 3. For this sample we calculated a ratio of 2.3, which fell into the range for dyed material (figure 6).

While the lab seldom uses destructive testing, this client allowed us to polish a flat on the bead to confirm the presence of dye (figure 7). Visible color concentrations in the drill hole and penetrating the surface of the stone corroborated the results of the Shen et al. (2006) test. With this spectroscopic approach, we feel we now have an acceptable nondestructive

Figure 6. The UV-Vis-NIR spectrum of the chalcedony bead revealed a ratio of Cu^{2+} to structural OH of 2.3, which indicates that the bead was dyed.



Editors' note: All items are written by staff members of the GIA Laboratory, East Coast (New York City) and West Coast (Carlsbad).

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Figure 7. A polished flat on the bead in figure 5 clearly shows distinct concentrations of color around the drill hole and on the surface of the stone, confirming the presence of dye. Field of view 11.8 mm.

method of establishing the presence of a copper-based dye in blue chalcedony.

Alethea Inns

DIAMOND

A Historic “Piggyback” Diamond

In the Winter 1985 Lab Notes section (p. 233), John Koivula described a “piggyback” yellow diamond: two diamonds mounted together to create the illusion of a larger stone. Dr. Max

Figure 8. Although the “center stone” in this pendant appears to be one large yellow diamond, it is in fact an assemblage of two smaller stones.



Bauer referred to such stones as “genuine doublets” (*Precious Stones*, J. B. Lippincott Co., Philadelphia, 1904, p. 96). After more than 20 years, we recently had a chance to examine this same doublet again—now as part of a unique, award-winning piece of jewelry designed by Virginia jeweler Charlie Kingrea (figure 8).

The fabrication of the jewel allowed for it to be disassembled into two separate pendants, as shown in figure 9. These were held together by a handmade 18K white and yellow gold retaining assembly: The table of the smaller diamond was centered on the back or “culet” of the large diamond, giving the illusion of a single larger stone. As mentioned in the 1985 Lab Note, the “face-up” appearance of the doublet was approximately equal to a 9–9.5 ct stone.

Although we were not able to remove the diamonds from their mountings, we were able to examine them more carefully this time and, specifically, to determine the origin of their deep yellow color. As reported in

Figure 9. When the pendant is disassembled, it becomes apparent that the “center stone” consists of two diamonds set in an unusual “piggyback” configuration.



the 1985 Lab Note, the top diamond weighed 4.72 ct and measured 17.50 × 12.55 × 2.46 mm; the bottom one weighed 2.41 ct and measured 12.50 × 7.23 × 4.48 mm. In both states, we observed a dull chalky green reaction to long-wave UV radiation, with a short-wave reaction that was similar but weaker. The color distribution seemed even, but due to the flat nature of the two pieces, uneven color distribution would have been difficult to observe. Both stones showed a 415 nm line in the desk-model spectroscope, with the 503 nm pair (496 and 503 nm) and a 595 nm distinct line indicating that they had been irradiated and annealed.

We have not examined another “genuine doublet” in over 20 years and welcomed the opportunity to review this type of assemblage. In addition, we were able to see it in a well-designed setting that highlighted the custom-fitted diamonds and also allowed us to establish their origin of color.

Thomas Gelb and

Thomas M. Moses

Natural Type IIb Blue DIAMOND with Atypical Electroluminescence

In scientific terms, *electroluminescence* is the nonthermal emission of light caused by the application of an electric field (H.-E. Gumlich et al., “Electroluminescence,” in D. R. Vij, Ed., *Luminescence of Solids*, Plenum Press, New York, 1998, p. 221). In the case of type IIb diamonds, when boron impurities replace carbon atoms in the diamond lattice, they can act as electron acceptors (i.e., holes) and conduct electricity through the absence of electrons. Nearly all type IIb diamonds are electrically conductive at room temperature, which may be observed using a simple gemological conduction meter. They also usually exhibit blue electroluminescence, visible as blue sparks, when an electric current is applied in a dark environment.

In the course of standard colored diamond testing, a natural type IIb Fancy Light blue diamond (figure 10) showed unusual electroluminescent



Figure 10. This 0.41 ct type IIb Fancy Light blue diamond proved to have some unusual characteristics.

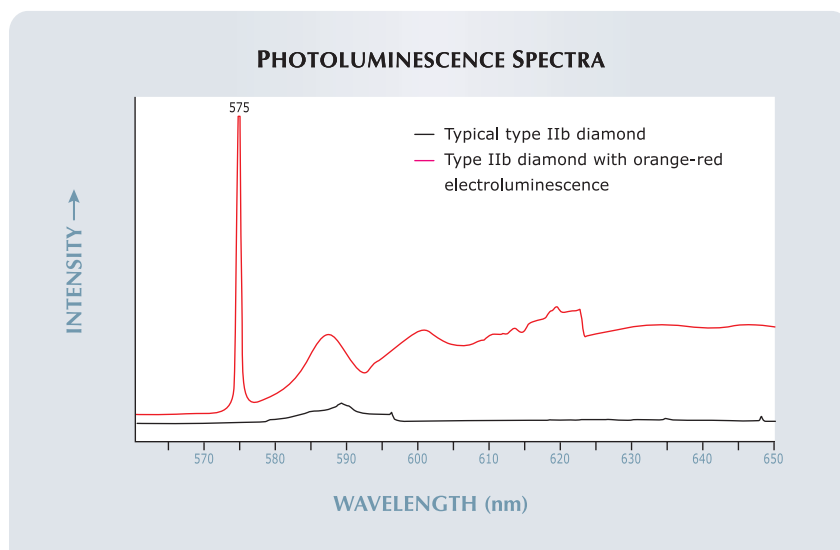


Figure 11. Orange-red sparks (electroluminescence) were obvious when the blue diamond was tested using a standard gemological conduction meter.

properties. Instead of the typical blue sparks, this diamond produced a fireworks-like display of both blue and intense orange-to-red electroluminescence during conductivity testing (figure 11). Photoluminescence (PL) analysis of the stone revealed an extremely large 575 nm peak (figure 12); we are unaware of any prior report of this intense feature in a type IIb diamond. In nitrogen-bearing diamonds, the 575

nm peak is attributed to the neutral nitrogen-vacancy center $[N-V]^0$. This defect has been well documented as a cause of orange fluorescence (P. M. Martineau et al., "Identification of synthetic diamond grown using chemical vapor deposition [CVD]," Spring 2004 *Gems & Gemology*, pp. 2–25), and we postulate that it might also be the

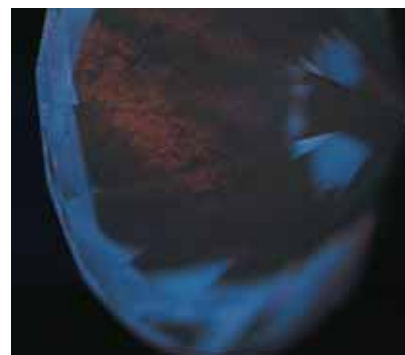
Figure 12. The photoluminescence spectrum of the diamond in figure 10 had an extremely large 575 nm peak, which previously has not been reported in the spectra of type IIb diamonds. The orange-red electroluminescence is most likely due to the $[N-V]^0$ center and related side bands. Laser excitation was 514.5 nm.



cause of the orange-red electroluminescence. However, additional work is required to precisely determine the source of the orange-red sparks. Orange and orangy red phosphorescence have been observed in both synthetic and natural type IIb diamonds [K. Watanabe et al. "Phosphorescence in high-pressure synthetic diamond," *Diamond and Related Materials*, Vol. 6, No. 1, 1997, pp. 99–106; S. Eaton-Magaña et al. "Luminescence of the Hope diamond and other blue diamonds," Fall 2006 *Gems & Gemology*, pp. 95–96), but we do not believe that the mechanisms ascribed by those authors apply to this unusual diamond.

DiamondView images showed mottled areas of orange-red fluorescence (figure 13), likewise suggesting localized concentrations of $[N-V]^0$ defects. The surrounding blue luminescence is typical of type II diamonds. Strong, uniform blue phosphorescence was also observed using the DiamondView, although no phosphorescence was seen with long- or short-wave UV excitation. Zoned fluorescence and electroluminescence suggest the presence of both nitrogen and boron-related defects in significant concentrations. Although no nitrogen was detected in the diamond's FTIR spectra, the occurrence of nitrogen-

Figure 13. DiamondView imaging of the 0.41 ct blue diamond revealed mottled areas of orange-red fluorescence (top left) that are likely due to localized concentrations of $[N-V]^0$ defects.



related features in the PL spectra clearly indicate its presence, but probably at concentrations below the level of detection that may be achieved in FTIR spectroscopy. Consequently, this diamond likely formed in a geologic environment that was atypical for most type I and type II diamonds.

It is a gemological treat to see a seemingly normal type IIb blue diamond, such as this one, unveil an extraordinary fireworks display of blue and orange electroluminescent sparks when tested with a conduction meter.

*Alethea S. Inns
and Christopher M. Breeding*

An Unsuccessful Attempt at Diamond Deception

The gem and jewelry industry is unfortunately and inevitably subject to a certain amount of fraud. One such case was revealed recently when the West Coast laboratory received a "D color, IF clarity" diamond for an update service along with a photocopy of what appeared to be its previous GIA report. The submitted stone matched the accompanying report in most respects, including color, shape, table and depth percentages, lack of fluorescence, and weight (reported to two decimal places), so at first glance nothing seemed out of the ordinary.

The diamond was found to be type IIa and was sent for advanced testing, which revealed that it had been treated by high pressure and high temperature (HPHT) to change its color. However, the report copy submitted with the stone did not indicate the presence of any treatment; at that point, we undertook a detailed investigation.

Preliminary examination with a microscope showed that the diamond was inscribed with a number corresponding to the GIA report, but the inscription was of poor quality and lacked the distinguishing letters "GIA" as well as a cut-brand inscription that was documented in the report. A trained eye confirmed that the inscription was not the work of GIA. Further observation revealed the

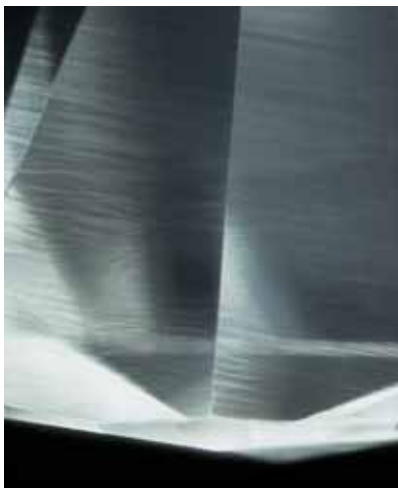


Figure 14. The strong whitish internal graining in this purportedly IF stone raised suspicions as to its true identity. Such graining is commonly observed in HPHT-treated diamonds. Field of view is 2.6 mm across.

presence of whitish internal graining (figure 14), which was not mentioned on the report and would have precluded a clarity grade of Internally Flawless (see J. M. King et al., "The impact of internal whitish and reflective graining on the clarity grading of D-to-Z color diamonds at the GIA Laboratory," Winter 2006 *Gems & Gemology*, pp. 206–220). While in some circumstances we might have suspected that the stone had been treated since the report was issued, it did not make sense that anyone would subject a diamond that was already top color to HPHT treatment.

In addition to the problems with the inscription and the internal graining, there was also a discrepancy in diamond type: The submitted stone was type IIa, and our records indicated that the stone for which the report had been issued was type I. Closer examination of the dimensions revealed that while the length, width, and depth measurements of the submitted stone were extremely close to what was stated on the report, its weight was 0.0028 carats more than the weight of the dia-

mond for which the original report had been issued, according to the laboratory's internal database. If the stone had been repolished (e.g., to remove part of the inscription) since the report was issued, the process should have removed weight—and certainly would not have added any. It was clear that an HPHT-treated stone had been purposely cut and inscribed to match the GIA report of a diamond with a natural origin of color.

We do not know who performed this fraudulent act, or when and where it occurred, we only know that a deception was attempted. The stone eventually left the West Coast laboratory with a new report listing a clarity grade of VVS₁ (based on its whitish internal graining) and the inscription "HPHT PROCESSED," in keeping with GIA policy for these treated-color diamonds.

*Laura L. Dale
and Christopher M. Breeding*

KYANITE Resembling Blue Sapphire

The West Coast laboratory recently received an 8.54 ct dark blue oval gem (figure 15) for a corundum report. The stone had a striking visual resemblance

Figure 15. This 8.54 ct kyanite was initially mistaken for sapphire because of its intense blue color and internal features that resembled those seen in corundum.





Figure 16. The cluster of zircon crystals at the top of this inclusion scene in the kyanite can appear with similar morphology in metamorphic blue sapphires. The quartz crystal on the bottom would be uncharacteristic for corundum. Width of view 1.2 mm.



Figure 17. Unlike corundum growth tubes, which intersect at 60°/120°, growth tubes in kyanite intersect at 90°. Width of view 1.2 mm.

to blue sapphire and some features that supported this initial impression, such as its inclusions and visible spectrum. However, RI values of 1.710–1.730 and an SG of 3.68 ruled out corundum and instead indicated kyanite.

The inclusion scene contained several elements that are commonly present in blue sapphire, such as clusters of zircon crystals (figure 16) and rutile (both identified using Raman spectroscopy). A large transparent quartz crystal (again, see figure 16) was the only inclusion that would be uncharacteristic for blue sapphire. Growth tubes resembled those seen in corundum; however, these could be distinguished by their intersection angles. Corundum growth tubes intersect at 60°/120°; in kyanite, they intersect at 90° (figure 17). Angular blue zoning confined above a colorless zone in the bottom half of the pavilion also resembled that seen in sapphire, but it did not show corundum's characteristic hexagonal growth features.

In the visible spectrum, the kyanite displayed red transmission and corresponding lines in the desk-model spectroscope due to Cr content,

which can also appear in Cr-bearing blue sapphires. The 450, 460, and 470 nm iron lines that are occasionally present in blue sapphire were absent, but weak 430 and 445 nm lines caused by Fe³⁺ substituting for Al³⁺ (see Spring 2002 Lab Notes, pp. 96–97) could have been mistaken for corundum iron lines. The chemical formulas of kyanite (Al₂SiO₅) and corundum (Al₂O₃) are similar.

Further testing using UV-Vis-NIR spectrophotometry also highlighted the similarities between blue sapphire and kyanite spectra (figure 18). Note the 380–385 nm and 430–450 nm regions, corresponding to Fe³⁺ substitution for Al³⁺, as well as the broad band at ~610 nm, which is responsible for the blue color and caused by the Fe²⁺-Fe³⁺ charge transfer in kyanite. The broad band in blue sapphire is caused by a combination of Fe²⁺-Fe³⁺ and Fe²⁺-Ti⁴⁺ charge-transfer mechanisms.

The many similarities had led the client to believe the stone was a blue sapphire. However, the RI, SG, and closer examination of the inclusions provided a correct identification as kyanite.

Alethea Inns

Figure 18. The UV-Vis-NIR spectrum of the kyanite showed similarities with that of metamorphic blue sapphire, particularly in the 380–385 and 430–450 nm regions (where Fe³⁺ substitutes for Al³⁺). The broad bands centered at ~610 nm in both kyanite and sapphire are caused by charge-transfer mechanisms.

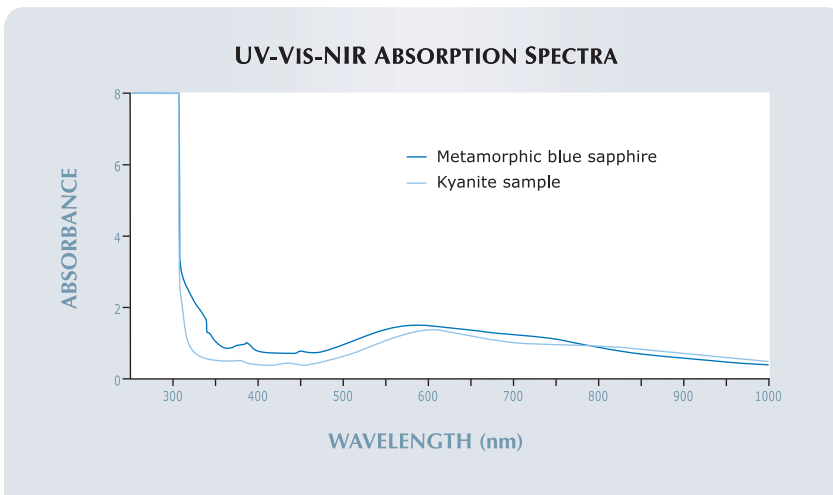




Figure 19. This crystal (27.30 × 21.10 × 19.10 mm), originally thought to be a diamond, proved to be phenakite.

PHENAKITE as a Rough Diamond Imitation

The GIA Laboratory regularly receives near-colorless transparent crystals, pieces of rough, or fragments for identification, often because they were sold as, or are hoped to be, diamond. Such was the case with a 67.94 ct near-colorless transparent crystal (figure 19) that was recently submitted to the East Coast laboratory.

The specimen was similar enough to a (water-worn) dodecahedron-like diamond crystal to prompt submission to the laboratory. It showed abundant dissolution features, parallel growth striations (figure 20), trigon-like features (figure 21), and an orangy red included crystal. However, initial physical indications, such as a lack of either adamantine luster or dispersion (both of which could have been obscured by the irregular surface) and a low “heft,” suggested that it was not diamond. In addition, during spectroscopic testing the sample was placed on a block cooled by liquid nitrogen. When it was removed, the crystal did not feel cool to the touch as a diamond should have, indicating low thermal conductivity.

Further testing revealed that the specimen was doubly refractive and uniaxial, with a spot RI of approxi-

mately 1.65 and a hydrostatic specific gravity of 2.96. These properties ruled out glass, cubic zirconia, and diamond. The crystal had a weak pinkish violet reaction to short-wave UV radiation, revealed no absorption lines in the spectroscope, and had no transmission luminescence. Step-like striations were evident, but the trigon-like features were raised (again, see figure 21), not depressed as usually seen in natural diamond.

Raman spectroscopy confirmed that the specimen was phenakite, Be_2SiO_4 , which has a trigonal rhombohedral structure with one cleavage direction, and is often confused with quartz. It has a specific gravity that is lower than diamond, but the rough exhibits features that could be mistaken for those of natural diamond. Interestingly, its etymology comes from the Greek word *phenakos*, meaning “to deceive.”

Donna Beaton, Joshua Sheby, and Riccardo Befi

Figure 20. The crystal showed parallel, step-like growth striations, similar to what is seen on some rough diamonds. Width of view 8.9 mm.



Glass-Filled SYNTHETIC RUBY

Recently, the East Coast laboratory was asked to identify the 12.84 ct red oval mixed cut in figure 22. Standard gemological testing produced results consistent with the published values for ruby.

However, examination with magnification and immersion in methylene iodide revealed that the specimen was heavily fractured in an unnatural honeycomb pattern (figure 23), similar to what is typically seen as a result of quench crackling. It fluoresced strong red to long-wave—and moderate red to short-wave—UV radiation, with an orangy yellow reaction in the fractures that indicated a foreign material was present. At higher magnification, the fractures appeared reflective and showed a blue flash effect, a common feature in glass- or resin-filled materials. Laser ablation-inductively coupled plasma-mass spectroscopy (LA-ICP-MS) analysis revealed a significant amount

Figure 21. Trigon-like features were also present in the crystal featured in figure 19, but unlike those seen in diamond they were raised rather than indented. Width of view 7.5 mm.





Figure 22. This 12.84 ct specimen (15.95 × 10.80 × 7.74 mm) proved to be a quench-crackled, glass-filled synthetic ruby.

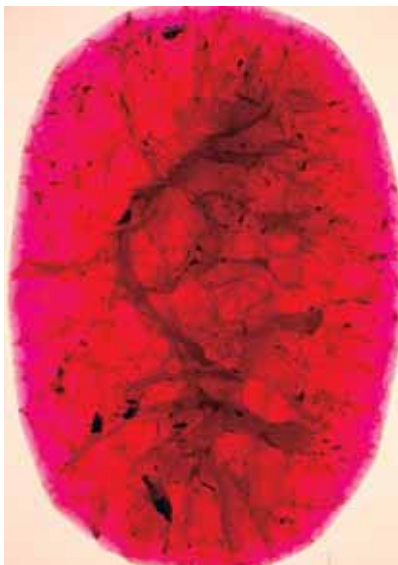


Figure 23. When viewed at 7.5× magnification while immersed in methylene iodide, the synthetic ruby showed a honeycomb fracture pattern typical of quench crackling in corundum.



Figure 24. Curved striae were also observed when the quench-crackled synthetic ruby was viewed at 12× magnification while immersed in methylene iodide.

of lead (Pb) in the filler material, confirming that the specimen was lead-glass filled. No other inclusions were seen. When the sample was immersed in methylene iodide and examined with a horizontally configured microscope, we observed subtle curved striae through a few upper girdle facets, conclusive proof of its synthetic origin (figure 24).

It is becoming more common to see lead-glass filling in low-quality natural rubies (see, e.g., S. F. McClure et al., "Identification and durability of lead glass-filled rubies," Spring 2006 *Gems & Gemology*, pp. 22–34). The laboratory still sees melt-grown synthetic corundum, often in an altered form, but it is unusual to see a synthetic ruby that has been subjected to two treatments: quench crackling to

imitate natural fractures, and lead-glass filling to minimize the visibility of the fractures.

On several occasions over the years, the GIA Laboratory has reported on treated synthetic corundum. The most dramatic examples were in flame-fusion synthetic corundum during the early 1980s (see J. I. Koivula, "Induced fingerprints," Winter 1983 *Gems & Gemology*, pp. 220–227). Other related instances were a glass filling in a flame-fusion synthetic ruby (Winter 1990 Lab Notes, p. 298) and a quench-crackled synthetic that had been "oiled" to conceal the fractures (Fall 1992 Gem News, pp. 208–209). We can only hypothesize that our 12.84 ct sample was yet another

instance in which significant steps were taken to mimic the natural material.

HyeJin Jang-Green
and Riccardo Belfi

PHOTO CREDITS

Jian Xin (Jae) Liao—1, 8, 9, 19, and 22;
Donna Beaton—2–4, 20, and 21; C. D.
Mengason—5; Alethea Inns—7, 16, and 17;
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Christopher M. Breeding—13; John I.
Koivula—14; HyeJin Jang-Green—23;
HyeJin Jang-Green and Riccardo Belfi—24.

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EDITOR

Brendan M. Laurs (blaurs@gia.edu)

CONTRIBUTING EDITORS

Emmanuel Fritsch, *IMN, University of Nantes, France* (fritsch@cnrs-immn.fr)

Henry A. Hänni, *SSEF, Basel, Switzerland* (gemlab@ssef.ch)

Franck Notari, *GemTechLab, Geneva, Switzerland* (franck.notari@bluewin.ch)

Kenneth V. G. Scarratt, *GIA Research, Bangkok, Thailand* (ken.scarratt@gia.edu)

DIAMONDS

Large diamond mine to be developed in Saskatchewan, Canada. Kimberlite bodies were first discovered near Fort à la Corne in central Saskatchewan in 1989 by Uranerz, a German uranium exploration company. In contrast to the usual vertical pipe- or carrot-shaped morphology, the Fort à la Corne kimberlites form complexes of lens-like, horizontally elongated bodies lying underneath approximately 90–100 m of overburden (sand, mudstone, and glacial till).

The original kimberlite volcanoes erupted into a shallow sea during the Cretaceous period (~100 million years ago), and the volcanic ejecta were preserved by quick burial under mud (now mudstone). The resulting shapes—extensive low domes, shallow bowls, and flat pancakes—constitute hundreds of millions of tonnes of kimberlite.

The kimberlite field is located in flat terrain about 60 km east of Prince Albert (see, e.g., figure 1). Uranerz discovered the kimberlites by drilling into airborne magnetic



Figure 1. The large Fort à la Corne kimberlite field in Saskatchewan has demonstrated considerable promise as a future diamond producer. Shown here is the Orion exploration site and core/sample processing facility. Courtesy of Shore Gold Inc.

anomalies discernable on government maps. As the Uranerz managers were not experienced with diamond exploration, they formed joint ventures, first with Cameco Corp. (a Canadian uranium exploration and mining company) and subsequently with Canada-based Kensington Resources and De Beers. Eventually, geologists identified a field of 72 kimberlites, of which 63 were located on the joint-venture Fort à la Corne (FALC) property. Initial FALC ownership was Kensington Resources 42.5%, De Beers 42.5%, Cameco 5%, and UEM (successor to Uranerz) 10%. FALC budgeted evaluation efforts at \$15 million annually (increasing to \$24 million) and focused on bodies 140/141 and 150, from which diamonds up to 10.23 ct were recovered in the top clay-rich layer.

In 1995, Canada-based Shore Gold Inc. acquired adjoining leases at the southeast end of what is now the FALC property and there discovered the Star kimberlite complex, which covers 240 ha in a shallow bowl shape and is up to ~88 m at its thickest part. Extensive drilling has shown that the deposit formed by successive layers of overlapping kimberlite pulses from one or more feeder pipes. Initial figures for the Star complex were ~276 million tonnes (Mt) at a grade of 14.25 carats per hundred tonnes (cpht), yielding 40 million carats (Mct) of diamonds with an average value of \$135/ct, for an estimated worth of \$5.5 billion (e.g., figure 2).

In October 2005, Shore Gold and Kensington Resources agreed to merge, as several of the kimberlite complexes overlapped their property boundaries. In September 2006, Kensington Resources, by then a subsidiary of Shore Gold, acquired the shares of Cameco, UEM, and, later that month, of De Beers as well. They then sold 40% equity to Newmont Canada; Shore Gold controls the remaining 60% in the new joint venture, called FALC-JV. Thus, the Star and FALC complexes are now merged into one operation. The most promising FALC kimberlites, 140/141 and 150, are now grouped into a unit called the Orion Belt, which is aligned with Star in a northwest trend. Kimberlite resources are estimated at 360–400 Mt in Orion South and 800 Mt in Orion North; these could yield up to 120 Mct at \$160/ct.

Evaluation drilling and processing of samples from the Star complex in the period June to September 2007 led to the recovery of 10,251 diamonds from approximately 46,000 tonnes of kimberlite. The combined weight of the diamonds amounted to 1,269.58 carats, with at least 12 stones ranging from 4.21 to 49.5 ct (57 were >2 ct and 157 were >1 ct). In some drill core samples, up to 30–40% of



Figure 2. This selection of diamond crystals (1.62–10.10 ct) was recovered from the Star complex during 2006. Courtesy of Shore Gold Inc.

the diamonds recovered were >1 ct. In general, approximately 70% of the diamonds recovered were classified as “white” and 20% as “off white.”

The combined yield of Star and Orion could be up to 200 Mct worth \$30 billion, which would be mined in several open pits. The first mine in the Star complex is tentatively scheduled to open in 2012. As this is approximately when the predicted gap between world rough supply and demand should start to widen, this new production would be most welcome.

A. J. A. (Bram) Janse
Archon Exploration Pty. Ltd.
Carine, Western Australia

Spurious “spiral phantom” in diamond. These contributors recently examined a faceted pink diamond from Australia’s Argyle mine, in which we observed what appeared to be a spiral structure (figure 3). At first, we thought this feature was a screw dislocation decorated by impurities, such as those observed in beryl and topaz. Further, it was perfectly oriented along the diamond’s octahedral direction, as evidenced by several incipient cleavages that were limited by graining planes (again, see the areas delineated on figure 3). We were very excited because such a structure has never been observed in diamond (either natural or synthetic), and is very rare in cubic minerals (see, e.g., Spring 2007 Lab Notes, p. 55).

However, while preparing the sample for Raman and infrared analysis, we discovered that the inclusion had mysteriously disappeared. We then realized that this “screw dislocation” was in fact nothing more than a dust particle adhering to the diamond’s surface!

This episode underlines the fact that microscopic observation, although very useful in gemology, needs to be conducted with care even by experienced gemologists.

Editor’s note: Interested contributors should send information and illustrations to Brendan Laurs at blaurs@gia.edu or GIA, The Robert Mouavvad Campus, 5345 Armada Drive, Carlsbad, CA 92008. Original photos can be returned after consideration or publication.

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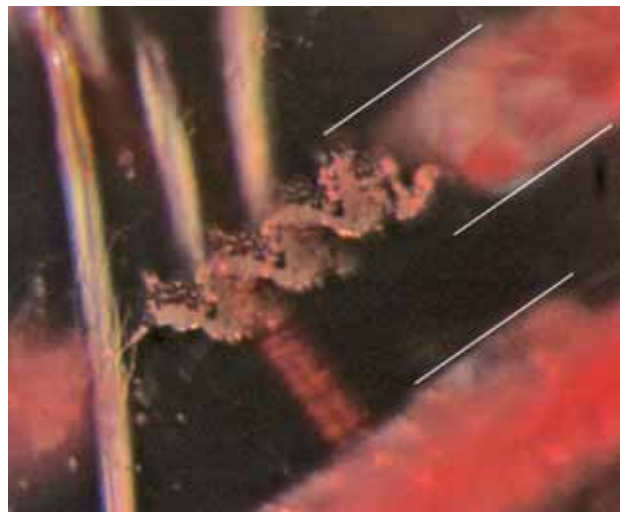


Figure 3. What at first appeared to be an oriented screw dislocation in a pink diamond was in fact only a dust particle on the surface of the gem. The white lines indicate the diamond's octahedral direction. Photomicrograph by B. Rondeau; magnified 60 \times .

Careful cleaning of samples before examination, while sometimes tedious, is an important step in any gemological investigation.

Benjamin Rondeau (rondeau@mnhn.fr)
Muséum National d'Histoire Naturelle
Paris, France

Emmanuel Fritsch and Franck Notari

Figure 4. Axinite from Baluchistan, Pakistan (here, 2.32–18.62 ct), is notable for its unusual color zoning. All of these stones except for the pear shape were characterized for this report. Courtesy of Herb Obodda; photo by C. D. Mengason.



COLORED STONES AND ORGANIC MATERIALS

Color-zoned axinite from Pakistan. In June 2005, Herb Obodda (H. Obodda, Short Hills, New Jersey) informed us about a new find of color-zoned axinite from Baluchistan, Pakistan. By November 2005, his supplier had purchased 6 kg of the material, which local shepherds had recovered over an eight-month period. The supplier described the locality as being in a remote part of the Taftan Mountains. Most of the production was heavily included, but Mr. Obodda selected ~100 g of transparent pieces of rough that were notable for their distinct patches of pleochroic color. The largest crystal measured 19 mm in longest dimension, and the largest stone he had cut weighed 18.62 ct (figure 4).

Mr. Obodda loaned or donated to GIA five crystals and eight cut axinites. Figure 4 shows the range of color seen in the faceted stones. Overall, the samples were medium to light brown, which was modified by strong pleochroism and color zoning in reddish purple, orangy red, blue to violet, green, and pink. The most common color zoning consisted of violetish blue areas that appeared strongest when the light was polarized in the reddish purple direction of the host axinite; these zones became much fainter as the polarizer was rotated 90° (figure 5). A particularly striking example of the pleochroic colors was shown by the axinite crystal in figure 6.

The following properties were determined on five cut stones: RI— $n_o=1.668-1.671$, $n_e=1.679-1.680$; birefringence 0.009–0.012; hydrostatic SG—3.28–3.30; Chelsea filter reaction—none; fluorescence—inert to long- and short-wave UV radiation; and weak absorption lines at approximately 440, 470, 495, 515, and 535 nm visible with the desk-model spectroscope. These properties are comparable to those reported for axinite by M. O'Donoghue (*Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, p. 386), except that we did not see an absorption peak at 415 nm. Microscopic examination revealed "fingerprints" composed of two-phase (fluid and gas) inclusions, as well as transparent angular growth zoning.

Figure 5. Violetish blue color zones are seen in the reddish purple pleochroic direction (left) of this 2.97 ct axinite from Pakistan; the colors almost disappear when the polarizer is rotated 90° (right). Gift of Herb and Monika Obodda, GIA Collection no. 37121; photos by Robert Weldon.



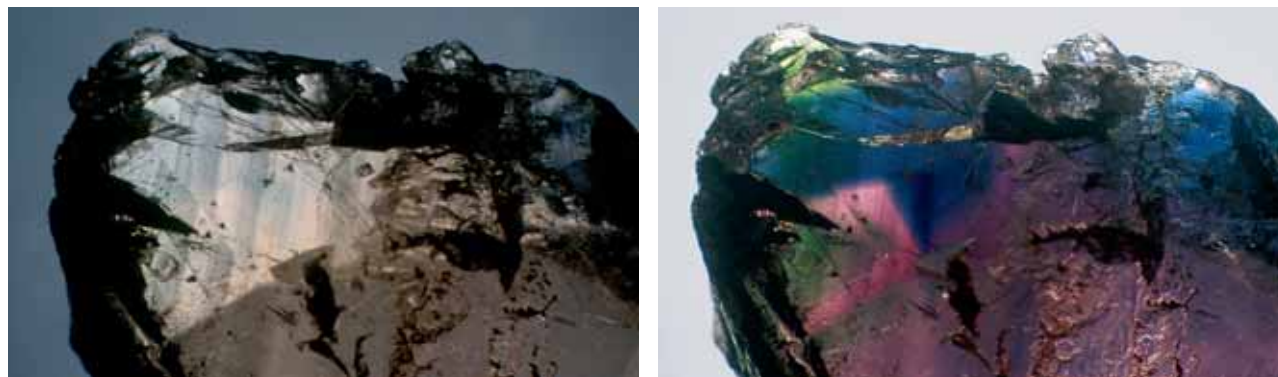


Figure 6. The strong pleochroism and unusual color zoning in the Pakistani axinite are well illustrated by this crystal, seen in two views as the polarizer was rotated 90°. Courtesy of Herb and Monika Obodda; photomicrographs by S. F. McClure, magnified 10×.

Electron-microprobe analyses of two of the crystals at the University of New Orleans showed they were ferro-

TABLE 1. Representative electron-microprobe analyses of a color-zoned axinite crystal from Baluchistan, Pakistan.^a

Oxide (wt.%)	Light brown zone	Blue zone
SiO ₂	42.81	42.74
TiO ₂	0.04	0.05
B ₂ O ₃ ^b	6.18	6.17
Al ₂ O ₃	17.49	17.47
FeO ^c	8.61	8.57
MnO	0.12	0.10
MgO	2.98	2.99
CaO	19.57	19.57
Na ₂ O	0.03	0.06
K ₂ O	0.02	nd
H ₂ O ^p	1.60	1.60
Total	99.46	99.30
Ions per 16 (O,OH)		
Si	4.012	4.012
Ti	0.003	0.004
B	1.000	1.000
Al	1.932	1.933
Fe ²⁺	0.675	0.672
Mn	0.010	0.008
Mg	0.417	0.418
Ca	1.965	1.968
Na	0.006	0.010
K	0.003	nd
OH	1.000	1.000

^a Data were collected using an ARL-SEM electron microprobe with 15 kV (for sodium) and 25 kV accelerating voltages, 15 nA beam current, and 3 μm beam diameter. The measurements were calibrated with natural mineral and synthetic compound standards, and a ZAF correction procedure was applied to the data. Cr, V, Bi, Pb, Zn, and F were analyzed for but not detected. Abbreviation: nd = not detected.

^b Calculated by stoichiometry.

^c All Fe reported as FeO.

axinite (Ca₂Fe²⁺Al₂BO[OH](Si₂O₇)₂); the RI and SG values reported above are also consistent with this identification (W. A. Deer et al., *Rock-forming Minerals: Disilicates and Ring Silicates*, 2nd ed., Vol. 1B, Geological Society, London, 1997, pp. 603–623). One of the crystals contained blue zones that were accessible for microprobe analysis, but we could not discern any systematic differences in composition from the surrounding light brown area (table 1). Laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) analyses of a similar color-zoned crystal at GIA revealed distinctly more Ti and Mn in the blue zone than in the light brown area (0.09 vs. 0.01 wt.% TiO₂; 0.31 vs. 0.18 wt.% MnO). UV-Vis spectroscopy of these same blue and light brown areas showed much stronger absorption at ~580 nm in the blue zone. Further research on precisely oriented samples would be required to evaluate the origin of the unusual coloration of this axinite.

Eric A. Fritz (eric.fritz@gia.edu),
Shane F. McClure, and Andy H. Shen
GIA Laboratory, Carlsbad

Brendan M. Laurs

William B. (Skip) Simmons and Alexander U. Falster
University of New Orleans, Louisiana

Multicolored fluorite from Brazil. Although fluorite is generally not a good jewelry stone because of its low hardness (Mohs 4) and four perfect cleavages, its availability in large sizes and a wide variety of colors—sometimes within the same gem—makes it very popular with collectors. Argentina has produced large quantities of transparent multicolored fluorite in yellow, orange, green, purple, and brown, among other colors. It is found in veins that are hosted by granite at the Valcheta and Los Menucos mines, both in Rio Negro Province.

In early 2007, a new source of multicolored fluorite was found in Brazil, reportedly in Bahia State. This fluorite may show dozens of very thin layers in yellow and pink shades, but most striking is the presence of “sapphire”-blue zones. These occur near the surface of the crystals,

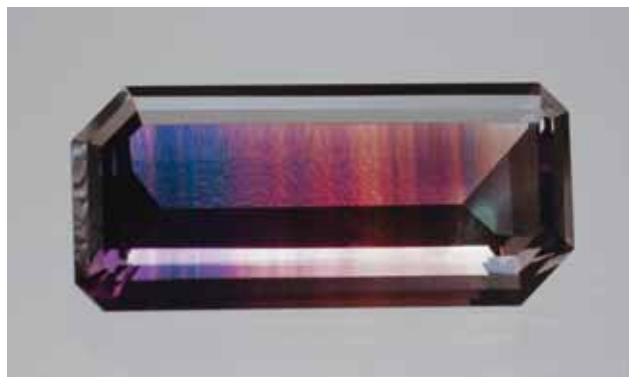


Figure 7. These attractive samples of multicolored fluorite were recovered from a new source in Brazil. The larger stone in the left photo weighs 18.36 ct, and the fluorite in the right image is 77.36 ct. Photos by J. Hyrsl.

with the inner portions usually pink or yellow. Depending on the orientation of the color zones, faceted stones can be produced with a resulting blue, pink, or multicolored (e.g., figure 7) face-up appearance.

This contributor recently examined several samples of this material. The rough was available only as cleavage fragments with few crystal faces and no matrix. Two of the pieces with crystal faces had small (≤ 1 mm in diameter) yellow metallic inclusions, visually identified as chalcopyrite, located about 1 mm beneath the surface. Such inclusions point strongly to an origin in a hydrothermal copper deposit.

As of May 2007, at least 1,000 carats of cut stones were available in Brazil, ranging from ~1 to 77 ct each, and more will almost certainly be produced in the future. Although this fluorite makes a nice collector's gemstone, there is also the possibility that the blue material may be offered as a sapphire imitation, in much the same way that some green fluorite has been found mixed with emeralds of the same color.

Jaroslav Hyrsl (hyrsl@kuryr.cz)
Prague, Czech Republic

Cr/V-bearing kyanite from Madagascar and elsewhere.

Madagascar has become known for a wide variety of interesting and exotic gems. In 2004, an attractive blue kyanite was faceted by Fabrice Danet (Style Gems, Antsirabe, Madagascar) from a mixed parcel of mostly rhodolite, zircon, and amethyst that was represented as coming from the eastern coastal area of Madagascar. Preliminary testing showed that the stone contained Cr and V, so Mr. Danet donated it to GIA for further testing. We were unaware of the prevalence of Cr and V in kyanite, so we were pleased to investigate the properties of this stone.

The 0.98 ct oval modified brilliant (figure 8) had the following characteristics: color—medium-dark greenish blue; pleochroism—moderate greenish blue, gray-purple, and near colorless; diaphaneity—transparent to semi-transparent; RI—1.716–1.731; birefringence—0.015; SG—3.69; Chelsea filter reaction—strong red; fluorescence—weak to moderate red to long-wave UV radiation and very weak green to short-wave UV. These properties are comparable to those reported for kyanite by R. Webster

(*Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, UK, 1994, pp. 348–349). Lines in the red end of the spectrum at 670 and 690 nm were visible with a desk-model spectroscope, along with a broad band centered at approximately 575 nm. Microscopic examination revealed fine needles in parallel orientation throughout the stone, small transparent doubly refractive crystals and needles, low-relief transparent crystals that appeared

Figure 8. Gem-quality kyanite is available in a range of colors. The 0.98 ct greenish blue faceted oval in the center (gift of Fabrice Danet, GIA Collection no. 36693) is reportedly from eastern Madagascar; it was characterized in detail for this report. For comparison, chemical analyses were obtained for four additional kyanites: a 12.76 ct bluish green crystal from Namibia, a 6.31 ct blue rectangular step cut from Brazil, a 1.43 ct blue cabochon from Nepal, and a 1.05 ct dark greenish blue rectangular step cut from Andilamena, also in eastern Madagascar. Courtesy of Franck Notari (Namibia, Brazil, and Andilamena) and the GIA Collection (Nepal); photo by Robert Weldon.



TABLE 1. Significant trace-element composition (in ppm) of kyanites from four countries, determined by LA-ICP-MS on two spots of each stone.^a

Element	Namibia (FN4253)		Brazil (FN138)		Nepal (GIA16111)		Madagascar (FN5688)		Madagascar (0.98 ct oval)	
	1	2	1	2	1	2	1	2	1	2
Fe	4,160	4,223	1,960	1,471	2,013	1,674	1,965	1,937	1,460	1,387
Cr	261	270	178	187	62	63	4,982	3,143	553	504
V	22	25	39	33	60	50	370	331	81	77
Ti	46	35	32	23	37	28	87	67	179	452
Ga	9	10	18	16	22	18	35	34	81	67
Pb	nd	nd	nd	1	nd	nd	2.1	2.4	5.3	6.5

^a Data collected using a Thermo X-Series ICP-MS equipped with a New Wave 213 nm laser-ablation sample introduction system. Laser parameters were 40 μm spot size, 7 Hz repetition rate, 60% power, and 25 second dwell time. Concentrations were calculated using NIST 610, 612, and 614 glasses as reference standards. Abbreviation: nd = not detected.

to be singly refractive, cleavages, “fingerprints,” and stringers of particles oriented perpendicular to the direction of the fine needles.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy indicated the presence of major amounts of Si and Al, as expected, as well as traces of Fe, Cr, V, Ti, and Ga. Trace-element analyses by LA-ICP-MS were obtained from this kyanite and, for comparison, from four additional kyanite samples from Namibia, Brazil, Nepal, and Andilamena, Madagascar (again, see figure 8, and table 1). All of the samples contained Fe, Cr, V, Ti, and Ga, and very small amounts of Pb were measured in a few of the analyses. The stone provided by Mr. Danet contained more V and Cr than the three non-Madagascar samples, but significantly less of both elements than the (darker) kyanite from Andilamena. The Namibian sample showed relatively high Fe, and Fe was the only enriched trace element in the Nepalese kyanite. Compared to the other samples, both of the kyanites from Madagascar showed more elevated concentrations of Ti, Ga, and Pb. The color variations in these kyanites are apparently due to differences in their contents of the chromophoric elements Fe, Cr, V, and Ti, but establishing the precise coloration mechanisms would require additional research.

*Elizabeth P. Quinn (equinn@aglgemlab.com)
American Gemological Laboratories
New York*

*Christopher M. Breeding
GIA Laboratory, Carlsbad*

Blue-green opal from Iran. Gem-grade blue-green opal has traditionally come from the Andes Mountains in Peru (see Summer 1991 Gem News, pp. 120–121; Spring 1994 Lab Notes, pp. 43–44). According to Makhmout Douman (Arzawa Mineralogical Inc., New York), a new deposit was recently found in Iran, about 110 km northwest of the town of Shahr-e Babak in Kerman Province. As of October 2007, mining efforts had nearly stopped due to groundwater seeping into the pits. Only a few stones have been polished, due to the cracked nature and shallow thickness of the pieces of rough that have been recovered so far.

Mr. Douman loaned two cabochons (2.40 and 2.59 ct; figure 9) and one rough sample to GIA, and the following properties were obtained on the polished stones (with those for the smaller cabochon given first here): color—bluish green and green-blue; diaphaneity—translucent; RI—1.45 and 1.47; hydrostatic SG—2.06 and 2.00; Chelsea filter reaction—none; fluorescence—inert to both long- and short-wave UV radiation; and a 600 nm cutoff seen in the desk-model spectroscope. Microscopic examination revealed milky white clouds in both samples. The smaller cabochon also showed a moss-like inclusion at the base. The 1.47 RI value is slightly high for opal, which typically ranges from 1.44 to 1.46 (R. Webster, *Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, UK, 1994, p. 244).

The Raman spectra of both samples closely matched the opal reference spectrum. Opals intrinsically contain enough water to saturate the mid-infrared region of the spectrum. Therefore, spectroscopy in the near-IR range was used to examine the hydroxyl-related characteristics, and the results closely matched those of published spectra

Figure 9. A new source of blue-green opal (here, 2.40 and 2.59 ct) has been discovered in Iran. Courtesy of Makhmout Douman; photo by Robert Weldon.



for opal (H. Graetsch, "Structure of opaline and microcrystalline silica," in P. J. Heaney et al., Eds., *Silica. Physical Behavior, Geochemistry and Materials Applications*, Reviews in Mineralogy, Vol. 29, Mineralogical Society of America, Washington, DC, 1994, pp. 209–229). EDXRF spectroscopy of the two samples showed major amounts of Si, minor Cu, and traces of Fe. UV-Vis-NIR spectroscopy showed typical Cu^{2+} absorptions at 527–1176 nm, indicating that copper is the cause of the blue-green coloration.

Kevin G. Nagle (knagle@gia.edu)
GIA Laboratory, Carlsbad

A remarkably large fire opal carving. Fire opals are well known in the gem trade, and—based on the number of trade queries these contributors have received—they are becoming more popular in India. Fire opal is found in a range of orange, red, yellow, and brown hues, with or without play-of-color.

Recently, we had the opportunity to examine and test an unusually large specimen of semitransparent brownish

Figure 10. This fire opal carving (13.90 × 10.30 × 4.30 cm) is unusual for its large size, attractive color, and translucency. Photo by G. Choudhary.



Figure 11. The fire opal carving displayed milky zones when illuminated with a strong fiber-optic source. As the light was moved around the sample, these zones appeared to radiate from its center. Photomicrograph by G. Choudhary; magnified 2×.

orange fire opal (figure 10), which did not show play-of-color. This 492 g (2,460 ct) carving was fashioned after Lord Mahaveera (one of the ancient Indian sages who established the tenets of Jain Dharma). Its identification as fire opal was established by its spot refractive index of 1.46 and low heft (it was too large for specific gravity testing). The carving was inert to UV radiation.

Examination with a microscope and fiber-optic illumination revealed some milky zones composed of fine pinpoint inclusions. These zones gave a slight haze to the carving, although this was visible only with strong lighting. As the fiber-optic light was moved around the specimen, the milky zones appeared to radiate outward from the center (figure 11). Milky zones or clouds are commonly encountered in opals, but the radiating pattern has not

Figure 12. Tiny dendritic inclusions, some of which were encased in fluid-like bubbles, were also present in the fire opal carving. Photomicrograph by G. Choudhary; magnified 45×.

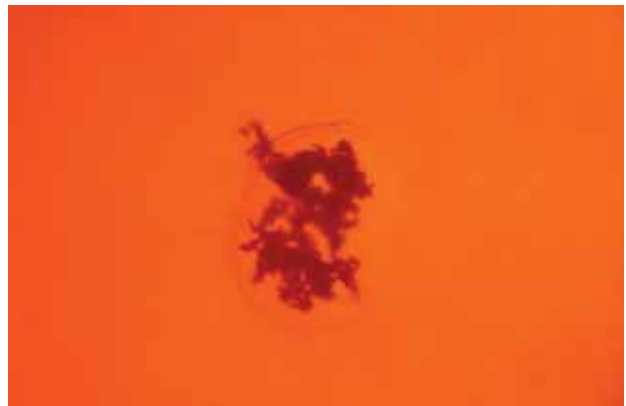




Figure 13. This 13.88 ct non-nacreous pearl exhibits some interesting surface and internal structures. Photo by N. Sturman.

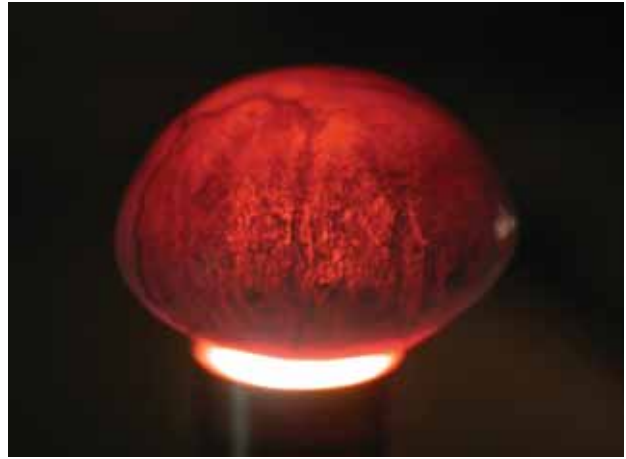


Figure 14. When viewed with a fiber-optic light, the pearl in figure 13 had unusual translucency. Photo by N. Sturman.

been documented previously to our knowledge. At higher magnification, dendritic inclusions were also seen; some of these were surrounded by what appeared to be fluid-filled bubbles (figure 12). Although dendritic inclusions are common in opals, it is unusual for them to be encased in such a fashion. A similar inclusion in an opal was illustrated by E. J. Gübelin and J. I. Koivula (*Photoatlas of Inclusions in Gemstones*, Vol. 2, Opinio Publishers, Basel, Switzerland, 2005, p. 492).

Although fire opal is known from many localities, especially Mexico and Brazil, the client did not know the source of this carving. Large specimens of fire opal, but with a much darker color, also have been reported from Juniper Ridge, Oregon (see Spring 2003 Gem News International, pp. 55–56). The carving documented in the present entry was exceptional due to its large size combined with its attractive color and translucency. In addition, despite the tendency of some fire opal to crack or “craze,” this carving showed no evidence of such damage.

Gagan Choudhary (gtl@gjepcindia.com)
and Mustaqeem Khan
Gem Testing Laboratory, Jaipur, India

An unusually translucent non-nacreous pearl. Approximately 95% of the work submitted to the Gem & Pearl Testing Laboratory of Bahrain is pearl related. Hence, it is no surprise that from time to time a particularly interesting pearl makes its way to our laboratory. Such was the case with the 13.88 ct unevenly colored brown to dark brown non-nacreous pearl in figure 13. This specimen measured 14.46–14.73 × 10.58 mm and exhibited moderate-to-significant surface-reaching cracks. It was obtained in India by a client who noticed the sample’s unusual translucency when viewed with a strong light source (figure 14), creating suspicion that the item might not be a pearl.

X-radiography revealed a distinct *radial* structure (figure 15), which in our experience is quite typical of some non-nacreous pearls, with a much less defined *concentric*

structure following the exterior button shape. In general, the absence of large amounts of organic material (i.e. conchiolin) within the structure of non-nacreous pearls is the reason for the poorly defined concentric structure in such X-radiographs. However, this is not always the case, and obvious concentric structures may be observed in some non-nacreous pearls. Likewise, the prominence of the radial crystalline structure in X-radiographs may vary from pearl to pearl.

Microscopic observation showed that the pearl’s radial columnar structure was manifested on its surface as a cellular pattern that was readily apparent with both transmitted and overhead fluorescent light (figure 16). The transmitted-light pattern varied slightly with orientation, but the form was consistent overall. Such patterns are typical of many non-nacreous pearls we have previously seen.

Figure 15. The X-radiograph of the non-nacreous pearl revealed a fine radial structure.



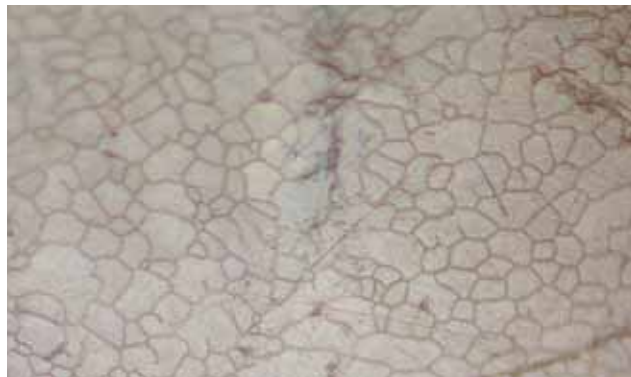
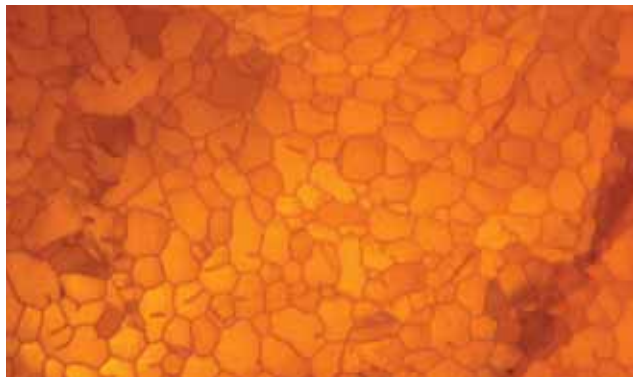


Figure 16. The surface of the non-nacreous pearl showed a distinctive cellular pattern when viewed with the microscope in both transmitted (left) and overhead fluorescent (right) light. Photomicrographs by N. Sturman; magnified 40 \times .

Exposure to long-wave UV radiation produced a moderate chalky “mustard”-yellow fluorescence, similar to what we have noted before, although fluorescence reactions in non-nacreous pearls are variable. The fluorescence, together with other visual observations, led us to believe that no artificial coloration was present, and a report was issued accordingly. Although we have seen pearls with a similar surface structure, we had never seen one as translucent as this sample.

Coincidentally, a group of similar looking non-nacreous pearls (~2–5 ct) were submitted to our laboratory shortly before this entry was finalized for publication. Their visual features were consistent with those reported above for the 13.88 ct pearl. We used our newly installed Renishaw inVia Raman spectrometer, equipped with a CCD-Peltier detector and argon-ion laser (514 nm), to analyze the spectra of the columnar structures where they intersected the surface. Raman peaks at 1087, 712, and 282 cm^{-1} matched the most prominent peaks of a calcite sample from our reference collection, and were also consistent with information in the literature on differentiating calcite from aragonite in pearls (e.g., see K. Scarratt and H. Hänni, “Pearls from the lion’s paw scallop,” *Journal of Gemmology*, Vol. 29, No. 4, 2004, pp. 193–203). We therefore concluded that these pearls, like the earlier one, were formed of calcite rather than aragonite, as would be expected for such columnar structured non-nacreous pearls.

Nick Sturman (nick@commerce.gov.bh)
and Ali Al-Attawi
Gem & Pearl Testing Laboratory
Manama, Kingdom of Bahrain

A possible diamond inclusion in quartz from Diamantina, Brazil. Quartz has more recorded inclusions than any other mineral, and rock crystal quartz with interesting inclusions is a popular collector’s stone. One long-held dream of this (and likely every) collector is finding an example of quartz containing a diamond inclusion. Although this possibility seems unlikely considering the geologic origins of diamond, a report published several decades ago mentioned three diamonds embedded in Brazilian quartz crystals—one from Bahia and two from

Minas Gerais—but did not report their dimensions or other details (W. D. Johnson and R. D. Butler, “Quartz crystal in Brazil,” *Bulletin of the Geological Society of America*, Vol. 57, No. 7, 1946, pp. 601–650). The current whereabouts of those crystals are unknown.

When considering a possible occurrence of diamond in quartz, a probable source is the area around Diamantina in northern Minas Gerais. Diamonds were first discovered there in 1725, and they are still mined today on a small scale. The diamonds are found in sedimentary rocks (conglomerates), as well as in younger reworked alluvial and eluvial deposits. This same area is also perhaps the world’s largest producer of collectible transparent quartz with inclusions, and many tons of polished and faceted quartz (mostly with muscovite, chlorite, and rutile inclusions) are produced from Diamantina crystals every year. This material comes from Alpine-type (hydrothermal) veins that are hosted by quartzite. The quartzite formed via regional metamorphism of sandstone (the same event also metamorphosed the conglomerates), and fractures in the

Figure 17. This quartz crystal (7 cm long) from Diamantina, Brazil, contains an inclusion that appears to be a diamond. Photo by J. Hyrsl.



quartzite were subsequently filled with veins of low-temperature hydrothermal quartz. In this environment, it seems possible (although not likely) that a diamond crystal derived from the conglomerates could have been weathered-out into alluvial sands that were later metamorphosed into quartzites and then protogenetically incorporated into the cross-cutting quartz veins.

While in Brazil in June 2006, this contributor encountered a well-formed quartz crystal from the Diamantina area that contained an inclusion strongly resembling diamond (figure 17). The sample measured 7 cm long, and several millimeters under the surface it contained a hexoctahedral crystal (~6 mm) with an associated layer of light green fine-grained micaceous material (probably chlorite or Cr-bearing muscovite). The included crystal was very pale yellow and showed an adamantine appearance (figure 18), as is typical of diamond. The large difference in refractive indices between the inclusion and its quartz host (as would be expected for a diamond inclusion) made the included crystal's surface appear mirror-like, although its transparency was evident with a strong focused light source. The surface of the crystal was covered by small trigons, a typical feature for natural diamond crystals.

The author had only about 30 minutes to study the sample, and did not have access to advanced analytical techniques such as Raman spectroscopy that would be needed to confirm the identity of the inclusion as diamond. Nevertheless, all of the observed properties support this extremely rare occurrence, and a very close examination of the sample did not reveal any features indicating that it was manufactured. Unfortunately, the astronomical price of this piece reserved it for wealthy collectors only.

Jaroslav Hyrsl

Figure 18. A closer view of the quartz inclusion (~6 mm in diameter) shows the hexoctahedral form and adamantine appearance that are typical of diamond. Photo by J. Hyrsl.

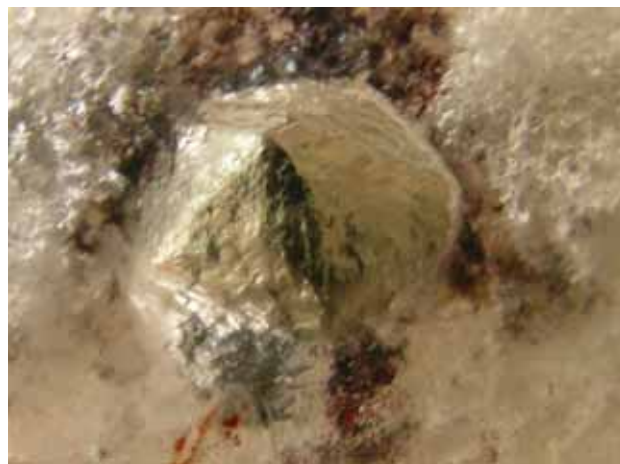


Figure 19. Depending on the viewing angle or the location of the light source, several subtle chatoyant bands can be seen in this 44.85 ct quartz cabochon from Brazil (shown in three different viewing positions). In the center, the cabochon is seen face-up with the light source perpendicular to the dome. The views on the left and right show the effects of moving the light source and tilting the stone, respectively. Photos by T. Hainschwang.

An unusual type of phenomenal quartz. This contributor recently examined five quartz cabochons (44.85–220.67 ct; e.g., figure 19) that displayed a weak cat's-eye or star effect when viewed in different orientations. According to the owner of the samples, the rough material was found in Brazil, but the precise location is not known.

With the light source directly overhead, each sample showed a subtle vertical ray that had—on closer examination—an additional, even weaker ray apparent at an angle of ~90° to the main chatoyant band (figure 19, center). When the samples were tilted or the light source was moved, four more rays became visible (figure 19, left and right). The samples could thus be called *2-ray* (face up) or *6-ray* star quartz, even though the appearance of these rays was quite unusual.

In all the cabochons, a dense aggregation of inclusions was present only at or near the base, while the top of the domes consisted of transparent colorless quartz. The inclusions were clearly responsible for the chatoyancy/asterism. Examination with magnification indicated that they were members of the chlorite group, and this was confirmed by specular reflectance infrared spectroscopy. The inclusions formed foliated worm-like aggregates, which is quite characteristic of the ripidolite variety of chlorite. For the most part, the chlorite-group mineral inclusions were pink to purple-red, with only small areas showing the more common green color (figure 20). Pink to red is mentioned in several references as a possible color of chlorite-group minerals, although it is much less common than green. Interestingly, the chatoyant bands were created by light reflecting only from the pink-to-red inclusions; the rays were interrupted wherever the green material was present. This was apparently due to the lower surface luster of the



Figure 20. The unusual phenomenal behavior shown by the quartz cabochons proved to be caused by light reflecting from foliated worm-like aggregates of a pink to purple-red chlorite-group mineral. The green chloritic inclusions were apparently not responsible for the chatoyant behavior because of their lower surface luster. Photomicrograph by T. Hainschwang; field of view 1.8 mm.

green inclusions (as seen in figure 20); this distinct difference in luster suggests that the pink and green inclusions are different minerals of the chlorite group, rather than the same mineral with different coloration.

Star quartz has been known for more than a century, and most colorless material originates from Sri Lanka, while star rose quartz is known from various localities (e.g., Madagascar). Both phenomena are generally caused by fine included needles, which have been identified as rutile (especially in rose quartz), sillimanite, and dumortierite (see K. Schmetzer and M. Glas, "Multi-star quartzes from Sri Lanka," *Journal of Gemmology*, Vol. 28, No. 6, 2003, pp. 321–332). Schmetzer and Glas (2003) discussed quartz that showed up to five different groups of needle-like inclusions, resulting in up to 18 intersecting light bands.

All known star patterns in gems are caused by crystallographically oriented epigenetic needle-like inclusions that are formed by exsolution processes. In the present samples, however, the chatoyancy/asterism is apparently due to chloritic inclusions that pre-dated (or mostly so) the growth of the quartz (i.e., they are protogenetic). It is most unusual that irregular chloritic inclusions that do not form crystallographically oriented aggregates could cause the phenomenal behavior. The weakness of the rays made it impossible to determine from which faces of the chloritic inclusions the chatoyant bands were reflected, and therefore the precise mechanism for this interesting behavior remains a mystery.

Thomas Hainschwang
 (thomas.hainschwang@gemlab.net)
 GEMLAB Gemmological Laboratory
 Ruggell, Liechtenstein

A new gemstone from Italy: "Violan quartz." *Violan* is a mineralogically obsolete term for violet-to-blue, Mn-bearing diopside and omphacite. The Praborna mine, near Saint-Marcel, Aosta Valley, northern Italy, is one of the only known localities for this type of clinopyroxene (A. Mottana et al., "Violan revisited: Mn-bearing omphacite and diopside," *Tschermaks Mineralogische und Petrographische Mitteilungen*, Vol. 26, No. 3, 1979, pp. 187–201), which occurs in euhedral crystals and massive lamellar-to-fibrous aggregates. "Violan" is also known from southern Baffin Island, Nunavut, Canada, where it is found as massive aggregates in calc-silicate lenses (C. D. K. Herd et al., "Violet-colored diopside from southern Baffin Island, Nunavut, Canada," *Canadian Mineralogist*, Vol. 38, 2000, pp. 1193–1199). The attraction of "violan" as a collectable mineral stems from its rarity and deep violet color, which may range into blue (presumably due to the presence of both Mn²⁺ and Mn³⁺; Mottana et al., 1979).

At the Verona Mineral Show in May 2007, an Italian geologist had two pear-shaped cabochons of colorless quartz with violet inclusions (12 and 20.5 ct; e.g., figure 21) that were sourced from a newly discovered quartz-rich vein in the Aosta Valley. A few tens of kilograms of gem-quality rough were available, and further production is expected as mining proceeds.

Standard gemological techniques and electron-microprobe analyses were used to characterize both cabochons. The gemological data identified the pieces as quartz:

Figure 21. This 12 ct quartz cabochon contains deep violet and bluish violet inclusions of "violan" (Mn-bearing diopside and omphacite). Photo by M. Macri.



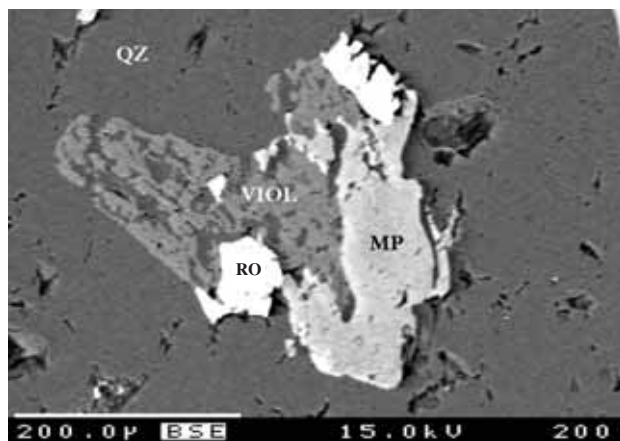


Figure 22. This backscattered electron image shows a polymineralic inclusion in the quartz cabochon that consists of “violan,” Mn oxide (romanèchite), and Mn-rich piemontite-Sr. Image collected by M. Serracino.

color—colorless; diaphaneity—transparent to milky; spot RI—1.54; and SG—2.67. The samples contained conspicuous deep violet and bluish violet mineral inclusions that were 0.1–1 mm in diameter. Rare opaque black and translucent red inclusions also were present.

The violet inclusions were identified as “violan” using a Cameca SX-50 electron microprobe (accelerating voltage of 15 kV and sample current of 15 nA) at IGAG-CNR (Istituto di Geologia Ambientale e Geoingegneria—Consiglio Nazionale Delle Ricerche), Rome, Italy. Other inclusions present in smaller amounts were black Mn oxide (romanèchite) and red Mn-rich piemontite-Sr, a mineral of the epidote group (figure 22). Chemical analyses of the various inclusions are reported in table 1.

TABLE 1. Electron-microprobe analyses of inclusions in a cabochon of violan quartz from Aosta Valley, northern Italy.^a

Oxide (wt.%)	“Violan”	Romanèchite	Piemontite-Sr
No. analyses	7	1	4
SiO ₂	55.10–57.00	0.11	32.80–34.29
TiO ₂	0.05–0.17	0.75	nd–0.05
Al ₂ O ₃	1.17–8.76	0.25	8.64–14.32
Cr ₂ O ₃	nd	nd	nd–0.05
MgO	7.61–12.43	0.01	nd–0.04
CaO	11.20–18.18	nd	11.47–14.91
MnO	4.92–6.20	72.54	22.22–28.71
FeO	2.72–4.94	nd	0.20–0.45
SrO	nd	nd	10.87–15.66
BaO	nd–0.06	17.68	nd–0.45
Na ₂ O	3.60–8.19	0.07	nd–0.03
K ₂ O	nd–0.04	nd	nd
Total	98.76–100.85	91.42	96.93–97.88

^a Abbreviation: nd=not detected.

To the best of our knowledge, this is the first occurrence of “violan” in quartz, and thus further enriches the gallery of known quartz inclusions (e.g., J. Hyršl and G. Niedermayr, *Magic World: Inclusions in Quartz*, Bode Verlag, Haltern, Germany, 2003). This material may be interesting for gem collectors and jewelers alike because of the attractive color of the inclusions.

Michele Macri (michele@minerali.it) and Adriana Maras DST, Università di Roma “La Sapienza” Rome, Italy

Fabrizio Troilo
Istituto Gemmologico Italiano
Milan, Italy

Marcello Serracino
IGAG-CNR, Rome

New sources of marble-hosted rubies in South Asia.

Beginning with the 2007 Tucson gem shows, information has become available on several new deposits of marble-hosted ruby in South Asia.

At the Tucson Gem & Mineral Society (TGMS) show, Dudley Blauwet (Mountain Minerals International, Louisville, Colorado) had a bright red ruby crystal embedded in white marble (figure 23) that reportedly came from the Khash district in Badakhshan, Afghanistan. He purchased the specimen in mid-December 2006 in Peshawar, Pakistan, from a Panjshiri dealer. Mr. Blauwet indicated that the marble matrix appeared much more granular than that typically seen hosting ruby from the well-known occurrence at Jegdalek, Afghanistan. He obtained several additional ruby specimens from the Khash district while in Peshawar in June 2007.

Figure 23. This marble-hosted ruby specimen reportedly was mined in Badakhshan, Afghanistan. The ruby is ~2 cm wide. Courtesy of Dudley Blauwet; photo by Robert Weldon.





Figure 24. The Basha Valley of northern Pakistan is the source of these rubies; the 1.09 ct stone was characterized for this report. Courtesy of Herb Obodda; photo by Robert Weldon.

In May 2007, Herb Obodda loaned GIA rough and cut specimens of ruby (figure 24) from a mining area near Bisil village in the Basha Valley of northern Pakistan. He obtained these samples during a buying trip to Peshawar, where he also saw 20 ruby specimens and ~50 carats of

Figure 25. The Basha Valley rubies are mined from marble layers in steep terrain. Photo by Dudley Blauwet.



Figure 26. The origin of this ruby (1.9 cm wide) is the Ahmadabad area in the Hunza Valley of northern Pakistan. Gift of Dudley Blauwet, GIA Collection no. 37127; photo by Robert Weldon.

faceted stones from this mining area. The faceted rubies had been cut in Karachi, and ranged from clean 0.10 ct stones to rather included 2 ct pieces. According to Mr. Blauwet, this material was first seen on the market in 2004 with dealers in Skardu, Pakistan, who indicated it was from the Shigar Valley (which lies just downstream of the Basha Valley). Mr. Blauwet visited the Bisil ruby deposit in June 2007, and saw two mining areas located in steep mountainous terrain at an elevation of ~2900–3050 m (e.g., figure 25). A series of small open cuts explored a steeply dipping marble layer that locally contained pale blue bands enriched with kyanite. Mr. Blauwet saw a rough ruby weighing ~2 g that he estimated could yield a 5 ct faceted stone, and he obtained 48 g of “mine run” ruby rough that he donated to GIA. Raman analysis of the associated minerals by GIA staff gemologist Eric Fritz identified calcite (white matrix material), rutile (small black grains), a bright green amphibole, and a mica.

The faceted Basha Valley ruby that Mr. Obodda loaned to GIA (1.09 ct; again, see figure 24) was characterized by GIA senior staff gemologist Cheryl Wentzell, and the following properties were obtained: color—purplish red; RI—1.762–1.770; birefringence—0.008; hydrostatic SG—4.00; fluorescence—moderate red to long-wave UV radiation, and very weak red to short-wave UV; and a typical ruby absorption spectrum seen with the desk-model spectroscope. Microscopic examination revealed closely spaced repeated lamellar twinning, fractures, “fingerprints,” translucent white inclusions on the surface (calcite identified by Raman analysis; probably part of the matrix), colorless mineral inclusions (magnesite), an elongate metallic inclusion (chalcocite), narrow flattened dark brown crys-



Figure 27. Drilling and blasting are used to prepare for an underground mining operation at the Ahmadabad ruby mine. Photo by Jim Clanin.

tals, rare short white needles, cotton-like linear clouds intersecting at 60°/120°, and long needles.

Mr. Blauwet also reported that one of the original ruby mining areas in the Hunza Valley, called Ahmadabad, had recently been reactivated. During his June 2007 trip to Pakistan, he obtained an attractive crystal specimen from this locality (figure 26). Drilling and blasting began in July 2007, shortly before the deposit was visited by Jim Clanin (JC Mining, Hebron, Maine). Mining is being done by Global Mining Corp. (part of the Shahzad International Group of Companies, Islamabad, Pakistan), using a gas-line-powered drill and dynamite. Mr. Clanin indicated that the company plans to explore a ruby-bearing marble layer that is 2.4 m thick and dips 35–60°. At the time of his visit, they were preparing a portal for an underground mining operation (figure 27). After obtaining some ruby production, the company plans to build a road to the area, which will allow them to expand their mining activities.

Brendan M. Laurs

Cr/V-bearing green spodumene from Afghanistan.

Spodumene ($\text{LiAlSi}_2\text{O}_6$) is a clinopyroxene; its name is derived from the Greek *spodumenos* (“burnt to ash”), in reference to the gray/ash-colored, non-gem material that has been mined commercially as a source of lithium ore (J. Sinkankas, *Mineralogy*, Van Nostrand Reinhold, New York, 1964, pp. 494–497). Common colors for gem-quality spodumene include pink-to-“lilac” (kunzite), pale greenish yellow (triphane), pale violet-blue, pale green, and colorless. In addition, a distinctive chromium-bearing “emerald”-green spodumene (hiddenite) is known principally from Hiddenite, North Carolina (e.g., M. A. Wise and A. J.

Anderson, “The emerald- and spodumene-bearing quartz veins of the Rist emerald mine, Hiddenite, North Carolina,” *Canadian Mineralogist*, Vol. 44, 2006, pp. 1529–1541).

In late 2006, Dudley Blauwet and Herb Obodda informed us about a new find of a distinctly green spodumene in Afghanistan. Mr. Blauwet first encountered this material in June 2006 while on a buying trip to Peshawar, Pakistan. At that time, local traders did not know the identity of the gem rough. It was typically available as small cleavage fragments, quite unlike the large well-formed crystals of spodumene that are coveted from Nuristan (e.g., L. Natkaniec-Nowak, “Spodumenes from Nuristan, Afghanistan,” *Australian Gemmologist*, Vol. 23, 2007, pp. 51–57). Farooq Hashmi, who visited Peshawar in June 2007, saw a 30 kg mixed-quality parcel of the green spodumene, and another 2 kg lot of higher-quality material; most was pale colored but some pieces were “emerald” green and appeared pink with the Chelsea filter. The main supplier of the spodumene told him that it came from “Waigal,” which is several hours’ walk from the village of Wadigram in the Nuristan area. It was reportedly found at a small digging in a single pegmatite in an area where other pegmatites are mined for blue tourmaline and kunzite.

Mr. Blauwet and Mr. Obodda loaned or donated to GIA several pieces of rough and a 1.45 ct faceted sample of the green spodumene (e.g., figures 28 and 29). Examination of the cut stone gave the following properties: color—light green, with no visible pleochroism; RI—1.662–1.678; birefringence 0.016; hydrostatic SG—3.25; fluorescence—inert to long- and short-wave UV radiation; Chelsea filter—weak positive reaction (grayish pink); and no absorption lines visible with the desk-model spectroscope. These properties



Figure 28. This Cr/V-bearing spodumene from Afghanistan (1.3 g total weight) ranges from green to light yellow-green, and a portion of the green area was separated to retain as a reference for fade-testing experiments. Sunlight exposure for three weeks did not cause discernable fading; note that the yellow-green portion on the bottom appears relatively pale colored due in part to the narrow thickness of the sample in that area. Gift of Herb and Monika Obodda, GIA Collection no. 36750; photo by Robert Weldon.

are consistent with those reported for spodumene by J. W. Anthony et al. (*Handbook of Mineralogy*, Vol. 2, Mineral Data Publishing, Tucson, AZ, 1995, p. 747), except that the SG is slightly higher than published values (3.03–3.23). Microscopic examination revealed multiple fractures and one long needle-like inclusion.

Some of the rough samples (e.g., figure 28) showed a noticeable gradation from green to yellow-green. Green in spodumene can also be produced by artificial irradiation; however, the induced color fades when exposed to sunlight for a few hours (G. R. Rossman, “Color in gems: The new technologies,” Summer 1981 *Gems & Gemology*, pp.

Figure 30. UV-Vis absorption spectroscopy of the larger sample in figure 28 (thickness of 2–5 mm) showed a transmission window at ~420–600 nm that is responsible for the green color. This window is more pronounced in the darkest green portion.

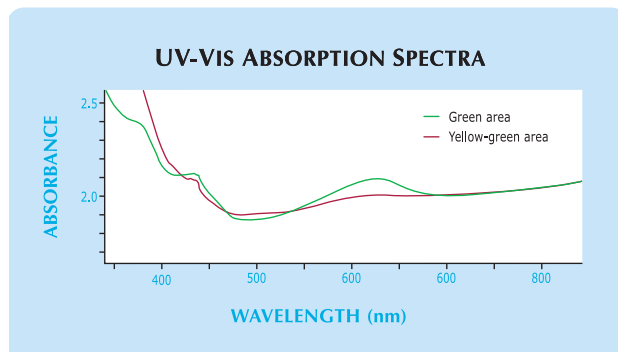


Figure 29. This 1.45 ct spodumene was cut from the Afghan material. Gift of Dudley Blauwet, GIA Collection no. 37118; photo by Robert Weldon.

60–71; K. Nassau, “Treatments used on spodumene: Kunzite and hiddenite,” *Colored Stone*, Vol. 1, No. 7, 1988, pp. 16–17). To test the color stability of this Afghan spodumene, the rough sample was divided into two pieces, the larger portion of which was left in the Southern California sun for three weeks. When compared to the control portion, it showed no indication of fading (again, see figure 28).

Further testing was conducted to determine the cause of color. EDXRF spectroscopy of the cut stone showed traces of the chromophoric elements Mn, Fe, Cr, and V. Electron-microprobe analyses of a rough sample donated to the University of New Orleans by Mr. Blauwet showed an average of 0.13 wt.% MnO and 0.02 wt.% FeO (all iron expressed as FeO; average of 6 analyses); Cr and V were below the detection limits of the instrument. (By comparison, Wise and Anderson [2006] reported up to 0.14 wt.% Cr₂O₃ and 0.08 wt.% V₂O₃ in spodumene from Hiddenite, North Carolina.) LA-ICP-MS analyses at GIA of another rough sample showed systematic variations in Cr and V, with the highest amounts measured in the green portions of the sample; there were no distinct differences in Fe and

TABLE 1. LA-ICP-MS analyses of three areas on a color-zoned spodumene from Afghanistan.^a

Element (ppm)	Green	Green	Yellow-green
Fe	6,920	6,770	7,130
Mn	1,450	1,420	1,530
Cr	282	256	143
V	72	63	59

^a Data collected using a Thermo X-Series ICP-MS equipped with a New Wave 213 nm laser-ablation sample introduction system. Laser parameters were 40 μm spot size, 7 Hz repetition rate, 60% power, and 30 second dwell time. NIST 610 and 612 glasses were used as standards for calibration, and Si was used as the internal standard.

Mn content according to color (table 1). The composition of the yellow-green portion was similar to data reported for a green-yellow spodumene from Afghanistan by Natkaniec-Nowak (2007).

The UV-Vis absorption spectrum of the sample in figure 29 showed that its coloration was caused by a transmission window at ~420–600 nm (figure 30), which is characteristic of Cr- ± V-bearing spodumene [E. W. Claffy, "Composition, tenebrescence and luminescence of spodumene minerals," *American Mineralogist*, Vol. 38, 1953, pp. 919–931]. The greener portion of the sample had greater absorbance in the 550–700 nm region, which in spodumene is attributed to Cr and/or V [R. G. Burns, *Mineralogical Applications of Crystal Field Theory*, 2nd ed., Cambridge University Press, Cambridge, UK, 1993, pp. 188–189].

There may be some debate as to whether the Afghan samples could be properly referred to as hiddenite. A survey of the literature showed that there is no consistent definition for this variety of spodumene. Although this term is typically used to refer to yellow-green to green Cr-bearing spodumene, it is unclear if the saturation of the green color is important to the definition. To our knowledge, Cr-bearing spodumene is now known from Brazil, India, Siberia, and Afghanistan, in addition to the original area near Hiddenite, North Carolina.

Karen M. Chadwick (karen.chadwick@gia.edu)
and Andy H. Shen
GIA Laboratory, Carlsbad

Brendan M. Laurs

William B. (Skip) Simmons and Alexander U. Falster
University of New Orleans, Louisiana

SYNTHETICS AND SIMULANTS

Large beryl triplets imitating Colombian emeralds. The Dubai Gemstone Laboratory recently received five large (~13.6–16.3 ct) transparent green emerald cuts for identification (figure 31). The client who submitted these samples prior to purchase had been informed that they were good-quality emeralds from Colombia.

The following gemological properties were obtained: RI— $n_o=1.588$ – 1.596 and $n_e=1.570$ – 1.578 ; hydrostatic SG—2.69–2.71; fluorescence—inert to both long- and short-wave UV radiation; Chelsea filter—green reaction; and a smudgy band in the red region of the spectrum seen with a desk-model spectroscope. These properties were consistent with emerald except for the absence of chromium lines in the absorption spectra, which prompted a more detailed investigation of the cause of color.

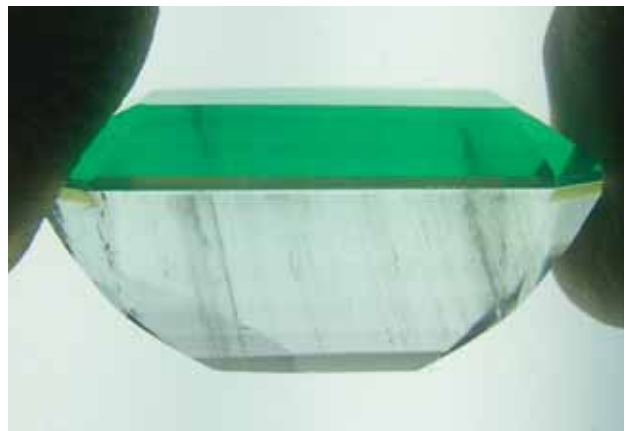
Observation of the samples in profile view with diffused transmitted light showed green-appearing crowns and colorless pavilions (figure 32), which established that they were assemblages. Microscopic examination of both halves revealed the two-phase (liquid and gas) inclusions, "fingerprints," and parallel growth tubes that are typical of beryl, as well as small flattened, rounded, and irregularly shaped gas



Figure 31. These large faceted samples (~13.6–16.3 ct), originally represented as Colombian emeralds, proved to be beryl triplets composed of two pieces of near-colorless beryl held together by green cement. Photo by S. Singbamroong, © Dubai Gemstone Laboratory.

bubbles along the separation plane in each of the assemblages. Examination with immersion in a direction parallel to the girdle plane proved that the samples were triplets composed of two pieces of near-colorless beryl (crown and pavilion) held together by green cement (figure 33).

Figure 32. Seen in profile view, with diffused transmitted light, the assembled nature of this triplet is evident. Note also the parallel growth tubes and fingerprints in both top and bottom pieces of the construct, which are typical for natural beryl. Photo by S. Singbamroong, © Dubai Gemstone Laboratory.



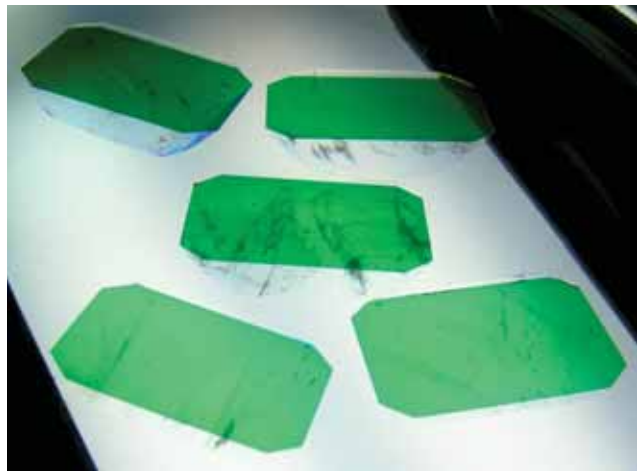
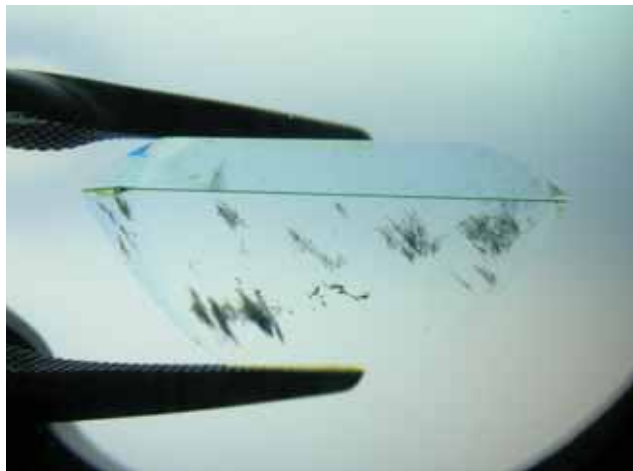


Figure 33. Immersion in benzyl benzoate with diffused transmitted light readily revealed the layer of green cement in the beryl triplets. Photos by S. Singbamroong, © Dubai Gemstone Laboratory.

FTIR spectroscopy performed on all samples (through the crown and pavilion) revealed features that were very similar to those of some synthetic resins used in the fracture filling of emerald.

The properties of these samples are consistent with those reported for beryl assemblages that have been produced by the firm Kämmerling of Idar-Oberstein, Germany, since 1966 and marketed under the trade name “Smayrll” (see R. Webster, *Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, UK, 1994, p. 462). Beryl doublets and triplets have been used to imitate emerald since the early 20th century; though less common today, they continue to show up in the marketplace.

Sutas Singbamroong (ssutas@dm.gov.ae)
and Moza Rashed Al Falasi
Dubai Gemstone Laboratory
Dubai, United Arab Emirates

Glass imitation of blue spinel. During a buying trip to Peshawar, Pakistan, in late 2004, Farooq Hashmi was offered a blue pebble with a waterworn appearance that was represented as spinel (figure 34). The piece reportedly came from an undisclosed river in northeastern Afghanistan. Mr. Hashmi obtained the piece, but its bright blue color and “alluvial” nature—both of which would be highly unusual for spinel from Afghanistan—caused him to doubt its authenticity.

Examination of the 5.5 g pebble showed the following properties: color—blue, with no pleochroism; spot RI—1.53; hydrostatic SG—2.48; Chelsea filter reaction—none; fluorescence—inert to long-wave, and weak yellow to short-wave, UV radiation; and a typical cobalt spectrum (absorption bands near 530, 590, and 650 nm) seen with the desk-model spectroscope. Microscopic examination revealed numerous gas bubbles, flow lines, white “breadcrumb” inclusions, and white crystalline masses. These properties are consistent with those reported for cobalt-bearing glass by G. Bosshart (“Cobalt glass as a lapis imitation” Winter 1983 *Gems & Gemology*, pp. 228–231). With

only a cursory examination, the devitrified crystalline masses in the glass (figure 35) could be mistaken for natural inclusions.

To help supplement GIA’s database of information on gem imitations, EDXRF analysis was performed. In addition to the expected major amount of Si, there were minor amounts of Fe and Ca, as well as traces of Al, K, Ti, Co, Zn, and As. These elements are comparable to those documented by Bosshart (1983). Even after more than two decades, Co-bearing glass imitations are still appearing in the gem market.

Eric A. Fritz

Figure 34. This 5.5 g pebble was represented as blue spinel from a new deposit in Afghanistan, but proved to be Co-bearing glass. Gift of Intimate Gems, GIA Collection no. 37273; photo by Robert Weldon.





Figure 35. The blue glass pebble contained devitrified crystalline masses, which could incorrectly suggest a natural origin. Photomicrograph by E. A. Fritz; field of view 1.6 mm.

TREATMENTS

Dyed greenish blue chalcedony from Brazil. At the 2007 Tucson gem shows, Ketan Dholakia (J.D.S. Inc., Royal Palm Beach, Florida) showed one of us (BML) some bright greenish blue dyed chalcedony. Originally bluish gray, the chalcedony was reportedly treated in Europe by a new method that provides good color stability. Mr. Dohlakia indicated that unlike other dyed-blue chalcedony that may be susceptible to fading, this new material is stable to exposure to sunlight (tested for several months) as well as to alcohol and acids. Large pieces (>20 kg) of the bluish gray chalcedony are mined from an area in Brazil that is near the border between the Paraíba and Rio Grande do Norte states. Only small pieces of rough (from the translu-

Figure 36. This dyed chalcedony (0.82 and 0.71 ct) was reportedly treated by a new process in Europe, using bluish gray material from Brazil. Gift of Ketan Dholakia, GIA Collection no. 36749; photo by Robert Weldon.



cent-to-transparent areas of the boulders) are treated, to ensure that the dye penetrates the entire stone. The material is marketed as "Paraíba chalcedony" because of its bright blue color and its source region in Brazil.

The first batches of this treated chalcedony were released in January 2007. In March, Mr. Dohlakia reported that he had begun machine cutting smaller pieces, yielding round brilliants and princess cuts ranging from 2 to 4 mm (stones <2.5 mm show good transparency). So far, he has sold 10,000 carats of machine-cut stones, as well as 40,000 carats that range from 6 × 4 to 12 × 10 mm.

Gemological properties were obtained on two faceted samples of the treated chalcedony that Mr. Dohlakia donated to GIA (figure 36): color—greenish blue; diaphaneity—translucent; RI—1.540 with little to no birefringence and 1.541–1.546 (birefringence 0.005); hydrostatic SG—2.57 and 2.59; fluorescence—inert to long- and short-wave UV radiation; Chelsea filter—yellowish reaction; and two absorption bands and a cutoff (at 660 or 690 nm, depending on the intensity of the light) were all seen in the red region of the spectrum with a desk-model spectroscope. Microscopic examination revealed homogeneous interiors with no inclusions, although one of the stones did exhibit very subtle banding. The properties of these stones are comparable to those listed for chalcedony in general by M. O'Donoghue (*Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 306–307), except that the range for the ordinary ray in that publication is lower (1.530–1.539). EDXRF analysis of both samples performed by staff gemologist Karen Chadwick detected significant amounts of Co, in addition to traces of Cu (which is the cause of color in natural chrysocolla chalcedony). UV-Vis spectroscopy did not show any features related to Cu, but it did reveal absorptions related to Co at 624, 660, and 690 nm. The presence of cobalt is consistent with a dye origin for the greenish blue color of this material.

Kimberly M. Rockwell (kim.rockwell@gia.edu)
GIA Laboratory, Carlsbad

Brendan M. Laurs

CONFERENCE REPORTS

First European Gemmological Symposium: "Presence and Future of Gemmology." Approximately 200 attendees and guests celebrated the 75th anniversary of the German Gemmological Association at a gemmological symposium in Idar-Oberstein, Germany, June 22–24, 2007. Extended abstracts of the presentations have been published in a special issue of *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft* (Vol. 56, No. 1/2, 2007); descriptions of selected technical presentations are presented here.

Dr. Volker Lorenz (University of Würzburg, Germany) discussed the geology and future potential of the Argyle diamond mine in northern Australia. He cited evidence for the formation of diamondiferous lamproite pipes at Argyle

and elsewhere in northern Australia during phreatomagmatic volcanic eruptions (i.e., involving the contact between magma and groundwater). **One of the present contributors** (JES) described recent color coatings on diamonds, as well as the coating of other gem materials (including cultured pearls) with colorless “diamond-like carbon” thin films, which have so far proved difficult to detect with instrumentation typically found in gem-testing laboratories. Although marketed to allegedly improve the appearance and durability of these gem materials, such claims about these ultra-thin colorless coatings need to be substantiated by further studies.

Christopher P. Smith (American Gemological Laboratories, New York) described the properties of blue sapphires that were initially reported to have been diffusion treated with beryllium—but were found to have been surface treated with cobalt. A very thin layer (~250 nm) of cobalt aluminate ($\text{Co}_2\text{Al}_2\text{O}_5$) produced a blue surface coloration that appeared mottled when viewed with magnification and showed three distinctive broad absorption bands, at ~550, 585, and 625 nm. **Dr. Henry Hänni** (SSEF Swiss Gemmological Institute, Basel) reviewed modern pearl testing techniques, which employ X-ray imaging and luminescence, EDXRF, UV-Vis-NIR, and Raman spectroscopy, scanning electron microscopy, and LA-ICP-MS. **Another of these contributors** (JIK) discussed how inclusions can provide unique information on a gem’s identity and origin, and described some of the challenges encountered when the gemologist must rely on nondestructive analytical methods for their identification.

Dr. Dietmar Schwarz (Gübelin Gem Lab, Lucerne, Switzerland) described the geologic settings and conditions of formation at a number of marble-hosted ruby deposits located between Afghanistan and Myanmar. These deposits are related to major geologic structures associated with the collision of the Indian and Eurasian continental plates. The rubies apparently formed by metamorphism of sediments containing evaporates; F and Cl in these layers acted to concentrate Al from the marbles for corundum formation. **Dr. Pornsawat Wathanakul** (Gem and Jewelry Institute of Thailand, Bangkok) reported on gem corundum from the Nam Khun–Nam Yuen area in Ubon Ratchathani Province, Thailand. Blue-green-yellow varieties of sapphire are recovered from alluvial sediments; violet-red rubies are much less common. The sapphires contain few inclusions, but typically display color zoning; heat treatment produces greenish yellow to yellow colors. **Dr. Hanco Zwaan** (Netherlands Gemmological Laboratory, Leiden) reviewed the theories of emerald origin in several geologic environments. He went on to describe the formation of emeralds at Sandawana, Zimbabwe, as the result of metamorphism along the contact of ultramafic rocks and pegmatites during a major deformation event that involved magmatic-hydrothermal activity and shearing. New gemological data on both emerald and alexandrite from the Malysheva mine near Ekaterinburg in the Ural Mountains, Russia, were sum-

marized by **Dr. Lore Kiefert** (AGTA Gemological Testing Center, New York). **Dr. Margherita Superchi** (CISGEM, Milan, Italy) reported on the composition and Raman spectra of multicolored tourmalines from the Sahatany and Betafo areas in central Madagascar; the tourmalines were found to be predominantly liddicoatite. **Dr. Herbert Roeser** (University of Ouro Preto, Brazil) described recent work on the heat treatment of Brazilian beryls. A change or homogenization of beryl color was achieved by heating samples for 1–2 hours at temperatures of 350–900°C. The color changes were green to blue, yellow to blue or colorless, and pink to colorless. Beryl is not suitable for a color diffusion treatment that requires exposure to higher temperatures for longer periods of time, but it can be colored by a surface coating.

*James E. Shigley (jshigley@gia.edu)
GIA Research, Carlsbad*

*John I. Koivula
GIA Laboratory, Carlsbad*

30th International Gemmological Conference. Over 100 delegates, observers, and guests participated in the 30th IGC, July 15–19, 2007, at the Russian Academy of Sciences in Moscow. Highlights of some of the approximately 90 oral and poster presentations made during the conference are summarized here.

Dr. Nikolai Bezmen (Institute of Experimental Mineralogy, Chernogolovka, Russia), reported that slight improvements in the color grades of near-colorless gem diamonds could be obtained by apparently altering the state of their nitrogen impurities (using “hydrogen high diffusive mobility”) and thereby reducing the yellow coloration. Progress in the long-standing effort to distinguish between natural and laboratory irradiation when assessing the color of green diamonds was reported by **George Bosshart** (Horgen-Zürich, Switzerland). A shallow green surface coloration on diamond crystals may be caused by natural exposure to alpha particles emitted by several radionuclides (^{238}U , ^{232}Th , ^{222}Rn , and ^{220}Rn), while the much rarer green bodycolor is the result of natural gamma and possibly beta irradiation. **A. V. Buzmakov** (Institute of Crystallography, Moscow) described a three-dimensional X-ray tomography system that could be used to investigate the inclusions in opaque, fibrous diamond crystals. **John Chapman** (Rio Tinto Diamonds, Perth, Australia) reviewed the means of distinguishing natural, treated, and synthetic pink diamonds. He emphasized the particular difficulty presented by pink surface-colored diamonds, especially in small sizes. **Dr. Maya Kopylova** (University of British Columbia, Vancouver, Canada) discussed the properties (crystal shape, mineral inclusions, and infrared spectra) and inferred geologic conditions of formation (i.e., at depths of 160–200 km about 1.8 billion years ago from a source that contained a substantial contribution of carbon of crustal origin) of the eclogitic diamonds from the Jericho kimberlite in the Northwest Territories. **Dr. A. A. Marakushev** (Institute of

Experimental Mineralogy) described the conditions of formation that result in very large diamond crystals, and suggested that periods of recrystallization could contribute to their growth.

Dr. Ichiro Sunagawa (Tachikawa, Japan) discussed differences in diamond growth in natural and laboratory environments as evidenced by crystal morphology and surface features. Characteristics indicative of this difference in growth environment include crystal shape, internal growth sector structure, and perfection of crystal faces and edges. In contrast to synthetic diamonds, natural diamonds undergo deformation and dissolution processes during their long residence time in the mantle and subsequent eruption to the earth's surface. The identification of small yellow synthetic diamonds found mixed with natural-color diamonds in commercial pieces of jewelry in Japan was discussed by **Hiroshi Kitawaki** (Gemmological Association of All Japan, Tokyo). **Dr. Victor Vins** (New Diamonds of Siberia Ltd., Novosibirsk) reviewed the methods used in irradiation or HPHT annealing to change the color of diamonds. In a study of HPHT-treated brownish or greenish yellow and yellowish green diamonds produced by the Iljin Co. in Korea, **Boontawee Sriprasert** (Department of Mineral Resources, Bangkok) reported on photoluminescence features by which they can be identified (e.g., peaks at 637, 578 and 575 nm, with the 637/575 ratio being greater than 1).

In two presentations, **Dr. Carlo Aurisicchio** (Istituto de Geoscienze e Georisorse, Rome) described how a combination of chemical composition data obtained by the electron microprobe and secondary ion mass spectrometry techniques, along with gemological properties, could be used to determine the geographic origin of emeralds found in ancient pieces of jewelry. **Dr. Olga Balitskaya** (Russian State Geological Prospecting University, Moscow) presented a genetic gemological classification of natural, treated, and synthetic quartz. **Dr. Vladimir Balitsky** (Institute of Experimental Mineralogy) summarized the current production of treated gems (by irradiation, heating, diffusion, coatings, dyeing, and impregnation) and more than 30 synthetic gem materials from Russia. **T. V. Bgasheva** (Mendeleev University of Chemical Technology, Moscow) described heating experiments—1100–1400°C, using mainly reducing atmospheres—conducted to reduce the orange component in Cr-Fe orange-red sapphires. **Dr. Aleksandr Bulatov** (Institute of Biochemical Physics, Moscow) reviewed the production and technological uses in Russia of silicon carbide (synthetic moissanite). **Nantharat Bunnag** (Chiang Mai University, Thailand) reported that the dark core in some rubies from Mong Hsu, Myanmar, has a chemical composition corresponding to eskolaite (Cr_2O_3), which forms a solid solution with corundum. **Dr. Henry Hänni** (SSEF Swiss Gemmological Institute, Basel) reviewed the current heating and filling treatments of ruby and sapphire, and the gemological means available to recognize them.



Figure 37. In a process referred to as chromophore cannibalization, the color of this blue sapphire is bleached directly adjacent to the parallel needle-like inclusions, indicating that the inclusions possessed a higher affinity for the chromophoric elements (Fe and Ti) than their sapphire host. This provides proof that the host sapphire is of natural color and that no heat treatment has taken place. Photomicrograph by J. I. Koivula; field of view 1.1 mm.

Dr. P. V. Ivannikov (Lomonosov Moscow State University) reviewed the limitations and advantages of color cathodoluminescence in gem identification. It is especially helpful when used in conjunction with a scanning electron microscope to identify the causes of this luminescence. **One of these contributors** (JIK) discussed evidence for both chromophore diffusion and infusion (“cannibalization”), where inclusions interact with their host gemstone to redistribute color-causing trace elements (figure 37). Efforts to improve the production of synthetic opal with natural-looking play-of-color patches were reviewed by **Dr. V. M. Masalov** (Macreol Ltd., Chernogolovka). **Dr. V. N. Matrossov** (Belarussian State Technical University, Minsk) described the growth, properties, and uses of synthetic alexandrite. **Dr. Visut Pisutha-Armond** (Gem and Jewelry Institute of Thailand, Bangkok) described an unusual sapphire+hercynite+nepheline+zircon mineral assemblage from Kanchanaburi, Thailand. **One of these contributors** (REK) provided a preliminary report on the sapphires from Tasmania, Australia. Once the Scotia mine is fully operational, the Australian–U.S. joint venture expects to produce 250 kg of corundum per month. **Y. B. Shapovalov** (Institute of Experimental Mineralogy) reported on continuing experiments to synthesize gem-quality tourmaline in the laboratory by producing thin layers (less than 0.5 mm) of dark-colored material on natural elbaite seed crystals.

In separate presentations, **Dr. Pornsawat Wathanakul** (Gem and Jewelry Institute of Thailand) and **one of these contributors** (SFM) discussed evidence for the natural occurrence of trace amounts of beryllium associated with clouds

of tiny inclusions in blue sapphires from Madagascar and Sri Lanka (up to 18 ppm and 13 ppm, respectively). **Dr. Michael Krzemnicki** (SSEF Swiss Gemmological Institute) reviewed the use of both the LIBS and LA-ICP-MS techniques for the chemical distinction of various colored stones and pearls. **Dr. Boris Shmakin** (Institute of Geochemistry, Russian Academy of Sciences, Irkutsk, Russia) described occurrences of amazonite feldspar in eastern Siberia at Slyudyanka, Priolkhonye, and Etyka. **Elisabeth Strack** (Gemmologisches Institut, Hamburg, Germany) described emeralds in jewelry objects of Mogul origin (mid-1700s) in the State Hermitage Museum in St. Petersburg, and presented evidence that suggests these emeralds were from Colombia. **Dr. Lin Sutherland** (Australian Museum, Sydney) indicated that gem corundum from the Mercaderes–Rio Mayo area in Colombia formed by crystallization of hydrous metasomatic fluids associated with Late Cenozoic Andean volcanism. **Dr. Chakkaphant Sutthirat** (Gem and Jewelry Institute of Thailand) discussed what appear to be two different geologic origins for rubies and sapphires from deposits in Thailand. In both instances, the corundum appears to have formed in particular layers within the upper mantle or crust prior to being transported to the surface by basaltic volcanism. **Theerapongs Thanasuthipitak** (Chiang Mai University) described the mineral composition of inclusions in blue sapphires from the Bo Ploi region of Kanchanaburi. These inclusions consist of several types of spinels along with pyrochlore, ilmenorutile, baddeleyite, and possibly other minerals.

E. A. Akhmetshin (Mendeleev University of Chemical Technology, Moscow) reported on the chemical treatment of cultured pearls using cationic dyes that interact with their organic components to produce a range of colors with a uniform appearance.

The 31st IGC conference is planned for 2009 in Tanzania.

James E. Shigley, John I. Koivula, and Shane F. McClure

*Robert E. Kane
Fine Gems International
Helena, Montana*

“Diamonds in Kimberley” symposium. Approximately 350 people attended this symposium in Kimberley, South Africa, hosted by the Geological Society of South Africa on August 23–25, 2007. A main topic of discussion was alluvial diamond deposits of the Vaal and Orange rivers, which are mined by relatively small companies.

The formal presentations were opened by **Jerry Mndaweni**, of the Department of Minerals & Energy, Northern Cape Province, which is where Kimberley and many other pipe and alluvial deposits are located. He stressed the willingness of the government to facilitate the development of mines within the framework of the “new order” (i.e., mining licenses applied for after May 2004, when the new mining law came into effect, require projects to have a Black Economic Empowerment partner

with at least 26% equity that is not free carried). **André Fourie** (De Beers Consolidated Mines, Kimberley) discussed recent changes at some De Beers properties, including the closure of their three Kimberley mines in the past few years, the sale of the Koffiefontein mine to Petra Diamonds, and the sale of a 26% equity in De Beers Consolidated Mines to Ponohalo Holdings (a Black Economic Empowerment group). He also described two new ventures: reopening of the Voorspoed mine (Free State Province) and launching of the new vessel *Peace in Africa*, which will mine ocean floor deposits off the coast of Namaqualand. **Gavin Armstrong** (Gondwanaland Diamonds, Kimberley), **Petrus Wolmarans** (Impulelo Technologies, Honeydew, South Africa), and **Ian Downie** (i to i Technologies, Stellenbosch, South Africa) discussed recent improvements in diamond recovery plants, including re-treating old tailings dumps. Processing tailings and developing or reopening alluvial deposits have much faster lead-in times (1–2 years) compared to developing primary pipe deposits (8–10 years).

Among the many excellent presentations on the second day, **Norman Lock** (Mineral Exploration and Evaluation Specialists [MSA], Parkhurst, South Africa) discussed differences in evaluating two pipe deposits: the Jwaneng pipe in Botswana, which required drilling through a 45 m overburden of Kalahari sands, and the Argyle pipe, which was exposed on the surface and could be evaluated by many shallow drill holes and the use of microdiamond (0.1–0.8 mm) to macrodiamond ratio diagrams. **Dr. Herman Grutter** (BHP Billiton, Vancouver, Canada) discussed new techniques for evaluating kimberlites in Canada using the thermobarometry of garnet and clinopyroxene; the latter is now considered a significant diamond indicator mineral, along with garnet, ilmenite, and chromite.

Dr. John Bristow (Rockwell Diamond Inc., Houghton, South Africa) gave a detailed review of alluvial deposits of the lower Vaal and middle Orange rivers, where many 100+ ct diamonds have been recovered from terraces and paleochannels up to 120 m above the present water level of the Vaal River. Mining is still taking place in areas where underlying gravels are buried under a hard calcrete cap that could not be penetrated by early diggers. Dr. Bristow concluded that compared to pipes, alluvial deposits present greater uncertainties with respect to continuity, grade, price consistency, and resource evaluation.

The symposium was preceded by a one-day field trip to the Letšeng diamond mine in Lesotho. The Letšeng mine is the world’s highest altitude (3,100 m) and lowest-grade (1.5–2 cph) diamond deposit, with the highest quality and largest average diamond size (>\$1,200/ct). It has produced 18 diamonds >100 ct since the mine was resurrected in 2003. Stones of this size make up 2% of production; 10.8+ ct stones account for 14% by weight and 74% by value. The first large high-quality diamonds (95, 125, and 215 ct; the last sold for \$38,000/ct) were recovered in 2003–2004 from nearby alluvial deposits in the Qaqa River, which

drains the Letšeng Main pipe and Satellite pipe (15.9 and 5.2 ha in size, respectively). Recent production is derived from rubble and surface layers of kimberlite in the pipes. The quality of the diamonds is exceptional, cutting mainly D-Flawless or D-VVS₁ stones. A recently recovered 603 ct type IIa D-color diamond, named the "Lesotho Promise," is the 15th largest rough diamond ever found and sold for \$20,500/ct. Such high diamond values are unusual for kimberlite mines: In general, such pipe diamonds have values of \$50–200/ct, whereas those from the Vaal and Orange River alluvial deposits are \$400–1200/ct.

The symposium concluded with a choice of field trips to the MSA indicator mineral laboratory or to nearby historical diggings, many of which are still operating.

A. J. A. (Bram) Janse

Diamond 2007. The 18th European Conference on Diamond, Diamond-Like Materials, Carbon Nanotubes, and Nitrides was held September 9–14 in Berlin. Topics of particular interest to the gemological community included the effects of irradiation and high-pressure, high-temperature (HPHT) treatments, silicon- and nickel-related optical defects, and pink diamond identification.

Bozidar Butorac and coauthors from King's College, London, presented results from the theoretical modeling of defect migration in diamond. The data indicate that defects like N-V and N-V-H are energetically very difficult to break apart, but they readily combine to form more complex structures at high temperatures. These results explain many lattice changes produced by HPHT treatment of gem diamonds. **Dr. Igor N. Kupriyanov** and coauthors from the Institute of Geology and Mineralogy, Novosibirsk, Russia, presented results from HPHT treatment experiments on mixed type Ib-IaAB and type IIb HPHT-grown synthetic diamonds. Their results indicate that HPHT annealing at temperatures lower than those typically used for treatment (~1800–2100°C) resulted in an increase in the concentration of isolated nitrogen and platelet defects. HPHT treatment to 2300°C did not affect single substitutional boron defects in the type IIb samples.

J. G. Seo from Hanyang University, Seoul, South Korea, and coauthors presented FTIR absorption and photoluminescence spectra of natural diamonds that were subjected to electron-beam radiation of varying intensity. Their results indicated that lattice defects associated with isolated nitrogen increased more than those located near aggregated nitrogen atoms due to differences in lattice bond energies. **Rolando Larico** and coauthors from the University of São Paulo, Brazil, introduced models of several possible configurations for nickel-nitrogen defects in diamond.

Dr. James Rabeau from Macquarie University, New South Wales, Australia, discussed single color centers (N-V, Si-V, and Ni) in CVD synthetic diamond and the nature of their occurrence. **This contributor** and coauthors discussed several natural colorless type IIa and type I gem diamonds that contained the Si-V defect center (737 nm), a feature pre-

viously reported only from CVD-grown synthetic diamond.

Dr. M. D. Sastry from the Gemmological Institute of India, Mumbai, and coauthors described photoluminescence features in heavily irradiated and annealed pink diamonds. **Branko Deljanin** and coauthors from the European Gemological Laboratory, Vancouver, Canada, summarized methods (including fluorescence, spectroscopy, and electrical conductivity) for separating natural, synthetic, irradiated and HPHT-treated, and surface-coated gem-quality pink diamonds. He discussed the Cross-referencing Identification System ("CIS") fluorescent method, involving micro-imaging of long- and short-wave UV fluorescence, as an effective tool for screening pink diamonds, particularly melee and those stones set in jewelry.

Christopher M. Breeding

ANNOUNCEMENTS

Visit *Gems & Gemology* in Tucson. Meet the editors and take advantage of special offers on subscriptions and back issues at the *G&G* booth in the publicly accessible Galleria section (middle floor) of the Tucson Convention Center during the AGTA show, February 6–11, 2007. GIA Education's traveling Extension classes will offer hands-on training in Tucson with "Colored Stone Grading" (February 5–7), "Pearls" (February 8), and "Identifying Diamond Treatments" and "Identifying Ruby" (February 9). Several free seminars will also be offered by GIA staff February 10–11. To enroll, call 800-421-7250, ext. 4001. Outside the U.S. and Canada, call 760-603-4001. The GIA Alumni Association will host an auction, dance, and cocktail party (with heavy hors d'oeuvres) at the Marriott University Park Hotel in Tucson on February 8, starting at 6:30 p.m. To purchase tickets, call 760-603-4204 or e-mail events@gia.edu.

MJSA Vision Awards competition. The 2008 Manufacturing Jewelers & Suppliers of America Vision Awards Design Competition recognizes designers whose work has a profound influence on the future of jewelry design. The entry deadline is December 30, and winners will be honored on April 13, 2008, at the MJSA Expo New York show. For entry forms and more information, call 800-444-6572 or visit www.mjasa.org.

Conferences

Mineral Exploration Roundup 2008. This international conference will take place in Vancouver, British Columbia, January 28–31. The program will include a short course titled "Kimberlites: Geological Principles Relevant to Evaluation, Resource Classification and Mining." Visit www.amebc.ca/roundupoverview.htm.

NAJA Annual Conference. The National Association of Jewelry Appraisers is holding its 29th annual *Winter Educational Conference* February 4–5, 2008, during the Tucson gem shows. Visit www.najaappraisers.com.

Hasselt Diamond Workshop. Held February 25–27, 2008 at Hasselt University, Diepenbeek–Hasselt, Belgium, this conference will cover a variety of diamond-related research subjects. Visit www.imo.uhasselt.be/SBDD2008.

PDAC 2008. The Prospectors and Developers Association of Canada convention will take place March 2–5 in Toronto. The technical session will include an update on the Canadian diamond industry (including progress at Snap Lake and Victor) and a review of current diamond prospecting in India. Visit www.pdac.ca/pdac/conv.

Pittcon 2008. The 59th Annual Pittsburgh Conference and Exposition on Analytical Chemistry and Applied Spectroscopy will be held in New Orleans, Louisiana, March 2–6. Among the topics covered will be chemical analysis of art objects. Visit www.pittcon.org/technical/index.html.

Bead Expo. The 2008 International Bead Expo will be held in Portland, Oregon, March 27–30. Over 60 workshops and educational lectures on bead jewelry design and manufacture are scheduled. Visit www.beadexpo.com.

BASELWORLD 2008. The BASELWORLD show will be held April 3–10 in Basel, Switzerland. During the show, *Gems & Gemology* editor-in-chief Alice Keller will be available at the GIA Booth in Hall 2, Stand W23. Visit www.baselshow.com, call 800-922-7359, or e-mail visitor@baselworld.com.

Sinkankas Garnet Symposium. Garnet will be featured in the sixth annual John Sinkankas Memorial Symposium, held April 19, 2008, at GIA in Carlsbad. A variety of experts will speak on garnet localities, inclusions, treatments, appraising, lapidary work, and literature at this all-day educational event. E-mail merksjade@cox.net.

Quebec 2008: GAC-MAC-SEG-SGA. Held May 26–28 in Quebec City, Canada, this joint conference organized by the Geological Association of Canada, Mineralogical Association of Canada, Society of Economic Geologists, and the Society for Geology Applied to Mineral Deposits will include special sessions on “Diamonds: from Mantle to Jewellery” and “Challenges to a Genetic Model for Pegmatites,” as well as a short course called “Rough Diamond Handling.” Visit www.quebec2008.net.

Exhibits

Gemstone Treasures from Namibia. The diversity and majesty of Namibia’s gems are presented in a special exhibit at the Deutsches Edelsteinmuseum in Idar-Oberstein until December 2, 2007. Visit www.edelsteinmuseum.de/edelsteine_Namibia.htm.

Wine and gems in Dijon. “Colour Sparkles: Legendary Wines and Gemstones,” a unique exhibition of fine gems and fine wines, is being held in the Sciences Garden at the Parc de l’Arquebuse, Dijon, France, through December 9, 2007. Items from the French National Museum of Natural History are on display with wines from the great vintners of Burgundy and beyond. The exhibit includes both wine tasting and hands-on experiments in light and color. Visit www.dijon.fr/fiche/eclats-de-couleurspierres-et-vins-de-legende.evt.5604.php.

Jewelry of Ben Nighthorse. Ben Nighthorse Campbell, who represented Colorado in the U.S. Senate from 1992 through 2004, has enjoyed a successful second career as an innovative jewelry designer. This collection of his work, which debuted at the Smithsonian Institution’s National Museum of the American Indian in 2004, is on display at the Colorado History Museum in Denver through December 31, 2007. Visit www.coloradohistory.org.

Exhibits at the GIA Museum. On display through March 2008, “Reflections in Stone” showcases famed gem carver Bernd Munsteiner’s work during the period 1966–2003. The exhibit includes carved quartz, tourmaline, and beryl, ranging from pieces set in jewelry to large table-top sculptures. Advance reservations are required; to schedule a tour, call 760-603-4116 or e-mail museum@gia.edu.

Gems! Colors of Light and Stone. The Michael Scott collection has returned to the Bowers Museum in Santa Ana, California, with an expanded display of rare colored stones, carvings, and sculptures. The exhibit will run until June 16, 2008. Visit www.bowers.org.

The Lester and Sue Smith Gem Vault. Opening November 17, 2007, at the Houston Museum of Natural Science in Texas, this new permanent exhibit hall will complement the museum’s existing Cullen Hall of Gems and Minerals with extraordinary polished jewels, as well as a 1,869 ct emerald crystal specimen from North Carolina. Visit www.hmns.org/generic/Gem_Vault_press_room.asp?r=1.

ERRATA

1. The caption for figure 1 of “Polymer impregnated turquoise” by K. S. Moe et al. in the Summer 2007 issue (pp. 149–151) should have included the name of the photographer: Jian Xin (Jae) Liao. *Gems & Gemology* regrets the omission.
2. The Summer 2007 GNI conference report on the Sinkankas jade symposium (pp. 181–182) pictured a Burmese slab that was indicated as jadeite. Subsequent Raman analysis of several spots on this slab, combined with UV-Vis spectroscopy, by Dr. George Rossman (California Institute of Technology, Pasadena, California) have shown that it was composed of diopside.

Challenge WINNERS

This year, hundreds of readers participated in the 2007 GEMS & GEMOLOGY Challenge. Entries arrived from around the world, as readers tested their gemological knowledge by answering questions listed in the Spring 2007 issue. Those who earned a score of 75% or better received a GIA Continuing Education Certificate recognizing their achievement. The participants who scored a perfect 100% are listed here.

Congratulations!

ANSWERS

See pages 81–82 of the Spring 2007 issue for the questions: 1 (B), 2 (D), 3 (B), 4 (A), 5 (C), 6 (D), 7 (A), 8 (D), 9 (C), 10 (A), 11 (B), 12 (B), 13 (D), 14 (C), 15 (D), 16 (C), 17 (C), 18 (B), 19 (A), 20 (C), 21 (C), 22 (D), 23 (B), 24 (D), 25 (C)

AUSTRALIA Queensland, Cairns: Elizabeth Cassidy. Queensland, Gold Coast: Bert J. Last. Western Australia, Coogee: Helen Judith Haddy • **BELGIUM** Brussels: Brigitte Revol MacDonald, Sheila Sylvester. Diegem: Guy Lalous. Diksmuide: Honoré Loeters. Hemiksem: Daniel DeMaeght. Koksijde: Christine Loeters. Overijse: Margrethe Gram-Jensen. Ruiselede: Lucette Nols • **CANADA** Ontario, St. Catharines: Alice J. Christianson. Ontario, Kingston: Brian Randolph Smith • **HONG KONG** Causeway Bay: Cristina O. Piercey-O'Brien • **INDONESIA** Jakarta: Warli Latumena • **JAPAN** Tokyo, Koganeishi: Naoko Tokikuni • **LITHUANIA** Vilnius: Saulius Fokas • **MYANMAR** Yangon: Thuzar Aung • **PORTUGAL** Vila do Bispo, Algarve: Johanne Jack • **SCOTLAND** Edinburgh: James Heatlie, Alec Ewen Taylor • **SPAIN** Barcelona: Jose M. Sanchez-Lafuente. Valencia: Monica Bergel. Vitoria: Ignacio Borrás Torra • **SRI LANKA** Kandy: Senarath B. Basnayake • **SWEDEN** Jarfalla: Thomas Larsson • **SWITZERLAND** Zurich: Eva Mettler • **SYRIA** Aleppo: Hagop Topjian • **THAILAND** Bangkok: Alexander Ross. Samutprakarn: Thomas Estervog • **UNITED KINGDOM** Kent, Tenterden: Linda Anne Bateley. West Midlands, Birmingham: Anu D. Manchanda • **UNITED STATES** Arkansas, Greenbrier: Beverly A. Brannan. Arizona, Cave Creek: Nelson Crumling. California, Carlsbad: Martin Harmon, Brenda Harwick, Mark Johnson, Abba Steinfeld, Jim Viall, Lynn Viall, Philip York. Fremont: Ying Ying Chow. Pacifica: Diana L. Gamez. Rancho Cucamonga: Sandy MacLeane. San Jose: Wendy Bilodeau. Colorado, Alamosa: Michael Cavaliere. Delaware, Bridgeville: Thäis Anne Lump-p-Lamkie. Florida, Clearwater: Tim Schuler. Hawaii, Haiku: Alison Fahland. Idaho, Twin Falls: Frederick House. Illinois, DuQuoin: William C. Duff. Maryland, Baltimore: Alissa Ann Leverock. Chevy Chase: Andrea R. Blake. Patuxent River: Pamela Stair. Maine, Newport: Cynthia Loreen Edwards. Massachusetts, Waban: Jane Prager. Michigan, Linden: Mary L. Mason. Paw Paw: Ellen Fillingham. Missouri, Perry: Bruce Elmer. Nevada, Las Vegas: Diane Flora. New Jersey, Cranbury: Edward Rosenzweig. Monmouth Beach: Michele Kelley. New York, New York: Lois Tamir. North Carolina, Kernersville: Jean Bonebreak. Ohio, Steubenville: Vincent A. Restifo. Rhode Island, Rumford: Sarah Horst. South Carolina, Sumter: James Markides. South Dakota, Piedmont: Randell Kenner. Tennessee, Knoxville: Lynn Shepard. Texas, Amherst: Joanne Hayworth. The Woodlands: Davena Liepman. Washington, Battle Ground: Joseph Bloyd. Bellingham: Mary L. Harding. Mill Creek: Nicki Taranto. Seattle: Janet Suzanne Holmes. Wisconsin, Beaver Dam: Thomas Wendt. Milwaukee: William Bailey. • **VIETNAM** Ho Chi Minh City: Khoan Nhut Nguyen

BOOK REVIEWS

EDITORS

Susan B. Johnson
Jana E. Miyahira-Smith
Thomas W. Overton

Adventures at the Bench: Tricks to Overcome a Jeweler's Daily Challenges

*By Juergen Maerz, 110 pp., illus.,
publ. by MJSA Press
[www.mjsa.org/info_press.php],
Providence, RI, 2006. US\$34.95*

You may know Juergen Maerz, aka "Mr. Platinum," as the gold- and silversmith from Idar-Oberstein who became one of the first Jewelers of America Certified Master Bench Jewelers. With an impressive background as an educator in the United States, he has been the director of technical education for PGI (Platinum Guild International) for many years.

The foreword (by Alan Revere, director of the Revere Academy of Jewelry Arts in San Francisco) is titled "A Bag of Timesaving Tricks"; one might argue that *lifesaving* would have been the more appropriate adjective. While Mr. Maerz's vast background certainly would have allowed, it does not appear he had any intention of writing the equivalent of a Wagnerian "Ring Cycle," with an underlying progression or plot. Instead, he has opted for a compilation of apparently randomly chosen articles, a little in the style of Schubert's *lieder*, his exquisite songs.

The overall design of this book is contemporary in the sense that both aesthetic and functional considerations have been taken into account. *Adventures at the Bench* is divided into five sections: "Bench Tricks & Tales," "Basic Platinum Fabrication," "Lasers & Platinum," "Step-by-Step Projects (With a Few Tricks)," and "Bench Resources." "Bench Tricks"

is a compilation of 29 techniques, each a page in length with up to six illustrations. These cover everything from how to distinguish platinum from white gold alloys to how to make sanding laps with a compact disc. The three subsequent sections cover three to nine projects apiece, each about two to five pages long, with numerous sequential how-to illustrations. "Bench Resources" concludes the book with an appendix of sponsored overviews of refiners, casters, and similar providers of goods and services to the trade.

Efficiency of communication is the mark of an experienced educator, and *Adventures at the Bench* stands out with its tightly focused articles. Descriptions are complete, detailed, and coherent, yet the wording is still concise. The illustrations, all but one of which are photographs, are remarkably accurate in their sequential context. Mr. Maerz clearly understands how to keep even the longest of projects from being excessively complex or difficult. Every now and then, he throws in a humorous account of the kind of hard learning experience-cum-disaster to which every jaded goldsmith can relate.

Purists may seize on the quality of the photographs. Shooting all but a dozen of the 400 or so color photos covering such a wide range of subjects would be a challenge for any professional photographer, let alone an amateur. While one would have hoped for more attention to the image processing, the sequential illustrations still come across clearly by merit of their underlying coherence.

At a time when a goldsmith's

skills are no longer passed from master to apprentice over the course of years, *Adventures at the Bench* serves as a welcome reference for students as well as self-taught tradespeople and bench jewelers, regardless of their background. Business owners, gemologists, and designers alike will find Mr. Maerz's oeuvre an indispensable addition to their libraries, as it answers many potential questions concerning procedures for the shop floor.

ROBERT ACKERMANN

*Design Instructor
Gemological Institute of America,
Carlsbad, California*

Jeweled Garden: A Colorful History of Gems, Jewels, and Nature

*By Suzanne Tennenbaum and Janet
Zapata, 216 pp., illus., publ. by
The Vendome Press, New York,
2006. US\$50.00*

As an eternal muse, Nature has inspired creative expression from prehistoric cave paintings to übermodern architect Santiago Calatrava's wind-swept wonders. Jewelry artists turn to the natural world as a perennial design theme, perhaps in part to honor the jewelers' earth-sprung medium.

In *Jeweled Garden*, a collaborative effort by jewelry collector Suzanne Tennenbaum and decorative arts historian Janet Zapata, readers are served a cornucopia of jeweled delights that transcend the book's modest subtitle. Following a brief historical introduction, the authors set their sights on the fertile 200-year period from the

early nineteenth century to the present. Under their guidance, the narrative unfolds with cohesion and a sense of time and place, all richly detailed by 375 full-color photographs and informed text.

In one fine example after another, the book illustrates how nineteenth century jewelry artists embraced botanical imagery, just as appreciation for the decorative qualities of plants took root beside their traditional uses as foods and medicines. Naturalist expressions such as the 2,637-diamond rose blossom brooch by Parisian jeweler Théodore Fester (1854) are followed by the enamel and gemstone orchid and iris brooches intricately fashioned by Henri Vever and Paulding Farnham for Tiffany & Co. decades later.

Five of the book's six chapters examine art movements of the twentieth century to the present, from Art Nouveau to the as-yet-unnamed present-day style the authors cite as distinctive and individualist. Art Deco *tutti frutti* styles yield to the naturalist revival of the 1930s and 1940s, typified by Cartier's stunning diamond palm tree (1939), which was said to have been inspired by African and Asian explorations. Foliate and floral artistry blossomed to new levels as design houses and artists such as Fulco di Verdura, Paul Flato, Seaman Schepps, and lesser-known trendsetter Suzanne Belperron incorporated carvings, cabochon, and dome-shaped bombé forms in their work.

With fashion designer Christian Dior's "New Look" inaugurating the jet-set style of the 1950s and '60s, designs emerged that evoked stylized conservatism, as in Van Cleef & Arpels' invisibly set flower-head brooches, as well as playfulness, exemplified by a knotted gold watch by Pierre Sterlé and a quirky *en tremblant* wisteria brooch by Marchak (ca. 1955).

The book concludes with the individualist styling of jewelry's new designer breed. The venerable orchid brooch motif takes on a modern flair in an exquisite design ca. 1960 by Oscar Ghiso of the Buenos Aires-based

design house. Peridots and brown diamonds comprise an inventive pussy willow brooch by Edmond Chin (2002) alongside floral feasts by JAR, Bulgari, Stefan Hammerle, and others.

The narrative takes a slight stumble in the last chapter, occasionally veering into branding slogans and ending as though out of steam. Overall, however, the text is written with scholarly insight, a keen eye for the extraordinary, and the authors' fitting enchantment with their subject matter. An index would have been nice, and a brief glossary of specialized terms might have helped readers missing green thumbs, although a few are explained in the book's useful endnotes.

The book's superb production and multisourced photography are accentuated by artful layout and clear legends. Bygone images of publicity materials, royals in regalia, rare archival photographs, and artists' sketches further enhance the book's visual delights.

While *Jeweled Garden* will intrigue anyone interested in jewelry design, fashion, and history, this 10-inch-square volume deserves a wider audience beyond the jewelry cognoscenti. Gorgeous to look at and a joy to read, it will also bring endless pleasure to aesthetes of every stripe, nature lovers, gardening enthusiasts, and all who stop to smell the roses.

MATILDE PARENTE
Libertine
Indian Wells, CA

**Pedras Preciosas No Arte e
Devoção: Tesouros Gemológicos
na Arquidiocese de Évora
[Precious Stones in Art and
Devotion: Gemstone Treasures
of the Archdiocese of Évora]**

By Rui Galopim de Carvalho, 154 pp., illus., publ. by Fundação Eugênio de Almeida, Évora, Portugal, 2006 [in Portuguese and English, no price information available].

Written by a man who is perhaps Portugal's best-known and most-

respected gemologist, this book is a testament to the author's passion for gemology and the trust he has won from those who guard his country's historical treasures. Having established himself over the last decade through his gemological classification of various important Portuguese museum collections, Mr. Galopim was invited by the Eugênio de Almeida Foundation and the Inventory of the Movable Cultural Heritage of the Archdiocese of Évora project to write this book. The goal was the correct identification of the gemstones and precious metals contained in the many jeweled objects belonging to the Archdiocese, and the dissemination of the artistic heritage they represent.

To say that the author succeeded in his goal is an understatement. *Pedras Preciosas* is more of a cross between a history book and a gem identification manual than a museum catalog. Mr. Galopim educates the reader on many aspects of gemology in each chapter: the history and historical sources of the gemstones referenced, name derivations, gemological testing techniques used, and current sources of production. The book ends with multiple pages of footnotes and a glossary.

Although rich in history and a valuable gemological guide, as a catalog of the collection it left me wanting more. Organized by gemological material, each section refers to only one or two pieces and provides little history about them, so the significance of each item is unclear. Were these the most important pieces belonging to the Archdiocese? Or were they the ones the author found most interesting gemologically? The general quality of the photographs is very good, and I would have enjoyed seeing more images of the collection instead of photomicrographs of the inclusions used to aid in the identification. In addition, it is evident that the book was written primarily for a Portuguese-speaking audience, as photographs of the pieces are included only in the first, Portuguese, half and omitted in the English section. I think the book

would have been even more effective if photos had been included with the English section, too.

Overall, I am sure the Archbishop of Évora, who contributed an introduction, was pleased with this lovely, very readable book. Thanks to Mr. Galopim, the people of Portugal have gained another valuable and attractive reference work on their historical religious treasures.

PATRICIA SYVRUD
Carlsbad, California

Shamelessly: Jewelry from Kenneth Jay Lane

By Nancy N. Schiffer, 240 pp., illus., publ. by Schiffer Publishing Ltd. [<http://www.schifferbooks.com>], Atglen, PA, 2007. US\$59.95

Costume Jewelry for Haute Couture

By Florence Muller, 271 pp., illus., publ. by The Vendome Press, New York, 2007. US\$75.00

Costume jewelry plays a critical but often underappreciated role in the awareness and interest in jewelry overall. It mirrors the contemporary styles of precious gem and metal jewelry, and it makes these trends affordable for a broader spectrum of society. These two books review similar yet distinct examples of the best that costume jewelry has to offer.

Shamelessly: Jewelry from Kenneth Jay Lane features one of the most notable designers in the costume jewelry genre. Right out of design school in the mid-1950s, KJL landed a job in the art department at *American Vogue*. Diana Vreeland, *Vogue's* editor-in-chief, became a close friend and introduced him to a wide circle of New York's most influential society mavens. When KJL began designing and fabricating jewelry in 1964, he would give these friends pieces to wear, and their patronage launched his career. Bold and stylish, with a flair for the dra-

matic, KJL's costume jewelry has been worn by an impressive list of luminaries, including the Duchess of Windsor, Britain's Princess Margaret, Jacqueline Kennedy Onassis, Nancy Reagan, Hillary Rodham Clinton, Joan Collins, Audrey Hepburn, Jessica Simpson, and Paris Hilton, to name just a few.

The book is laid out in what might be considered an extended outline form. A brief biographical chapter, "KJL Himself," is followed by three chapters that each contain 11 short sections on related themes. Under "Design Inspirations," for example, there are sections on ancient Egypt, China, India, and other cultures, while "Motifs" contains sections on flowers, fruit, birds, and so forth. Each section is lavishly illustrated with color photos of jewelry, KJL with his royal and celebrity friends, models and actresses wearing his jewelry, and magazine covers and spreads featuring his work.

There is very little text. A brief paragraph introduces each chapter and section, and the remaining text consists of photo captions interspersed with amusing and telling quotes from the designer about his work. Unfortunately, the captions cause some confusion, as the descriptions of the gem materials are not consistent. While some of the jewelry uses natural gem materials (mother-of-pearl, tiger's-eye, and bone), most of it contains imitation gems. A small caveat at the beginning lists the synthetic gem materials that appear in the book. Amethyst, jade, and ivory aren't on the list, yet they appear in the captions. Is the "amethyst" a natural variety of quartz, a synthetic, or glass? Is the "jade" a nephrite carving or molded glass? Is the "ivory" actually carved natural bone—elephant ivory would be highly unlikely—or is it plastic?

Despite these shortcomings, *Shamelessly: Jewelry from Kenneth Jay Lane* is a charming compendium that collectors and appraisers will find useful for identifying the work of this legend in his own time.

Costume Jewelry for Haute

Couture, originally published in French as *Les Paruriers, Bijoux de la Haute Couture*, was the catalog for an exhibition of the same name that went on view in France in 2006. The term *paruriers* refers to manufacturers of costume jewelry for the French *haute couture* fashion houses.

Because the cost of natural gems and precious metals imposes certain limitations on the size and nature of a fine piece of jewelry, *haute couture* houses of the early 1900s, such as Poiret and Chanel, hired *paruriers* to create costume jewelry as accessories for their latest dress designs. Costume jewelry, using imitation gems set in inexpensive metals, could look extravagant yet still remain affordable.

Paruriers collaborated with the fashion house to create an agreed-upon design. They were selected for their imagination, fashion sense, good taste, and high quality of fabrication. Because pieces were stamped with the *couturier's* name, if they were marked at all, the *parurier's* contribution to high fashion remained virtually unknown until recently.

The design aesthetic of *haute couture* jewelry is in a class by itself. Like the clothing it accompanies, it is on the vanguard of jewelry design, intended for dramatic impact on the catwalk. Highly unconventional and exaggerated for effect, *haute couture* jewelry incorporates a wide range of materials, including glass, plastic, enamel, beads, wood, shell, fabric, and feathers, in bold, eye-catching pieces that cannot be ignored. Few of these pieces imitate precious jewelry designs: Most break new ground in terms of color, size, movement, and style.

The book is organized into three main chapters. The first outlines the origins and history of costume jewelry from antiquity to the 19th century. It goes on to describe how jewelry by *paruriers* departed from the mainstream and was elevated to an art form through its alliance with *haute couture*. The second chapter, by far the largest, gives very brief historical profiles for the *haute couture* houses

followed by apparently everything that could be gleaned about the *paruriers*. The final chapter, "The Jewelry Trade and Its Demands," discusses materials, techniques, and the manner of collaboration between *paruriers* and *couturiers* from the 1930s to the present day.

The translation from French to English makes this book a challenging read, but it is worth forging ahead. *Costume Jewelry for Haute Couture* champions this exclusive niche in the costume jewelry world. The author has researched the subject in depth, and has supplemented the text with footnotes, an index of designers, and an extensive bibliography.

Throughout, the book is handsomely illustrated with color images of the jewelry itself and fashion models wearing various pieces. Historic black-and-white photos of the workshops, advertisements, models on the runway, and the *paruriers* themselves add tone and balance to the whole.

Costume Jewelry for Haute Couture provides insight into a little-known segment of the jewelry world, illustrating the important link between jewelry design and clothing fashion in the 20th century. Jewelry historians will find this perspective informative and enlightening.

ELISE B. MISIOROWSKI
GIA Museum
Carlsbad, California

OTHER MEDIA RECEIVED

Pearl Oyster Information Bulletin, No. 17. By various authors, 48 pp., illus., publ. by the Secretariat of the Pacific Community, www.spc.int/Coastfish/News/POIB/17/POIB17.pdf, December 2006, free. This electronic newsletter, back in publication after a nearly three-year hiatus, includes abstracts of selected presentations at the 2005 and 2006 World Aqua-

culture Society conferences and the 2006 International Symposium on Genetics in Aquaculture. Also included is a report from the Secretariat of the Pacific Community Regional Pearl Meeting in Fiji in December 2005, as well an article on pearl culturing in Africa.

THOMAS W. OVERTON
Gemological Institute of America
Carlsbad, California

The Jeweled Menagerie: The World of Animals in Gems. By Suzanne Tennenbaum and Janet Zapata, 216 pp., illus., publ. by Thames & Hudson, New York, 2007, US\$34.95. This is a paperback version of the 2001 work by Tennenbaum and Zapata (see the Winter 2001 *Gems & Gemology*, pp. 344–345, for the full review).

TWO

Kimberlite and Related Rocks of India. By Fareeduddin and M. S. Rao, Eds., 271 pp., illus., publ. by the Geological Society of India [www.gsi.gov.in], Bangalore, 2007, Rs20. This special issue of the *Journal of the Geological Society of India* (Vol. 69, No. 3) is the product of a conference and related field work that took place in Bangalore in November 2005. The topics include a historical review of diamond exploration in India, a review of current knowledge of Indian kimberlites and lamproites, and detailed analyses of known occurrences throughout India.

TWO

Paraíba Tourmaline "Electric Blue Brilliance Burnt into Our Minds." By Masashi Furuya, 23 pp., illus., publ. by the Japan Germany Gemmological Laboratory [jgg@l@sapphire.co.jp], Kofu, Japan, 2007, ¥1,500. This illustrated guide to "Paraíba" tourmaline was written for a broad audience, including gemstone enthusiasts and dealers. Contained in the booklet are chemical and gemological properties

of many types of tourmaline, as well as a brief account of Paraíba tourmaline's introduction into the gemstone market. The author describes the history and current activity at many of the mining areas for copper-bearing tourmaline in Brazil, Nigeria, and Mozambique through location maps and 120 color photos of gemstones and mining operations. This discussion includes his personal accounts of visits to most of the "Paraíba" mining areas in Brazil. Chemical (EDXRF) and absorption spectroscopy data are provided for tourmalines from many of the mines. Mr. Furuya also gives a brief evaluation of the future market for Paraíba tourmaline.

CHRISTOPHER M. BREEDING
GIA Research
Carlsbad, California

The Geology of Gem Deposits. Edited by Lee A. Groat, 276 pp., illus., publ. by the Mineralogical Association of Canada [www.mineralogicalassociation.ca], Quebec, 2007, US\$50.00. This volume was published to accompany a two-day short course that was held May 21–22, 2007, in Yellowknife, Canada, in conjunction with the joint annual meeting of the Geological and Mineralogical associations of Canada. The book consists of 10 chapters on different gemstones; each chapter is written by experts on the geologic occurrence of these gem materials. These chapters summarize the presentations made at the two-day meeting, which covered the following topics: the geology of diamonds, corundum, emerald, other gem beryls such as aquamarine, jade, and several other important gem minerals; gem occurrences in pegmatites; and a review of colored gem occurrences in Canada. Suggestions for gem exploration are provided.

JAMES E. SHIGLEY
GIA Research
Carlsbad, California

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Characteristic spectral features of iron as a gemstone chromophore. G. Pearson [gpearson@netspace.net.au], *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 430–446.

The spectral features of iron-bearing beryl, chrysoberyl, spinel, peridot, natural and synthetic sapphires from several localities, and some additional gems were recorded using digital UV-Vis spectroscopy. Some shared features, repeatedly observed when the data were converted into transmission spectra, show characteristics not reported previously in the gemological literature. At the same time, however, certain spectral features long considered to be “diagnostic for iron” were not seen in the transmission spectra. The most prominent visible-range absorption peak for iron in the examined materials occurred in the deep blue to violet region of the spectrum, which is difficult to observe directly because of the lower sensitivity of human vision at such wavelengths. *RAH*

Determination by Raman scattering of the nature of pigments in cultured freshwater pearls from the mollusk *Hyriopsis cumingi*. S. Karampelas [steka@physics.auth.gr], E. Fritsch, J.-Y. Mevellec, J.-P. Gauthier, S. Sklavounos, and T. Soldatos, *Journal of Raman Spectroscopy*, Vol. 38, No. 2, 2007, pp. 217–230.

Raman spectra were recorded for 30 untreated Chinese freshwater cultured pearls of various colors, using seven excitation wavelengths between 363 and 1064 nm. The spectra of all the colored cultured pearls exhibited two major Raman features due to polyenic compounds assigned to double and single car-

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

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bon-carbon bonds (at about 1500 and 1130 cm^{-1} , respectively). These features were absent in similar spectra recorded for white cultured pearls. Using a single excitation wavelength, the authors observed changes in the intensities, shapes, and positions of these two peaks for samples of different colors. Using several excitation wavelengths from the same location on the same sample, they noted similar changes in these peaks. The exact position of the Raman peak for the single carbon-carbon stretching vibration of polyenic molecules depends strongly on the number of double carbon-carbon bonds in their polyenic chain (there are between 6 and 14 such bonds).

By using a constrained decomposition of double carbon-carbon Raman peaks at about 1500 cm^{-1} , the authors detected up to nine different pigments in the same cultured pearl. All colored samples contained at least four pigments, and the various pearl colors could be explained by different mixtures of these pigments in various proportions. Further spectroscopic studies are under way to better understand the exact nature of these polyenic pigments, which may produce coloration in other biogenic materials. There is no evidence that these pearl pigments are carotenoids, as they were previously described in the literature. JES

Gem corals: X-ray diffraction, solid state NMR, elemental analysis. R. Bocchio [rosangela.bocchio@unimi.it], S. Bracco, A. Brajkovic, A. Comotti, and V. Rolandi, *Australian Gemmologist*, Vol. 22, No. 12, 2006, pp. 524–532.

Gem corals are derived mainly from branching calcareous skeletons formed by colonies of marine animals called polyps. The skeletons consist of calcium carbonate (CaCO_3 , as aragonite or calcite) as well as some organic substances (proteins, polysaccharides, and lipids). Hydrozoa and Anthozoa are the only two classes of the phylum Cnidaria that produce calcareous skeletons useful for gem purposes.

The authors examined the crystallographic and chemical features of 21 gem-quality Hydrozoa and Anthozoa corals using powder X-ray diffraction analysis, ^{13}C magic angle spinning nuclear magnetic resonance, and LA-ICP-MS. The corals consisted of either calcite (seven samples) or aragonite (14 samples); the Ca content was higher in the latter samples. The authors found the Mg/Ca and Sr/Ca ratios to be reliable in discriminating between the two types: In calcitic corals, Mg was high and Sr was low, while the opposite trend was noted in aragonitic corals. In the calcitic samples, the unit-cell volume increased with decreasing Mg content; in the aragonitic samples, the unit-cell volume increased with increasing Sr. Trace-element contents (Li, B, Ti, V, Cr, Co, Ni, Zn, Rb, Y, Zr, Nb, Cs, Ba, Pb, and U) overlapped in both types of coral. HJ-G

Gemmological characteristics of pink jadeite jade with white ribbons. Q.-M. Ouyang, H.-S. Li, X. Guo, and

J. Yan, *Journal of Gems and Gemmology*, Vol. 8, No. 3, 2006, pp. 1–3.

The authors studied the gemological properties of Burmese pink jadeite containing white ribbons and veins, and further characterized the material using polarized microscopy, electron-microprobe analysis, Raman and infrared spectroscopy, and cathodoluminescence (CL). The samples ranged from opaque to semitransparent, had an average SG of 3.35, and were inert to UV radiation. The white veins showed uneven thickness and wavy, cloud-like shapes.

IR spectroscopy revealed that both the pink masses and white veins were composed of jadeite. Microscopic observation revealed a coarse texture in the pink area, while the white veins were fine grained. CL imaging showed that the pink area luminesced bluish purple (the same as lavender jadeite), while the white veins luminesced yellowish green (the same as white jadeite). Electron-microprobe analysis detected Fe and Mn in the pink portion (similar to lavender jadeite). The authors suggest that Fe and Mn caused the pink bodycolor, and shear stress caused the white veins.

Qianwen (Mandy) Liu

Identification of the horse origin of teeth used to make the Japanese kakuten using DNA analysis. H. Kakoi, M. Kurosawa, H. Tsuneki [htsuneki@pha.u-toyama.ac.jp], and I. Kimura, *Journal of Gemmology*, Vol. 30, No. 3/4, 2006, pp. 193–199.

Small ornamental objects such as *netsuke* and *ojime* from the Edo period in Japan (ca. 1615–1868) are considered collectors' items today. *Netsuke* are miniature carvings that were used to fasten a small container to a kimono sash, and *ojime* are sliding beads on cords that kept the container closed.

Kakuten (the term refers to the red crown of a Japanese crane) are a type of *ojime* consisting of reddish striped beads that generally measure $19\text{--}21 \times 30\text{--}32$ mm. Using high magnification and FTIR spectroscopy, the authors concluded that two *kakuten* samples analyzed came from the tooth of a grass-eating animal. DNA analysis of the species-specific mitochondrial cytochrome b gene (CYTB) sequence showed that the material was made from the tooth of a horse. HJ-G

Looking after organic gems. R. Child, *Organic Gems Magazine*, No. 1, 2006, www.maggiecp.co.uk/free_organic_gems-magazine/looking_after_organic_gems.html.

This article addresses the storage and care of organic gem materials, underscoring their special nature. The author divides them into two groups: purely organic materials, which are relatively stable to temperature and moisture but react rapidly to light and pollution; and materials that have undergone some sort of fossilization or other alteration (such as ivory, bone, or pearls), which may be attacked by chemicals or easily damaged by shock.

Temperature, humidity, pollution, and light are all identified as agents of damage. High temperatures can dry out materials and accelerate deterioration. Alternating high and low humidity can adversely affect an object's shape and size. High humidity can also encourage mold growth and insect activity. Atmospheric pollutants, which are often acidic, can cause both aesthetic and structural damage to objects. Ultraviolet radiation, present in all light sources, is a major cause of fading and surface deterioration. JEC

The origin of jadeite-forming subduction-zone fluids: CL-guided SIMS oxygen-isotope and trace-element evidence. S. Sorensen [sorensen@si.edu], G. E. Harlow, and D. Rumble III, *American Mineralogist*, Vol. 91, 2006, pp. 979–996.

Jadeite ($\text{NaAlSi}_2\text{O}_6$), a member of the pyroxene group, is valued as a gem and is also scientifically important for studying fluid-rock interactions in subduction zones. Jadeite can be found in primary deposits at eight locations worldwide, as well as in a few secondary deposits. It may form as veins, dikes, or rounded masses in serpentinite-matrix mélanges associated with eclogite, garnet amphibolite, or blueschist.

The authors studied thin sections of jadeite that were pale green (Guatemala), white with bright green stringers (Japan and Kazakhstan), light “straw” color (United States), chalky white (Myanmar), or pale pink (Myanmar). Various cathodoluminescence (CL) colors suggested that one or more cycles of crystallization occurred. A CL sequence of red or blue followed by green was observed in all samples except the U.S. jadeite. That sample contained prismatic crystals (up to 3 cm long) showing numerous red and blue oscillation zones. Electron-microprobe analyses revealed that traces of rare-earth elements were relatively abundant in the green zones. Oxygen-isotope analysis of the Guatemalan sample suggested that $\delta^{18}\text{O}$ was heavier in green to yellow-green CL zones than in red, blue, or dark green zones. However, the opposite trend was observed in the Japanese and chalky white Burmese samples. The latter were found to consist of low-temperature jadeite, as evidenced by jadeite-albite oxygen isotope-based temperature estimates. The low average $\delta^{18}\text{O}$ value of the Guatemalan sample suggested that it may have formed from heterogeneous fluids that interacted with metagabbros and metamorphosed pillow basalts in subduction complexes.

In the chalky white Burmese sample, early-formed blue and red CL zones were overgrown by oscillatory yellow-green zones, and subsequently by blue and red zones. A sudden decrease in Zr from the yellow-green to blue CL zones suggested that this jadeite crystallized in an open rather than closed system.

This study concluded that the chemical composition of jadeite grains records the evolution of the fluids in which they grew. The devolatilization of blueschist,

which is rich in saline fluids and Na, could yield jadeite-forming fluids. Jadeite formation occurs in a serpentinite host within active subduction zones and thus may represent a variety of subduction-zone fluids. Veins or patches of the highly valued Imperial jadeite, which contain Cr, formed during the latest stages of crystallization. KSM

Special vaterite found in freshwater lackluster pearls. L. Qiao [biomater@mail.tsinghua.edu.cn], Q. Feng, and Z. Li, *Crystal Growth and Design*, Vol. 7, No. 2, 2007, pp. 275–279.

Calcite, aragonite, and vaterite are the three main phases of calcium carbonate. Vaterite is a rare, unstable crystalline form that may act as the precursor to the formation of calcite and aragonite in pearls. The authors documented vaterite in freshwater cultured pearls from southern China with poor luster, and also vaterite in association with aragonite in commercial-grade samples. The vaterite forms tablet-shaped crystals that measure approximately $8 \times 2 \times 0.4 \mu\text{m}$. The stacking arrangement of the tablets often gives the appearance of “brick and mortar,” similar to the structure of nacre. This indicates that the growth mechanisms for vaterite and nacre are similar. EAF

DIAMONDS

Canada: A world class diamond producer. *Mining Engineering*, April 2007, pp. 46–49.

The first of several world-class diamond-bearing deposits was found in Canada's Northwest Territories in 1991. The mines are located in remote areas close to the Arctic Circle, and they are only accessible by air or by an ice road that is constructed each winter. Canada became a major producer with the opening of the Ekati mine in 1998. The Canadian diamond industry is now worth more than \$2 billion annually and employs around 1,200 people, with an additional 1,000 workers in support industries.

Canada has been a leader in the movement to control the trade in conflict diamonds. There is considerable interest in Canadian diamonds due to the guarantee of origin and the country's high social and environmental standards for mining. It is expected that within 10 years at current growth rates, Canada will supply 15–20% of world diamond production by value. The article speculates that within 20 years, this figure could approach 50%. EAF

Diamond, subcalcic garnet, and mantle metasomatism: Kimberlite sampling patterns define the link. V. G. Malkovets, W. L. Griffin [wgriffin@els.mq.edu.au], S. Y. O'Reilly, and B. J. Wood, *Geology*, Vol. 35, No. 4, 2007, pp. 339–342.

A study of kimberlites in the Daldyn-Alakit region of the Sakha Republic of Russia has revealed a genetic relationship between diamond and a common indicator mineral:

subcalcic, Cr-bearing pyrope. Both minerals appear to have been formed by metasomatic processes within harzburgitic rocks at depths of 140–190 km in the earth's mantle, and were then transported to the surface by kimberlitic volcanism. The authors suggest that diamond formation in the mantle is probably due to the oxidation of a methane-rich, silicate-bearing fluid by iron present in chromite. The latter mineral also appears to be involved in a separate chemical reaction to form the pyrope. The distribution of diamond in the mantle likely reflects the location of metasomatizing fluid conduits within the harzburgite, which originally contained no diamond or pyrope.

JES

Dichroism and birefringence of natural violet diamond crystals. A. F. Konstantinova [afkonst@ns.crys.ras.ru], S. V. Titkov, K. B. Imangazieva, E. A. Evdishchenko, A. M. Sergeev, N. G. Zudin, and V. P. Orekhova, *Crystallography Reports*, Vol. 51, No. 3, 2006, pp. 465–471.

The authors studied the optical properties of 12 purple diamond crystals from the kimberlite fields in Yakutia, Russia. [*Abstractor's note:* According to one of the authors, the word *violet* in this article was mistranslated from Russian and should be *purple*.] These octahedral crystals (0.4–0.8 ct) had purple lamellae parallel to the {111} planes. From among these crystals, the authors fashioned thin plates: two oriented parallel to the lamellae and two oriented perpendicular to them. UV-Vis absorption spectra of each plate were recorded as the angular position between the diamond and the analyzer was varied. Both types of lamellae orientation showed bands centered at ~390, 456, 496, and 550 nm, with the intensity of absorption varying with the angle between the plate and the analyzer. The 550 nm band—typically associated with plastically deformed brown, pink, and purple diamonds—was most pronounced in the plates with the purple lamellae oriented perpendicular to the beam. The variation in absorption with orientation indicated that these purple diamonds were weakly dichroic. From these data, the authors calculated the diamonds' birefringence. When a beam was oriented perpendicular to the lamellae, the birefringence was smaller ($\sim 5.4 \times 10^{-5}$) than when it was positioned parallel to the lamellae ($\sim 8.2 \times 10^{-5}$). However, the researchers cautioned that this apparent difference may be related to the experimental geometry.

SE-M

Mining for a greater future at Mwadui. W. Mutagwaba, J. Seegers, and R. Mwaipopo, *African Mining*, January–February 2007, pp. 48–52.

The area surrounding the Mwadui diamond mine in Tanzania is worked by ~12,000 unlicensed, unregulated artisanal miners. The majority of these operations are both illegal and dangerous. However, simply expelling the artisanal miners would create greater problems by depriving thousands of people of a livelihood. In an effort to improve

safety and help maintain employment in the area, the Tanzanian government, the established mining community, and the artisanal miners have collaborated on a new program. The Mwadui Community Diamond Partnership helped create a network of formal channels that the artisanal miners can use to obtain mining permits, purchase equipment, and sell the diamonds they find. One of many benefits of this new arrangement is that the diamonds sold by these miners can now be certified through the Kimberley Process and legally enter the world diamond trade.

EAF

Placer diamonds from Brazil: Indicators of the composition of the earth's mantle and the distance to their kimberlitic sources. R. Tappert [rtappert@ualberta.net], T. Stachel, J. W. Harris, K. Muehlenbachs, and G. P. Brey, *Economic Geology*, Vol. 101, 2006, pp. 453–470.

The small number of known primary deposits in Brazil cannot account for the widespread abundance of the country's placer diamonds. If additional primary deposits exist, locating them will be difficult due to extensive tropical weathering, which can destroy the indicator minerals used for prospecting. Characterizing Brazil's alluvial diamonds and their associated mineral inclusions may give clues to their origin, yet there have been very few studies of this type.

Sixty-eight alluvial diamonds originating from three placer deposits (Arenapolis, Boa Vista, and Canastra) were analyzed by microscopy to determine visible morphologic features, colors, and surface textures, and by secondary-electron imagery with high-resolution CL to reveal internal zoning patterns. The major-element composition of the inclusions was determined using electron-microprobe analysis. Most of the diamonds studied were colorless, although brown and yellow bodycolors were represented in all the deposits. Green and brown radiation spots were common. Examination of the inclusions revealed that the majority of the diamonds belonged to a peridotitic (deep-seated, olivine-rich) suite. The diamonds from Arenapolis probably originated from distant kimberlitic sources, while those from Boa Vista and Canastra came from nearby sources.

PJ

The vacancy as a probe of the strain in type IIa diamonds. D. Fisher [david.fisher@dtc.com], D. J. F. Evans, C. Glover, C. J. Kelly, M. J. Sheehy, and G. C. Summerton, *Diamond and Related Materials*, Vol. 15, No. 10, 2006, pp. 1636–1642.

Crystallographic strain is present in many diamonds. It is generally introduced by defect centers (usually either atomic point defects or extended defects such as dislocations) that are in part created when the diamond is subjected to deformation. Brown color in type IIa diamonds (which generally contain <1 atomic ppm nitrogen) is associated with plastic deformation, with the color being distributed along

deformation-related slip bands. Brown diamonds exhibit more strain than do colorless type IIa diamonds.

This study was undertaken to correlate variations in strain with the depth of brown color, and to monitor changes in this strain during decolorization by HPHT treatment. More than 200 type IIa diamonds were polished into flat parallel plates, and changes in strain were monitored by carefully measuring the width of the photoluminescence (PL) peak at 741.1 nm both before and after HPHT annealing. This feature exists due to a neutral vacancy defect (the GR1 center) in the diamond structure, which can be detected even at low concentrations by PL spectroscopy.

The width of the PL peak at 741.1 nm increased with the strength of brown color. Visible-range spectroscopy revealed that the brown color in the untreated samples was due to general absorption that increased toward shorter wavelengths, with deeper color associated with stronger absorption. HPHT annealing resulted in a significant reduction in this absorption, producing colorless or light yellow bodycolors (the latter being due to the generation of a small amount of single nitrogen). The treatment removed the GR1 center, so this defect was reintroduced by electron irradiation.

The PL data suggested a possible link between the degree of plastic deformation in type IIa diamonds, the amount of strain as indicated by the GR1 peak width, and the depth of the brown color. HPHT annealing to remove the brown color was accompanied by a reduction in the amount (but not the total removal) of strain, as assessed by the GR1 peak width. JES

Zoning in diamonds from “Mir” kimberlite pipe: FTIR data. E. A. Vasilyev and S. V. Sofroneev, *Proceedings of the Russian Mineralogical Society*, Vol. 136, No. 1, 2007, pp. 90–101 [in Russian with English abstract].

FTIR microspectroscopy of plates prepared from diamonds from Russia’s Mir pipe showed that B1 defects formed due to annealing during crystal growth, but that B2 centers developed mainly after growth. The secondary formation of the B2 defects was related to the aggregation of admixed nitrogen. Since the kinetics of this process correspond to the decomposition of an oversaturated solid solution, there are possibilities for determining the temperature and duration of diamond growth. RAH

GEM LOCALITIES

Corundum-bearing metasomatic rocks in the Central Pamirs. M. S. Dufour [dufourms@rambler.ru], A. B. Koltsov, A. A. Zolotarev, and A. B. Kuznetsov, *Petrology*, Vol. 15, No. 2, 2007, pp. 151–167.

Gem-quality corundum occurs at scattered localities in the Muzkol metamorphic complex in the Central Pamir

Mountains of southeastern Tajikistan. It is associated with scapolite, biotite, muscovite, and chlorite, as well as with smaller amounts of tourmaline, apatite, rutile, and pyrite. The corundum occurrences are spatially related to zones of metasomatic alteration in calcite and dolomite marbles. The widespread alteration of the marbles by silica-undersaturated fluids (which are thought to have originated from associated crystalline schists) took place during the final stages of a regional metamorphic event. Inferred conditions of corundum formation are temperatures of 600–650°C and pressures of 4–6 kbar. Corundum formation appears to have been related to desilication reactions between the fluids and the impure marble host. JES

Emeralds from the Delbegetey deposit (Kazakhstan): Mineralogical characteristics and fluid-inclusion study. E. V. Gavrilenko [egavr@ccia.uned.es], B. Calvo-Pérez, R. Castroviejo-Bolibar, and D. Garcia del Amo, *Mineralogical Magazine*, Vol. 70, No. 2, 2006, pp. 159–173.

Gem-quality emeralds have been recovered from north-eastern Kazakhstan, approximately 100 km south of Semeytau (formerly Semipalatinsk). The mineralization occurs along the contact between granite and sandstone, at the intersection of two major faults. Emeralds are associated with quartz, muscovite, tourmaline, and fluorite in small metasomatic veins along an east-west trending fracture zone. To date, the largest emerald crystals recovered are 15 mm long, but most are smaller.

Twelve crystals were examined for this study (four of which were subsequently faceted). The emeralds were pale to intense bluish green, and had a prismatic habit and distinct color zoning parallel to the prism and pinacoid faces. The crystals exhibited numerous dissolution pits and furrows. Refractive indices were $n_o=1.566$ – 1.570 and $n_e=1.558$ – 1.562 ; SG was 2.65 ± 0.005 . The samples fluoresced weak red to long-wave UV radiation, and were inert to short-wave UV. Visible-range spectra recorded from optically oriented polished plates exhibited broad regions of absorption at ~430 and 610 nm, and sharp bands at 636, 657, and 680 nm. Near-infrared spectra displayed a broad band centered at 810 nm and a sharp band at 956 nm. Electron-microprobe analyses of 10 crystals yielded average values of 0.29 wt.% Cr₂O₃, 0.07 wt.% V₂O₃, and 0.25 wt.% FeO. The values for MgO, MnO, Na₂O, and K₂O were 0.05 wt.% or smaller. The samples were generally free of mineral inclusions—the two exceptions being small biotite platelets and numerous tiny rutile needles along linear zones. Vapor-filled (and, to a lesser extent, fluid-filled) inclusions were common. Estimated conditions of emerald crystallization—420–600°C and 570–1240 bar—suggest a shallow depth of formation. According to the authors, the gemological features of these emeralds are quite distinctive from those of other natural or synthetic emeralds. JES

The emerald- and spodumene-bearing quartz veins of the Rist emerald mine, Hiddenite, North Carolina. M. Wise [wisem@si.edu] and A. Anderson, *Canadian Mineralogist*, Vol. 44, 2006, pp. 1529–1541.

The formation conditions and mineral composition of hydrothermal veins at the Rist mine in Hiddenite, North Carolina, were investigated to provide a foundation for future fluid-inclusion studies, isotopic analysis, and examinations into relationships between emerald and Cr-bearing spodumene (hiddenite) mineralization and granitic pegmatites. The mine is located in the deformed Inner Piedmont belt of western North Carolina. This area of metamorphosed sillimanite-grade rocks extends from North Carolina to Alabama and is nearly 100 km wide. Emerald and hiddenite formed within quartz veins and open cavities that occupy tensional fractures in the folded metamorphic rocks. The early stage of vein development is characterized by the deposition of massive quartz followed by Ca-Fe-Mg carbonates. The crystallization of Be-, Li-, Ti-, and B-bearing minerals, contaminated by Cr and V, occurred shortly after the formation of the cavities. Late-stage coatings of pyrite, chabazite, and graphite suggest that low-temperature reducing conditions were present during the final stages of mineral formation. A number of investigators have pointed out the resemblance of these formations to European "Alpine clefts" (i.e., hydrothermal veins). To date, no relationship has been found between these emerald- and hiddenite-bearing veins and pegmatites. EAF

Neues Vorkommen kupferführender Turmaline in Mosambik [A new find of cuprian tourmalines in Mozambique]. C. C. Milisenda [info@gemcertificate.com], Y. Horikawa, K. Emori, R. Miranda, F. H. Bank, and U. Henn, *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 55, No. 1–2, 2006, pp. 5–24 [in German with English abstract].

At present, copper-bearing elbaite is known from Brazil, Nigeria, and Mozambique. Such tourmalines can show unusually intense "electric" or "neon" blue coloration caused mainly by Cu²⁺. After outlining the Brazilian and Nigerian occurrences, the authors describe the most recent find of Cu-bearing elbaite from near "Mawoko" (Mavuco) in the Alto Ligonha region of Mozambique. These tourmalines, which derive from pegmatites that formed during or after the Pan-African orogenesis, are mined from secondary deposits. They show a wide range of colors including purple, violet- and pink-to-blue, greenish blue, yellowish green, and green. Most, but not all, of the purple-to-violet material can be treated to "turquoise" blue by heating at around 600°C. Gemmological and chemical analyses showed that the tourmalines are elbaite colored by Cu and Mn, as in their Brazilian and Nigerian counterparts.

The new find in Mozambique has revived the ques-

tion of nomenclature. In accordance with CIBJO regulations, the trade has widely accepted the term *Paraíba tourmaline* as the designation for Cu-colored elbaite, regardless of origin. Nevertheless, a determination of origin is sometimes desired. The authors performed LA-ICP-MS analyses of 107 samples from all known deposits. It appears that the Pb/Be ratio versus CuO+MnO (wt.%) is characteristic for each occurrence, and may serve as a means to determine origin. However, this has yet to be confirmed by a larger number of analyses. RT

Old opal fields revisited at Coober Pedy. I. J. Townsend, [townsend.jack@myaccess.com.au], *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 475–478.

In 2004, the South Australia government provided funds to the Coober Pedy Miners Association to purchase an auger drilling rig for the purpose of obtaining new drill-hole data and investigating new methods of locating opal. By the end of February 2006, over 700 exploratory drill holes had been sunk to an average depth of about 20 m and a number of new finds had been made, including some alongside areas that had been considered worked out. Additional subsidized exploration is continuing, and the data are being made available by the South Australia government. RAH

Oxygen isotope systematics of gem corundum deposits in Madagascar: Relevance for their geologic origin. G. Giuliani [giuliani@crpg.cnrs-nancy-fr], A. Fallick, M. Rakotondrazafy, D. Ohnenstetter, A. Andriamamonjy, T. Ralantoarison, S. Rakotosamizanany, M. Razanatsheho, Y. Offant, V. Garnier, C. Dunaigre, D. Schwarz, A. Mercier, V. Rarimo, and B. Ralison, *Mineralium Deposita*, Vol. 42, No. 3, 2007, pp. 251–270.

The authors measured the oxygen isotopic composition of gem corundum samples from 22 localities in Madagascar. Primary deposits are hosted by magmatic and metamorphic rocks. Secondary deposits, found in detrital basins and karsts, are the most economically important sources of the gem corundum.

Oxygen isotope ratios (¹⁸O/¹⁶O) can provide a reliable indication of corundum's geologic origin. The Madagascar samples from primary deposits displayed a wide range of δ¹⁸O values, from 1.3 to 15.6‰. Isotope ratios for metamorphic rubies fell into two groups: 1.7–2.9‰ for samples collected from cordierite-rich rocks, and 3.8–6.1‰ for those recovered from amphibolites. Magmatic rubies from xenoliths in alkali basalts had values of 1.3–4.7‰. Data for sapphires also fell into two groups: 4.7–9.0‰ for samples from pyroxenites and gneisses, and 10.7–15.6‰ for those from skarns. Samples from secondary deposits exhibited isotope ratios from –0.3 to 16.5‰; in some instances, a magmatic or metamorphic source could be ascertained. The oxygen isotope data pointed to a common link for corundum from India, Sri Lanka, and East Africa. JES

Les saphirs multicolores de Sahambano et Zazafotsy, région granulitique d'Ihosal, Madagascar [The multi-colored sapphires from Sahambano and Zazafotsy in the granulitic domain of Ihosal, Madagascar]. T. Ralantoarison, A. Andriamamonjy, Y. Offant, G. Giuliani, A. F. M. Rakotondrazafy, D. Ohnenstetter, D. Schwarz, C. Dunaigre, A. Fallick, M. Razanatsheho, S. Rakotosamizanany, B. Moine, and P. Baillot, *Revue de Gemmologie*, No. 158, 2006, pp. 4–13 [in French with English abstract].

This article describes the geologic setting, formation, and mineralogical properties of two sapphire deposits in southern Madagascar, at Sahambano and Zazafotsy. Both are situated near Ihosal in a shear zone formed during the remobilization of ancient continental crust 950–450 million years ago. This process led to the formation of sapphires when metasomatic fluids interacted with feldspathic gneisses.

The sapphires are idiomorphic and show various habits from prismatic to tabular. Colors include gray and blue; various shades of orange, pink, "mauve" to red, and "fuchsia"; and some "padparadscha." The color depends on the local composition of the host rocks, which supply the chromophores Fe and Cr. Electron-microprobe analyses showed that the color was determined by Fe/Cr; Fe content was nearly constant and always higher than Cr, which decreased from the red to blue hues.

Both deposits supply beautiful mineral specimens, but only a very small percentage of the corundum produced would be suitable for gem material after heating.

RT

Stichtite from western Tasmania. R. S. Bottrill [rbottrill@mrt.tas.gov.au] and I. T. Graham, *Australian Journal of Mineralogy*, Vol. 12, No. 2, 2006, pp. 101–107.

The Dundas area of western Tasmania is the type locality for stichtite. This colorful but uncommon mineral, $\text{Mg}_6\text{Cr}_2(\text{CO}_3)_2(\text{OH})_{16} \cdot 4\text{H}_2\text{O}$, is most plentiful on Stichtite Hill, near the Adelaide and Red Lead silver-lead-crocoite mines; several other localities are listed, all near Dundas. The host rocks are serpentinized dunite. The stichtite is pale pink to deep purple, fine grained, and commonly contains disseminated chromite grains. It is hosted by massive yellowish green to dark green serpentine, making the material suitable for attractive ornamental carvings.

RAH

Les tourmalines magnésiennes d'Afrique de l'Est [Magnesium-bearing tourmalines from East Africa]. C. Simonet [cedric@ssm-kenya.com], *Revue de Gemmologie*, No. 157, 2006, pp. 4–7 [in French].

The author describes the occurrences and gemological properties of Mg-bearing tourmalines from two regions in East Africa: the gem-bearing belt of southern Kenya, which extends into the Uмба Valley of Tanzania, and the

Masai steppe in Tanzania. The tourmalines are mined from plumasites (similar to ruby at the John Saul mine) or from anatectic (e.g., Yellow mine) and ultrabasic pegmatites (small placer deposits) or pegmatites associated with marbles (e.g., Landanai).

In contrast to "real" chrome tourmalines, which contain up to 8% Cr_2O_3 , the green material from East Africa is Mg-rich (dravite-uvite series) and is colored by no more than 1 wt.% Cr_2O_3 . These tourmalines also occur in brown-to-yellow hues, the latter due to titanium. Some show a color-change effect.

Although these tourmalines are bright and beautiful gems, their share in the market will always be restricted because of their rarity and irregularity of production. RT

INSTRUMENTS AND TECHNIQUES

Noninvasive methods for the investigation of ancient Chinese jades: An integrated analytical approach. F. Casadio [fcasadio@artic.edu], J. G. Douglas, and K. T. Faber, *Analytical and Bioanalytical Chemistry*, Vol. 387, 2007, pp. 791–807.

The authors explored means of analyzing ancient Chinese jades using nondestructive desktop and portable spectrometers. Proper characterization of ancient and modern jades is important for identification of the sample's mineralogy, provenance, and archeology.

Six ancient jades (all nephrite, Neolithic through Han dynasties) and several samples from contemporary Chinese mines were investigated with the portable equipment. A Raman spectrometer was successful in identifying nephrite, although minor problems with fluorescence were noted. With this technique, it was also possible to estimate iron content, which could then be correlated to geologic origin. XRF and visible reflectance spectroscopy showed that the jades' colors did not correspond to their chemical composition. This is in contrast to previous research suggesting that increasing iron content correlates to a darker color. In addition to the above methods, a heating experiment was performed to investigate the identification of possible ancient treatment practices, as well as modern forging techniques. Using a sectioned pebble of low-iron tremolitic nephrite, the conversion of tremolite to diopside through heating was easily detectable with Raman spectroscopy. DMK

Optical optimization. M. Prost, *Colored Stone*, Vol. 20, No. 2, 2007, pp. 32–35.

About 10 years ago, the plastics industry implemented optical systems for sorting resins by color and type. Manufacturers in other fields found that the same process worked with glass, paper, and organic products. More recently, the technique has been applied to the recovery of gems, first with diamonds and then with colored stones such as emerald, ruby, sapphire, tanzanite, and topaz. As

long as at least 10% of the gem is exposed from the matrix, it can be detected in any size from 0.5 to 300 mm.

The technology involves dropping crushed ore onto a conveyor belt that is continuously scanned with high-resolution sensors. As the crushed ore falls, it is lit from a certain angle by specially designed light sources. The sensors analyze the resulting spectrum of transmitted light and detect the gems using customized parameters involving light, color, and/or shape. Jets of compressed air then knock the gems out of the ore stream into a collection receptacle.

Though highly efficient, the equipment is also expensive, costing US\$450,000 to \$1 million, plus shipping, installation, operation, and maintenance costs. Depending on the type of gem mineral and individual deposit, payback on the investment might occur in 6–24 months, but strong financial backing is required in case the deposit does not yield enough production to cover the expense. One effect of this technology is to render economic many deposits in well-developed countries where labor costs are high. Although optical sorting also reduces theft and labor costs, it displaces local workers in the process. JEC

JEWELRY HISTORY

A História da Joalheria. A evolução das jóias através dos tempos [The history of jewelry. The evolution of jewels through the ages]. M. A. Franco, *Diamond News*, Part I: Vol. 6, No. 22, 2005, pp. 50–60; Part II: Vol. 6, No. 23, 2006, pp. 49–60; Part III: Vol. 6, No. 24, 2006, pp. 47–58 [in Portuguese].

This three-part series gives a comprehensive survey of the history of jewels, covering most of the important aspects of the topic: the development of methods and techniques of jewelry production (e.g., granulation, enamel, diamond cutting), the materials used (metals, stones), the trade channels, the evolution of style, and the symbolic, healing, and ornamental functions of jewelry. Part I covers the period from the beginnings of adornment in the Paleolithic Age through the high cultures of the ancient world to the end of the Roman Empire. Part II deals with the developments of Byzantium through the Middle Ages to the Turkish conquests in the 15th century. Part III starts with the discovery of the New World and describes developments up to the French Revolution. Each part contains a foldout synopsis and is well illustrated with examples of important jewels. RT

Problems that may be encountered when identifying gemstones in antique jewelry: Some practical tips. R. Bauer, *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 455–459.

Identifying gemstones set in jewelry can be awkward at best and extremely difficult to impossible at worst. Antique jewelry can be especially challenging because of the fabrication methods used in earlier eras. For example, high-set prongs

that were popular during the Victorian period can be a detriment to otherwise useful testing equipment.

Synthetic and imitation materials became very plentiful in the late 19th and early 20th centuries. Commonly encountered imitations include those for pearls, turquoise, and coral. Imitation pearls typically are coated glass beads; the coating may show visible peeling. Turquoise and coral were often imitated by a ceramic material that tends to exhibit “pocked” surface indentations. When synthetics were first introduced, they tended to be viewed as fine gemstones and were set into equally fine 9K, 15K, and 18K gold settings. During the Art Deco period (ca. 1920–1940) synthetic rubies and sapphires were commonly set into diamond bracelets to reduce the expense of creating the jewelry and because their color could be easily matched. The testing of amber and its imitations is also reviewed.

Descriptions of old diamond cuts are provided, and weight-estimation techniques are discussed. The “bulge factor” common in older cut diamonds can be related to the size of the culet facet: a small culet can add 5–10% to the estimated weight of the stone, medium culets 25%, and large culets as much as 35%. When estimating the weight of rose cuts, often the depth is hidden; a rule of thumb is to use 34% of the width as a given depth for such diamonds. Color is reflected in rose cuts more than in brilliant-cut diamonds, so a rose cut should always be graded from the side rather than face-up. When tilting the piece of jewelry, note whether the color in the upper third of the stone has changed. If so, the gem is picking up color from the mounting. JEC

JEWELRY RETAILING

Service with a style. D. Wellman, *Retail Merchandiser*, Vol. 46, No. 12, 2006, pp. 28–29.

Independent retailer O. C. Tanner of Salt Lake City, Utah, is profiled in this report on how to build repeat business. Tanner vice president Curtis Bennett noted that many retailers fail because they regard staff as a labor cost instead of an investment. Many of his employees have been with the operation 15–25 years, which has created a high comfort level among his customer base. Additionally, such long-term employees are knowledgeable and work to make sure customers are satisfied, which creates a strong bond of trust. RS

SYNTHETICS AND SIMULANTS

Emeraude synthétique hydrothermale russe à «givres» [Russian hydrothermal synthetic emerald with “feathers”]. J. M. Arlabosse, *Revue de Gemmologie*, No. 158, 2006, pp. 14–16 [in French].

This note describes the special characteristics of Russian hydrothermal synthetic emeralds. Their standard gemo-

logical properties overlap those of natural emeralds. FTIR spectroscopy, however, shows differences in structural H₂O and the absence of CO₂ peaks in the synthetic material. The included "feathers" also differ from similar inclusions in natural emeralds. RT

Thick single crystal CVD diamond prepared from CH₄-rich mixtures. G. Bogdan [anna.bogdan@uhasselt.be], K. De Corte, W. Deferme, K. Haenen, and M. Nesladek, *Physica Status Solidi (A)*, Vol. 203, No. 12, 2006, pp. 3063–3069.

The authors explored a growth technique for producing high-purity and low-defect synthetic diamonds for both electronics and gemstone applications using single-crystal chemical vapor deposition (CVD). The synthetic diamond films were characterized for surface quality, optical quality, and crystalline defects.

The films were grown on (100)-oriented type Ib substrates in an ultra-pure gas phase in the following conditions: microwave power 600 W, temperature 700°C, pressure 180 torr, methane concentrations 6–16%, and growth rates of 3–4 μm/hr. Thicknesses of 270–730 μm were achieved.

The resulting films were identified as type IIa based on FTIR spectroscopy. Some of the film surfaces were smooth, with surface roughness as low as 0.5–1 nm, as determined by atomic force microscopy. Nomarski contrast imaging showed some of the films to be highly uniform without a mosaic structure. The samples showed cross-shaped birefringence patterns, corresponding to the presence of dislocations; such birefringence is standard for CVD-grown synthetic diamond. Color grading of the samples was performed using a Gran colorimeter, and thinner films had better color grades than thicker films. The authors interpret this to mean that the structural quality and defect density are detrimentally affected with increasing deposition time. [Abstractor's note: This conclusion may be a misinterpretation, since color grading was not normalized to sample thickness.] JS-S

TREATMENTS

The adverse impact of scatter on the tone of Shandong sapphire. L. Jianjun [geoli@vip.sina.com], *Australian Gemmologist*, Vol. 22, No. 10, 2006, pp. 408–412.

Dark-colored sapphires from Shandong Province, China, contain abundant microinclusions that scatter incident light. This effect greatly reduces both the transmission and internal reflection of the light, resulting in a dark tone. During heat treatment, the presence of these inclusions gives rise to fractures due to thermal stress, and some of the inclusions may expand in size, causing a further scattering of light. The author concludes that standard heat treatment cannot be used to lighten the tone of Shandong sapphires. RAH

Bleaching and micro-cracking phenomena induced in various types of sapphires by keV-electron beam irradiations. B.-H. Lee [bhlee@daiyan.pwr.eng.osaka-u.ac.jp], T. Teraji, and T. Ito, *Nuclear Instruments and Methods in Physics Research B*, Vol. 248, 2006, pp. 311–318.

Various natural and synthetic sapphires were irradiated with increasing electron fluence levels, and the resulting irradiation-induced phenomena and cathodoluminescence (CL) spectroscopic measurements were reported. Study specimens included Be diffusion-treated natural sapphires, untreated natural sapphires, and orange, red, and colorless Verneuil synthetics. Each specimen was irradiated at room temperature in a vacuum chamber with a working pressure of 3–5 × 10⁻⁴ Pa using electron beams at various fluences up to ~6 × 10²⁰ electrons/cm².

Increasing levels of electron irradiation produced a reversible color change—or "bleaching"—in all colored specimens and subsequent irreversible "micro-cracking" in the surface and subsurface regions. These changes were dramatically reduced by coating the samples with a thin metal surface layer, which indicates that the phenomena were induced by the presence of accumulated charges in the specimens. Be-diffused samples were the most sensitive to the electron radiation levels; sensitivity of the untreated natural sapphires was variable and sample-dependent. CL studies showed that the intensity of the F⁺-center peak (330 nm) was affected by increasing electron radiation levels, while the Cr³⁺-center peak (697 nm) remained almost unchanged. SW

Change of cathodoluminescence spectra of diamond with irradiation of low energy electron beam followed by annealing. H. Kanda [hisao@nims.go.jp] and K. Watanabe, *Diamond and Related Materials*, Vol. 15, No. 11–12, 2006, pp. 1882–1885.

The authors recorded the effects of irradiation and subsequent annealing on the CL spectra of HPHT-grown synthetic diamonds. The samples were irradiated at 20 kV using a 1000 nA beam current in the CL system, and CL spectra were then recorded using a beam current of 40 nA. The irradiated portions of the synthetic diamond surface showed the development of peaks at 420 and 540 nm along with a broad band centered at ~410 nm. CL peaks at 485, 535, and 545 nm were diminished; however, these peaks were still recorded from nonirradiated sections of the synthetic diamond surface. The CL spectra of the irradiated portions were stable at room temperature for one year, but they showed dramatic changes after annealing at 500°C for 10 minutes. The 420 and 520 nm peaks disappeared, and the 485, 535, and 545 nm peaks reappeared. The broad band at 410 nm that developed during irradiation survived annealing at this temperature. Since the electron beam energy of 20 kV was deemed too low to create new defects such as vacancies and interstitials, the authors surmised that the observed changes in the CL spectra are related to the ionization of defects. SE-M

MISCELLANEOUS

The age of gold: A day out. J. Ogden, *Gems & Jewellery*, Vol. 16, No. 2, 2007, pp. 12–13.

A trip by Swiss researchers to pan for gold in the river sands of the Grosse Fontanne near Lucerne yielded gold grains that contained unexpectedly high levels of trapped helium, results that were confirmed by a comparison to native gold from other sources. The helium is believed to arise from the radioactive decay of uranium. Further development of this dating technique may provide a rough method for dating gold samples, since any trapped helium would be released by heating and working of the gold. The method may never be more accurate than specifying either “many centuries old” or “new,” but it should be sufficient for evaluating authenticity as an adjunct to traditional art historical, technical, and analytical approaches. RAH

Diamond and jewelry industry crime. K. Ross, *FBI Law Enforcement Bulletin*, February 2007, pp. 17–21.

Jewelry was among the fastest-growing categories of stolen property in the U.S. between 1999 and 2003, ranking second in value behind automobiles. The enormous number of jewelry outlets, manufacturers, and wholesalers provides favorable conditions for criminals to steal jewelry and funnel it back into the legitimate market. The high value of these goods also makes them attractive for storing and moving proceeds of crime in ways that are difficult to detect by authorities.

Several factors hinder law enforcement’s ability to clamp down on jewelry crime, including the easy concealment of diamonds and jewelry and their untraceability. Identifying stolen products is difficult because law enforcement agencies typically have only a limited knowledge of these items, such as the Four Cs of a diamond. Without the ability to identify specific characteristics, authorities find it very difficult to track such goods. In addition, their lack of knowledge and training in diamonds may make it difficult to properly enforce Kimberley Process legislation, in both the U.S. and Canada.

The growing diamond mining industry in Canada also is creating new criminal opportunities. By analogy, South Africa’s diamond mining industry loses approximately 12% of its annual production to theft, and a similar percentage in Canada would total \$180 million. RS

The secret world of diamonds. G. Kennedy, *ACCJ Journal*, Vol. 43, No. 12, 2006, pp. 40–45.

The diamond industry in Antwerp is changing. The trade, once dominated by Hasidic Jews, is now giving way to Indian firms that years ago had served as cutting contractors for lower-quality rough. The Indian companies now control about 70% of Antwerp’s trade by volume. However, Antwerp manufacturers still specialize in the difficult goods and precisely cut premium stones.

The article also discusses how the traditional secrecy of the diamond world deters attempts to create investment vehicles from diamonds, although one firm has launched a diamond-based fund. It further discusses the conflict diamond issue from a variety of viewpoints. RS

Widespread lead contamination of imported low-cost jewelry in the U.S. J. D. Weidenhamer [jweiden@ashland.edu] and M. L. Clement, *Chemosphere*, Vol. 67, No. 5, 2007, pp. 961–965.

The significant dangers of lead exposure, especially in children, have been known for decades, but most research has focused on lead contained in paint and gasoline. However, several recent incidents of fatal lead poisoning in children have directed attention toward the lead content of low-cost imported jewelry.

The authors obtained 139 pieces of inexpensive (<\$10) jewelry from retail stores in Ohio, Delaware, Florida, and Michigan. Almost all (130) were imported from China, with the remainder from India (2), South Korea (3), or unknown sources (3). Each item was tested to determine both its total lead content and the accessibility of the lead to acid leaching (to simulate dissolution in the digestive tract).

The results were divided between jewelry that was manufactured in accordance with federal standards (0.06 wt.% lead) and that containing dangerous levels of lead. Although somewhat less than half of the tested items (41.4%) were below the limit, more than half of the assayed items contained ≥ 50 wt.% lead, and almost a quarter (24.1%) exceeded 90 wt.%. Six of 10 samples tested for lead leachability exceeded the U.S. Consumer Product Safety Commission guidelines.

The authors speculate that the source of the lead is likely scrap metal, possibly from recycled electronic waste. Given the high neurotoxicity of lead to young children, they conclude that such inexpensive pieces of jewelry pose a threat to children’s health. TWO

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