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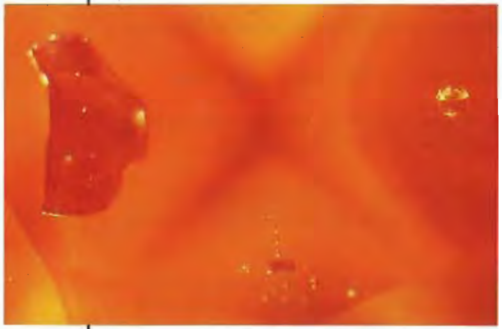

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FEATURE ARTICLE

NOTES AND NEW TECHNIQUES

REGULAR FEATURES

ABOUT THE COVER: I. Snowman's circa-1910 portrait of Her Royal Highness Queen Alexandra, consort of King Edward VII of England, shows the plethora of jewelry worn by ladies from the royal and wealthy upper classes of Europe and America at the turn of the 20th century. Alexandra's neck is wrapped with a pearl choker and many pearl necklaces; the longest sautoir is pinned up in a swag effect using a pearl-and-diamond brooch. The gauzy tulle that decorates her décolletage is held in place by pins and brooches of every size and type, including a diamond star burst, a crescent, and two ruby-and-diamond bow brooches on either side of her neckline. Note the gold snake bracelet adorning her left wrist. The lead article in this issue examines the styles, materials, and motifs of the elegant jewels favored by the distinctive group known as the Edwardians, who reigned as the leaders of high fashion in the late 19th and early 20th centuries.

The painting is courtesy of A. Kenneth Snowman, Wartski, London.

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The Spring 1993 issue featured the seventh annual *Gems & Gemology* Challenge, and our readers responded in record numbers, from all over the world. We are proud to list, below, the names of those who earned a perfect score.

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Answers: (see pp. 65 and 66 of the Spring 1993 issue for the questions):(1) D, (2) B, (3) B, (4) C, (5) D, (6) B, (7) C, (8) B, (9) D, (10) A, (11) A, (12) D, (13) C, (14) D, (15) D, (16) B, (17) C, (18) B, (19) B, (20) B, (21) A, (22) A, (23) D, (24) A, (25) B.

LETTERS

BLUE COLOR IN SAPPHIRE CAUSED BY FE^{2+}/FE^{3+} INTERVALENCE CHARGE TRANSFER

It is widely accepted that the blue color in sapphire is due to Fe^{2+}/Ti^{4+} charge transfer, often accompanied by Fe^{2+}/Fe^{3+} intervalence charge transfer (IVCT; Schmetzer and Bank, 1981; Fritsch and Rossman, 1988). However, to date the extent of the contribution of the Fe^{2+}/Fe^{3+} IVCT to the color of sapphire has not been established, since no sapphire has been reported in which this chromogen contributes the primary absorption. We are now writing to report that such material has recently been studied, and it proves that Fe^{2+}/Fe^{3+} IVCT alone can produce a blue color in sapphire.

The two grayish blue sapphires examined are 1.57 ct and 1.19 ct (figure A). Their U.V.-visible-near infrared spectra (figure B) reveal a broad band centered at 890 nm, which corresponds to the broad band centered at 870 nm that has been attributed by Ferguson and Fielding (1971) and Schmetzer and Bank (1981) to Fe^{2+}/Fe^{3+} IVCT. The other distinct features—at 376, 388, and 451 nm—are due to the Fe^{3+} ion or to Fe^{3+} pair transitions, according to the same researchers. The spectra shown in figure B exhibit little or no absorption due to Fe^{2+}/Ti^{4+} (which typically occurs at approximately 560 nm), although the stones appear distinctly grayish blue. To our knowledge, this is the first time that Fe^{2+}/Fe^{3+} intervalence charge transfer has been demonstrated to cause blue color in sapphire. Note that the blue color generated by this mechanism appears to be significantly grayer than the color produced by Fe^{2+}/Ti^{4+} charge transfer.

Figure A. These two grayish blue natural sapphires are colored primarily by Fe^{2+}/Fe^{3+} intervalence charge transfer. Stones from Rwanda courtesy of Jean-François Damon, Twin Gems, Washington, DC. Photo by Robert Weldon.

Further investigations are being conducted into the polarized absorption spectra of these samples and the response of the Fe^{2+}/Fe^{3+} IVCT absorption to various treatment processes. Fe^{2+}/Fe^{3+} IVCT plays a major role in the color of many dark blue sapphires from basaltic origins, such as localities in Australia, China, Thailand, and Cambodia (Schmetzer and Kiefert, 1990; Poirot, 1992). Many such sapphires would benefit from having their color lightened, but traditional heat-treatment processes—designed to reduce the Fe^{2+}/Ti^{4+} charge-transfer absorption in sapphires of metamorphic origin (from localities such as Sri Lanka, Myanmar,

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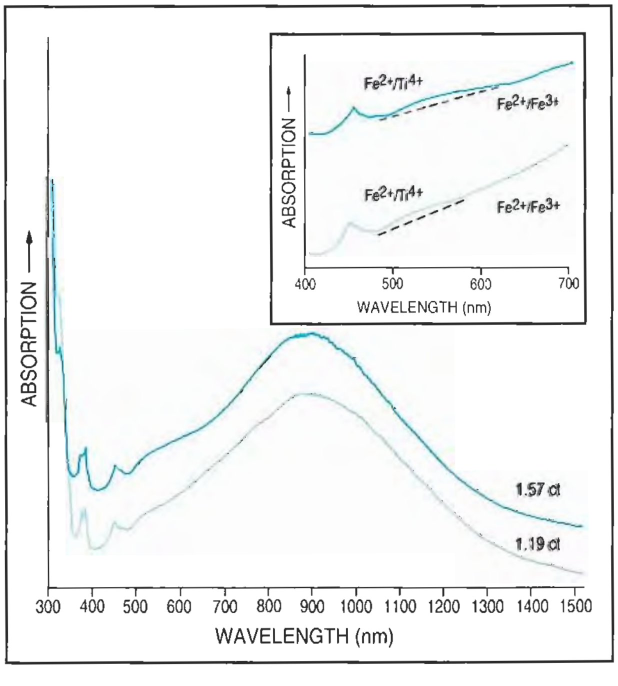
Figure B. The directional U.V.-visible-NIR spectra of the two grayish blue natural sapphires show that their color is primarily due to Fe^{2+}/Fe^{3+} intervalence charge transfer, with a maximum absorption centered at approximately 890 nm. The inset illustrates that the Fe^{2+}/Ti^{4+} charge transfer does not play a significant role in the coloration of these stones, as shown by the height of its absorption peak superimposed on the Fe^{2+}/Fe^{3+} absorption, indicated by the dotted line. The spectra were taken on a Hitachi U4001 spectrophotometer in the table-to-culet direction of each stone, approximately perpendicular to the optic axis.



JEWELS OF THE EDWARDIANS

By Elise B. Misiorowski and Nancy K. Hays

Although the reign of King Edward VII of Great Britain was relatively short (1902–1910), the age that bears his name produced distinctive jewelry and ushered in several new designs and manufacturing techniques. During this period, women from the uppermost echelons of society wore a profusion of extravagant jewelry as a way of demonstrating their wealth and rank. The almost-exclusive use of platinum, the greater use of pearls, and the steady supply of South African diamonds created a combination that will forever characterize Edwardian jewels. The Edwardian age, truly the last era of the ruling classes, ended dramatically with the onset of World War I.

ABOUT THE AUTHORS

Ms. Misiorowski is a senior research librarian at the Gemological Institute of America, Santa Monica, California; Ms. Hays, former assistant editor of Gems & Gemology, *is associate editor at Jems Communications, Carlsbad, California.*

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Over the last decade, interest in antique and period jewelry has grown dramatically. Not only have auction houses seen a tremendous surge in both volume of goods sold and prices paid, but antique dealers and jewelry retailers alike report that sales in this area of the industry are excellent and should continue to be strong (Harkness et al., 1992). As a result, it has become even more important for jewelers and independent appraisers to understand—and know how to differentiate between—the many styles of period jewelry on the market.

Although a number of excellent books have been written recently on various aspects of period jewelry, there are so many that the search for information is daunting. The purpose of this article is to provide an overview of one type of period jewelry, that of the Edwardian era, an age of prosperity for the power elite at the turn of the 19th century.

There are differing opinions in the literature as to the period that constitutes the Edwardian era. Some sources state that, strictly speaking, because it is named for Edward VII of England, it could only encompass the years that he was on the throne, 1902–1910 (e.g., Minney, 1964). However, although Queen Victoria ruled the British Empire until she died in 1901, she withdrew into deep mourning following the 1861 death of her beloved husband, Prince Albert, leaving societal functions by default to her son. Therefore, others state that Edward's influence on society started in 1863, when he married the Danish princess Alexandra and they began to entertain at Marlborough House (Menkes, 1989). For the purposes of this article, however, we have chosen 1880–1915. By the 1880s, Edward and Alexandra were the accepted leaders of society in England, setting standards of dress and etiquette for all to follow. In contrast to the repressive regimentation of Edward's youth, the pace of life at Marlborough House and at their country estate, Sandringham, was a fast and furious round of entertaining that included card parties, dinners, masquerade

Figure 1. Jewels worn by the highest social classes of England, Europe, and America at the turn of the century shared a quality of workmanship and materials that is distinctive of the Edwardian era. Although fine Victorian-style pieces, like this ruby-and-diamond butterfly brooch set in silver on gold, were still worn, the wealthy members of Edwardian society gradually moved toward jewelry composed primarily of platinum, diamonds, and pearls. The delicate pearl and diamond necklace shown here exhibits the scroll and floral motifs typical of the garland style; calibrated emeralds made their first appearance in jewels of this period. The sapphire and diamond chain bracelet by Cartier has a popular star motif for its center link. Jewelry courtesy of Frances Klein Antique and Estate Jewels; photo © Harold and Erica Van Pelt.

balls, and weekend hunts. Edward and Alexandra also took up the social duties of charity events, exhibition openings, and other functions that required representation by the crown. Because England was a dominant world power and because the heads of state of many other European countries, including Russia and Prussia, were linked to England by marriage, Edward's influence extended far beyond the British Isles. The lifestyle that he and Alexandra established for themselves—and that was adopted by others in the upper classes of England, Europe, and America—continued for about five years after Edward's death, ending with the harsh realities brought on by the onset of World War I. During this timespan, 1880–1915, a certain way of wearing jewelry evolved to suit the pomp and splendor of the royal court. Much of this jewelry had specific design elements and materials that set them apart as pieces worn by this privileged class (figure 1).

Many terms have been used to describe the style of jewelry of this time. *Fin de siècle,* French for "end of the century," is a fairly broad designation that could encompass any of the styles made during this time, not just those worn by the upper classes. *Belle Époque,* French for the "beautiful age," refers generally to the time of prosperity and luxury for the upper classes that marked the decades prior to and just after 1900. Frequently, the term *garland* is used to describe the jewelry of this period, because floral garlands and wreaths are a prevalent motif in Edwardian-era jewels. The following overview looks at the garland and other styles of jewelry favored by the highest classes of Edwardian England and their counterparts in other Western countries. Distinct from the more conservative Victorian styles that preceded Edward and Alexandra, from the sinuous Art Nouveau styles of their avant garde contemporaries, and from the geometric Art Deco styles that evolved after World War I, Edwardian jewelry has its own very special character.

BIRTH OF A STYLE

The 19th century was a time of extraordinary change. Technological advances included the development of steel, railroads, steamships, the telephone, and electricity. These radical inventions profoundly changed the style and quality of life ("Marvels of the nineteenth century," 1899).

The introduction of electricity into homes of the wealthy exposed the overdone Victorian clothes and ponderous furnishings to harsh scrutiny. The heavy brocades and velvets in somber hues of maroon, purple, dark blue, and brown, which had appeared so rich by gaslight or candlelight, looked dull and outdated in the brightness of electric light. To compensate, clothing fashion shifted to the use of rustling silks, luscious satins, and gauzy fabrics in soft, pastel shades of mauve, pale pink, peach, straw yellow, light green, sky blue, and lavender (Nadelhoffer, 1984). The fussy bustle of the 1870s and 1880s gave way to the smooth hourglass silhouette. Women of the 1890s appeared as regal swans, in fashions that enhanced rather than altered the feminine figure (Bennett and Mascetti, 1989).

Figure 2. This majestic tiara, crafted by Cartier around 1910, is an excellent example of the garland style for which the firm was noted. The combination of scroll and foliate motifs worked in platinum and diamonds makes a particularly grand impression, while the central design offers hints of the exotic East. Photo courtesy of Cartier.

The change in clothing fashions was mirrored by a change in jewelry fashions as well. During the late 1800s, several styles of jewelry—Victorian, Art Nouveau, and the garland style—evolved and overlapped. Members of Edwardian society wore a mixture of Victorian and garland jewels (again, see figure 1), but they generally shunned the Art Nouveau style, with its sensuous curves and frequently bizarre subject matter, as being vulgar and decadent (Misiorowski and Dirlam, 1986). Edwardians wanted jewelry of an imperial style that would demonstrate their wealth and status even as it reflected their lifestyle of ease and luxury.

The *haute* jewelers of the era developed the garland style specifically for the social elite. The garland style is characterized by a look that is light and lacy, yet imparts a sense of majesty in the intricacy of the designs and its use of diamonds and pearls. It melds design elements taken from classical Rome and Greece, from the baroque and rococo styles of the French kings, as well as from Napoleonic Directoire and Second Empire ornamentation. Typical motifs include scrolls, feathers, tassels, swags of foliage, garlands of flowers, ribbons tied in flowing bowknots, triumphal laurel wreaths, and Greek keys. In general, these motifs are not obvious, but are subtle and in good taste.

Louis Cartier is well documented as one of the designers who first interpreted those classical elements and developed the garland style (Nadelhoffer, 1984). He made sketches and drew ideas from ornamentation on building façades and furniture, as well as from paintings, textiles, and sculpture. Later, as a result of his travels and trade in the East, Cartier took inspiration from Indian, Chinese, and Arab cultures. Islamic grilles and Chinese gongs were some of the motifs incorporated into Cartier jewels (figure 2).

Other prestigious jewelers of the time—among them Garrards and Hennells in England, Tiffany and Marcus Co. in the U.S., Fabergé in Russia, and Boucheron, Chaumet and Lacloche in France—also

Figure 3. In early platinum Edwardian jewels (left), gold backings were often fused to the mounting (right), as their silver counterparts had been "backed" during the Victorian era. This approximately 7.70-ct pink topaz brooch also shows the asymmetric rococo scroll and floral motifs prevalent in garland-style jewels. The piece is signed by J. E. Caldwell & Co. Courtesy of Linda Raymond; photo © GIA and Tino Hammid.

made jewels and jeweled objects that incorporate garland-style elements (Vever, 1908; Bennett and Mascetti, 1989). In this light and delicate, yet triumphal style, jewelers developed a predominantly monochromatic look that would complement the new fashions and blend with any color. Platinum, diamonds, and pearls were the signature elements for these imperial jewels.

MATERIALS USED IN EDWARDIAN JEWELS

Platinum. This precious metal was first discovered by European explorers in the 16th century, in what is now Colombia, and is known to have been used for decorative objects in 18th-century courts. Because of platinum's very high melting point, its use in jewelry was difficult, if not impossible, until the technology for jewelers' torches improved in the mid-19th century. Before this time, diamonds were usually set in polished silver to set off the whiteness of the stone. Silver, however, tarnishes with time, which eventually makes jewels look dark and dingy. After the 1880s, when major deposits were discovered in Russia's Ural Mountains, platinum began to replace silver as the metal of choice for setting diamonds. Cartier's records show that platinum was being used in tiepins and earrings in the 1880s, and in necklaces by 1890 (Nadelhoffer, 1984). Jewelry exhibited at the Paris Universal Exhibition of 1889 used platinum as the claw settings for diamonds (Bury, 1991). Initially, platinum was simply substituted for silver in diamond or pearl mountings. Just as silver mountings had been backed with gold to protect the wearer's skin and clothing from tarnish, so platinum was also gold-backed—an equal thickness of platinum fused to an equal thickness of gold—in pieces made before 1900 (figure 3). Platinum was not initially recognized as a precious metal, so in the early years of its use the gold backing also served to give the piece credibility (Nadelhoffer, 1984). By 1900, platinum had gained acceptance, and most important jewels were made completely of platinum without the technically unnecessary gold backing.

Platinum has distinct advantages for use in jewelry. Not only is it nontarnishable (unlike silver), but it is also harder and stronger than either silver or gold, so it can be worked to a very delicate thickness while still maintaining its shape. These characteristics made platinum particularly adaptable to the piquant garland style, with its lace-like flowers and flowing ribbons, allowing jewelers to create pieces that would accentuate the feminine qualities of the women who wore them. Gems seemed to float, held securely in collets on knife-edged wires. Every visible edge of metal was worked with hand-engraved details or so as to appear beaded. This latter technique, called millegrain, added an extra glimmer to the fine settings (Becker, 1987). Other techniques, like saw-piercing, produced fragile-appearing confections of great delicacy that were, nevertheless, extremely rigid. Using a saw blade as fine as a single hair, jewelers would pierce a sheet of platinum to create lace-like patterns. These were then further embellished with gems, usually diamonds (Hinks, 1983). The desired result was often to imitate the fine petit point embroidery that many ladies wore. By 1900, jewels made of platinum were masterworks of engineering that would have been impossible in either gold or silver. The extraordinary quality of workmanship in platinum jewels made in the early 1900s is one of their distinguishing features (Hinks, 1989).

Diamonds. The first authenticated report of a diamond discovery in South Africa was in 1867 (Bruton, 1978). Mining commenced in earnest in the 1870s and, by the 1880s, South African diamonds were pouring into the European market to such an extent that prices plummeted. The establishment of De Beers Consolidated Mines, Ltd., in 1888 stabilized prices and brought order to the marketplace. Diamonds ultimately became indispensable to the garland style, and were in tremendous demand. When the Boer War (1899–1902) forced the closure of the South African mines, De Beers found a ready market for their reserve stock, despite charging a 30% premium (Bury, 1991).

Figure 4. Fancy-colored diamonds were occasionally used in the delicate garland-style jewels favored by the Edwardians. These pear-shaped fancy blue diamonds, 2.66 and 2.98 ct, are set in a fine millegrain platinum mounting that is further embellished with numerous small diamonds. Signed by T. B. Starr. Courtesy of Christie's, New York; photo © Tino Hammid.

Supply, coupled with advances in diamond-cutting technology and a greater understanding of crystal optics, stimulated the development of new cuts. Prior to 1900, most diamonds were cut in rose, old mine, round brilliant, oval, cushion, and pear or pendeloque shapes. After 1903, the marquise, or navette, cut came into popular use (Hinks, 1983). Its shape suggests the hull of a racing yacht, a favorite pastime of King Edward VII and many of his wealthy contemporaries. The emerald cut was also developed at about this time; variations were the baguette, kite, and triangular step cuts. Another cut seen frequently in garland-style jewels was the briolette, a fully in-the-round drop-shaped adaptation of the rose cut. The briolette cut was a good way to use diamonds of lower color and clarity (Hinks, 1983). Fancy-color diamonds are also found in Edwardian jewels: Pinks, yellows, blues, and browns were unusual but favored as novelties (figure 4).

The South African mines produced not only enormous quantities of diamonds, but many large diamonds as well. These include the 90.38-ct D-color Briolette, the 127-ct emerald-cut Portuguese, and the 154-ct crystal known as the Porter Rhodes. There is even speculation that the famed 94.80-ct D-color Star of the East, purchased by American heiress Evalyn Walsh McLean (figure 5) from Pierre Cartier in 1908, reportedly with an exotic provenance, was actually a relatively "recent" South African stone (Krashes, 1988). The largest and most famous diamond found in South Africa during this period, however, is the Cullinan. The 3,106-ct rough stone was found on January 25, 1905, at the Premier Mine; it was presented to King Edward VII on his 66th birthday, November 9, 1907 (Magnus, 1964). Cut by the Dutch firm I. J. Asscher, the Cullinan yielded nine major stones, 96 small brilliants, and approximately 10 carats of "unpolished ends" (Field, 1987). The king named the Cullinan I the Great Star of Africa and had this 530.20-ct pear-shaped gem mounted in the British Royal Scepter, where it remains to this day. The Cullinan II, a

317.40-ct cushion cut, was mounted in the brow of the British Imperial State Crown (Balfour, 1992).

Pearls. At the turn of the century, pearls were a relatively rare commodity that in fine quality commanded very high prices. Until the culturing of round pearls was perfected in the 1920s, and large quantities reached the marketplace, prices for matched, natural pearls equaled or exceeded those for diamonds. In 1910, the sources for the finest white pearls, preferred by Western society, were Bahrain in the Persian Gulf, Ceylon (now Sri Lanka), and Australia. Freshwater pearls came from Ohio and the Mississippi River valleys of Wisconsin, Tennessee, and Arkansas, as well as from the Tay and other rivers in Scotland. Black pearls were still considered something of a novelty, although they were first introduced to Europe in the mid-1800s; these came from Tahiti and Panama (Kunz, 1908).

Every wealthy Edwardian woman had at least one strand of fine pearls. At her coronation in 1902, Queen Alexandra wore several strands. Two hung from around her neck, while others were pinned at either side of her bodice to cascade down the front. Some of these were historic pearls that had belonged in turn to France's Queen Catherine de Medici, to Mary, Queen of Scots, and to Queen Elizabeth I of England. In fact, an important provenance was part of the charm of many of the pearls sold during this period. Wealthy American heiress Consuelo Vanderbilt, who became the Duchess of Marlborough, frequently wore a strand of pearls that had once been the property of both Catherine the Great of Russia and Empress Eugénie of France (Bury, 1991). Being able to recite the history of one's pearls provided the new owner with a romantic link to the past, and many beautiful strands were sold with a story attached (Nadelhoffer, 1984).

Figure 5. In this photo, taken around 1912, American heiress Evalyn Walsh McLean is wearing the 94.80-ct Star of the East diamond set as an aigrette attached to a diamond bandeau. On her neck is the 45.52-ct Hope diamond. She purchased the Star of the East in 1908 and the Hope in 1911, both from Cartier. Notice the long sautoir of pearls she is wearing around her neck and how her dress is decorated with freshwater pearls. Photo courtesy of Laurence Krashes, Harry Winston, Inc., New York.

Colored Stones. During the Edwardian era, gems of all types were plentiful, and there were many new discoveries. Although diamonds and pearls were used most frequently, many fine colored stones are also seen in Edwardian jewelry (figure 6). The settings almost always incorporated diamonds as accent stones, and often pearls as well. As pale tones of purple (mauve, lilac, lavender, and heliotrope) were Alexandra's favorite colors, amethyst was the colored stone she preferred (Hinks, 1983). The Ural Mountains of Siberia were the source for demantoid garnet, pink topaz (again, see figure 3), and amethyst. At the end of the 19th century, sapphires were coming from Kashmir (figure 7), Ceylon (Sri Lanka), Australia, and the U.S. The American "New Mine" sapphires found in Yogo Gulch, Montana, in 1890 were particularly popular because they reputedly stayed blue in artificial light, rather

Figure 6. These brooches and pendants illustrate some of the ways colored stones appear in jewelry worn by Edwardian ladies. The use of many diamonds or pearls as accent stones softens the bright colors for wear with pastel fashions. The motifs shown here were particularly popular at the turn of the century (clockwise from top left): a diamond-set crescent brooch; a peridot, pearl, and diamond shamrock; a jabot brooch with sapphire and diamond "terminals"; a heart-shaped amethyst set in a gold bow brooch with seed pearls; and an enameled swallow carrying a delicate diamond-and-platinum garland. Jewelry courtesy of Frances Klein Antique and Estate Jewels; photo © Harold & Erica Van Pelt.

than appearing black like those from Australia, or purple like those from Ceylon (Hinks, 1983). Yellow sapphires (probably from Ceylon) appeared on the market in 1908. Other widely used gems were peridots from St. Johns Island (allegedly King Edward's favorite gem; Hinks, 1989), rubies from Burma, emeralds from Colombia, and turquoises from Persia. Turquoise was believed to be lucky, and every Edwardian lady at the turn of the century had at least one jewel set with "a bit of blue" (Hinks, 1983).

Following closely on the discovery of significant tourmaline deposits in California in 1903, kunzite (the pink variety of spodumene) was identified by and named for George Frederick Kunz in 1904. Three years later, in 1907, Kunz identified the pink variety of beryl and named it morganite in honor of wealthy American financier and gem collector J.(ohn) P.(ierpont) Morgan. Aquamarine and red spinel are also found in Edwardian jewelry.

The Edwardians loved novelty jewels and, to judge by the numbers of phenomenal gems that appear in men's stickpins and in the novelty brooches that women wore, were fascinated by unusual stones. Australian opals perfectly accented the pastel color palette of Edwardian clothes and were often incorporated into jewelry as flower petals or butterfly wings (Armstrong, 1973). Russian alexandrite, Mexican fire opal, Ceylonese moonstone, and cat's-eye chrysoberyl are other phenomenal gems that were widely used in jewelry worn by the Edwardian set (Hinks, 1983, 1989).

Cutting styles for colored stones were the same as for diamonds, with the addition of cabochon cuts and beads. During the Victorian era, Europeans used cabochon cuts primarily for garnets, moonstones, and opaque materials. With the consolidation of British power in India during the 18th and 19th centuries, many Indian jewels containing cabochon-cut rubies and emeralds were sent back to England as tribute to the Crown. Edward brought back caskets of jewels for Victoria and Alexandra from his 1875–76 visit to India, and Victoria became Empress of India in May of 1876. These events, followed by the durbars (formal state ceremonies) held in Delhi for the coronations of King Edward VII in

1902, and King George V in 1911, promoted the use of fine emeralds, rubies, and sapphires cut *en cabochon* in Edwardian jewels (Menkes, 1989).

Some high-quality solitaire stones, often cushion or pear shaped, were ringed with calibrated cut gems. Before the Edwardian period, only turquoise, garnet, and coral were cut and set in calibration. Now, however, caliber-cut diamonds, emeralds, rubies, and sapphires were channel set to accent a fine single gem or to enhance the design (again, see figure 1), while the mounting would be further embellished with millegrain and engraved details.

EDWARDIAN JEWELS

Tiaras. Although not new to the Edwardian era, tiaras played a particularly important role in Edwardian society. The tiara was an outward symbol of status that immediately identified its wearer with the monied, power elite. As with most aspects of Edwardian life, rules of etiquette strictly governed the wearing of tiaras. Primarily an evening jewel, tiaras were mandatory for court functions and even for dinner if royalty was to be present. The height of the tiara also had to be in keeping with the wearer's age and social rank (Neret, 1988). The Duchess of Marlborough wrote in her diary of an evening when she arrived at a dinner in honor of the then Prince and Princess of Wales wearing a diamond crescent in her hair instead of a tiara. Prince Edward chided her by saying "The Princess [Alexandra] has taken the trouble to wear a tiara, why have you not done so?" The duchess hastened to explain that charitable work had detained her and that she had arrived at the bank, where she kept her tiara for safekeeping, too late to retrieve it (Nadelhoffer, 1984).

Figure 7. Exceptional colored stones, like this 32.52-ct Kashmir sapphire, were appreciated by the Edwardian elite. This brooch, dated circa 1905, shows the fine workmanship characteristic of platinum mountings of the era. Courtesy of Christie's, New York; photo © Tino Hammid.

Tiaras became more elaborate as the Edwardian age advanced. In the 1880s and 1890s, tiaras were typically a graduated row of gabled points. These points would often be topped with five to seven stars, trefoils, flower heads, or other simple motifs that were detachable to wear singly as brooches. In some cases, a fringe necklace was made so that by fitting it to a rigid frame, it could also be worn as a tiara (figure 8).

The imperial Russian tiara, or kokoshnik, was highly fashionable in the 1890s (Bennett and Mascetti, 1989). Designed after the peasant woman's headdress known as *kokoshnik* (cockscomb in English), the royal version was fashioned from platinum, with several straight, narrow rays set with diamonds and graduated evenly from back to a high center front. The *tiara Russe,* as it was also called, produced a halo-like effect, radiating light from the wearer's head. Princess Alexandra was given a Russian imperial tiara by the Ladies of Society for her silver wedding anniversary in 1888; 365 ladies contributed to its purchase (Scarisbrick, 1989).

For the coronation of Edward VII, the peeresses had obtained permission to wear tiaras as well as their coronets which, as one observer noted, had the dubious effect of a man attempting to wear two hats (Scarisbrick, 1989). Ever resourceful, the Duchess of Marlborough had a small coronet made that she could place smoothly on her head behind her tiara at the moment that Queen Alexandra was crowned (figure 9). There was much fumbling on the part of the other peeresses who hadn't had the foresight to account for size and placement of both tiara and coronet (Bury, 1991).

In the early 1900s, winged tiaras were popular, perhaps because of the invention of airplanes. Wings as a motif could also be a classical allusion to the Greek god Hermes, or to the Valkyries from Wagner's opera, *The Ring of the Nibelungen.* Other classical themes of triumph were frequently incorporated in tiaras of this time, such as laurel wreaths, olive branches, oak leaves and acorns, acanthus leaves, wheat sheaves, and the Meander or Greek key. Many other types of foliage were also

Figure 8. Convertible jewelry allowed expensive pieces to be used in several ways. Here, a single piece is shown both as a tiara and as the fringe necklace to which it converts. Note the gabled points popular for tiara design in the 1880s; the knife-edged platinum settings for the larger diamonds give the illusion that the gems are floating in air. Courtesy of Port Royal Antique Jewelry; photo © Harold & Erica Van Pelt.

used: strawberry leaves (which denote ducal rank; *Debrett's Peerage,* 1952); shamrocks; thistle heads; roses, daisies, and other flowers; as well as flowering garlands and wreaths tied up with flowing ribbons. The sun tiara was another grand style similar to a kokoshnik: diamond-set platinum spikes radiating in a fan shape from a large diamond set in the center. The wealthy industrial families of America, such as the Vanderbilts, Morgans, Goulds, and Rockefellers, came late to the style of wearing tiaras and did their best to outdo Europe in grandeur. They felt that tiaras were an excellent outward expression of financial clout: the more impressive the better (Nadelhoffer, 1984).

Tiaras continued to be worn in Great Britain and the United States until 1915, even though on the continent after 1910 they were superseded in popularity by the bandeau and the aigrette. These two styles were considered more modern and less formal than the tiara, with the added advantage of being lighter in weight, so they were more comfortable (Bury, 1991). Bandeaux were generally worn straight across the forehead rather than on top of the head. Made of flexible platinum sections set with diamonds, bandeaux were tied with ribbons at the back of the head to fit snugly. Bandeaux were sometimes designed in a streamlined, geometric pattern, foreshadowing the Art Deco period of the 1920s, when bandeaux were the most popular form of headdress.

Feathered head ornaments have long symbolized rank and status. They became important in Europe in the 17th century, and by the 19th century wearing feathers was mandatory for presentation at court in England. Interaction with exotic Eastern cultures further stimulated the fashion, and by the 1890s, aigrettes were popular for evening dress at other than formal court presentations (Nadelhoffer, 1984). Aigrettes were made of feather plumes from the Egyptian egret (hence, the derivation of the name), although ostrich or bird-of-paradise feathers were also used. These plumes were held in a jeweled mounting that could be fastened to a tiara (Nadelhoffer, 1984). During the later years of the Edwardian era, they were also adapted to attach to narrow bandeaux so they could be worn with the feathers in front (again, see figure 5), in back, or rakishly over one ear (Hinks, 1983). This fashion was stimulated in great part by the Ballet Russe's performance in 1910 of Diaghilev's ballet "Scheherezade." Set in a Sultan's seraglio, it featured dancers resplendent in harem pants and feathered plumes which fired the imagination of clothing and jewelry designers alike.

Jeweled combs (figure 10) and brooches pinned through a rosette of tulle or lace were other, less formal ways a lady could dress up her coiffure. Diamond bowknot brooches were often used for this purpose. *Á la Diane* (in reference to the Roman goddess of the hunt, Diana) was the French term used to describe the style of wearing a crescent brooch in the hair (Hinks, 1989), a fashion that appeared in the 1880s and persisted through the turn of the century.

Figure 9. Her Grace, the Duchess of Marlborough, is dressed in formal regalia for the coronation of King Edward VII in 1902. Note the pearl sautoir wrapped twice around her neck and shoulders, the additional pearl necklaces, the 15-strand choker necklace, and her ducal coronet sitting neatly inside her pearl and diamond tiara. She is also wearing a 3-in. (7.5-cm) wide belt of diamonds and a pearl and diamond crescent brooch. Photo from Kunz and Stevenson (1908).

Figure 10. For a less formal evening when a tiara was not mandatory, an Edwardian lady might wear a diamond-set comb in her hair. Other jewels for evening would usually include a platinum, diamond, and pearl dog collar, as well as a number of elegant brooches like this diamond-set platinum bow brooch. Jewelry courtesy of Frances Klein Antique and Estate Jewels; photo © Harold & Erica Van Pelt.

Necklaces. Fringe necklaces were very popular in the 1880s and 1890s, and continued to be worn after the turn of the century. As noted above, these

Figure 11. A rivière of diamonds immediately identified the wearer as someone of exceptional wealth. Usually large, round diamonds (graduating down in size from the largest—center—stone) were set singly in simple collets. Although rivières generally ranged in length from about 16 ins. to 24 ins.(41 to 61 cm), this example is a tight choker of about 13 ins. (33 cm). The center stone weighs 37.82 ct, and the diamonds weigh a total of approximately 210 ct. Courtesy of Christie's, New York; photo © Tino Hammid.

necklaces were sometimes fashioned so they could also be worn as tiaras (again, see figure 8). Another favored accessory of the elegant Edwardian lady was the rivière, a necklace of gems (usually diamonds) set singly in either collets or openwork gallery mountings, typically graduated from a large center stone. This fashion, initiated in the 1700s, was the ideal way to display many large, fine gems in a grand show of wealth (figure 11). However, the necklace that is by far the most evocative of the Edwardian period is the choker—or "dog collar," as it was generally known (Bennett and Mascetti, 1989). The 18th-century fashion of wearing a ribbon around the neck was reintroduced in Paris in the mid-19th century, when wide ribbons, usually black velvet or moiré silk, were worn and commonly decorated with a brooch or locket. Princess Alexandra further popularized chokers, which she wore to conceal a scar on her neck (Field, 1987). The rest of society copied her and the fashion took hold. Even though they are uncomfortable, dog collars remained popular through 1915 (Hinks, 1983). The most common type was a gem-set plaque, also known as a *plaque-de-cou*, 2–4 ins. (5–10 cm) wide that was worn on a wide ribbon of black velvet or held snugly by a multi-strand pearl choker with narrow diamond spacers (again, see figures 9 and 10). Occasionally, dog collars were made entirely of hinged platinum sections set with diamonds and other accent gems (figure 12). Fit for dog collars was crucial. If they were too loose, the necklace would sag and the effect would be ruined; if they were too tight, the wearer would have difficulty breathing or swallowing (Bury, 1991).

Dog collars were frequently worn together with other necklaces, most commonly long strands (also known as sautoirs) of pearls, which often hung to or below the waist. Depending on their length, these

Figure 12. This exquisite bowknot necklace by Cartier is an excellent example of the segmented platinum and diamond dog collar that became popular around 1910. The lace-like floral motifs and the detailed millegrain work are typical of the garland style. Photo courtesy of Sotheby's, New York.

could be looped loosely once or twice around the neck, pinned with a gem-set brooch in a swag effect to one side of the bodice (see cover), or tucked into the waistband of the skirt. Often they were allowed to hang free (figure 13). Multi-strands of seed pearls were sometimes twisted into a rope sautoir, called a *bayadère*, that terminated with elaborate jeweled tassels. Seed pearls woven into long, flat bands became fashionable after 1910. This type of sautoir was usually terminated in pearl and diamond tassels or in an elaborate gem-set pendant.

Sautoirs were also made of other materials. Chains punctuated at intervals by spectacle-set diamonds, sapphires, or spinels were one popular form (again, see figure 13). Coral, onyx, or turquoise beads were often used in sautoirs for day wear, as were slim chains set off by freshwater pearls held in little wire cages. Another less formal sautoir was made of dainty guilloché-enameled baton links, frequently with a matching enameled pendant. Guilloché enameling is an exacting technique in which precious metal is first machine engraved in a regular pattern, typically wavy lines that imitate moiré silk, and then coated with a translucent enamel which allows the pattern to show through. As skirts were made without pockets during this period, sautoirs were sometimes used to suspend a

Figure 13. Mrs. George J. Gould was one of the many wealthy American women who adopted the Edwardian style of wearing jewels. In this 1907 photo, she is wearing a pearl and diamond tiara, a diamond and platinum dog collar, three pearl necklaces, a pearl and diamond corsage ornament, and two pearl sautoirs, one of which is a combination of baroque-shaped pearls and lengths of spectacle-set diamond links. Photo from Kunz and Stevenson (1908).

Figure 14. For day, an Edwardian lady commonly wore her pocket watch on a sautoir. Often, these would be fashioned of guilloché enamel to match, like the set shown here. Other guilloché-enamel accessories might include these cuff links with diamond sparks. Novelty brooches like the demantoid, diamond, pearl, platinum, and gold polo player or the gold and diamond fox mask and riding crop are other typical day jewels for this elite group of women. Jewelry courtesy of Neil Lane Jewelry; photo © GIA and Tino Hammid.

small purse, watch, or lorgnette (Hinks, 1983). These accessories would often be enameled to match one another and the sautoir on which they were suspended (figure 14).

After 1900, the Lavallière, Edna May, and negligée pendant necklaces were fashionable. The Lavallière was named for the actress Eve Lavallière, who adopted the name of Louise de La Vallière, mistress to Louis XIV of France. It consists of a single gem—cut in a round, oval, or pear shape—that is suspended as a drop from a chain (Newman, 1981). The Edna May, named for a famous opera singer of the time, is a larger single gem suspended from a smaller single gem or cluster of gems on a chain. Variations on this theme might include more than one gem suspended in a line as the central element. The negligée necklace incorporates two large stones or gem-set motifs suspended at unequal lengths from a chain. The negligée necklace was an ideal way to display two exceptional, unmatched gems, such as a black and a white pearl, a diamond and a pearl, or an outstanding diamond with another gem of similar quality (Scarisbrick, 1989).

The plaque pendant also appeared about this time. For this style, a round, flat sheet of platinum was finely saw-pierced in a honeycomb lattice or a symmetrical radiating motif and then set with diamonds. This pendant would be suspended from a sautoir of woven pearls or spectacle-set diamonds. The exquisite quality of the saw-piercing, which increased in fineness as the period advanced, identifies jewels made between 1909 and 1915. Occasionally, the pendant would come with interchangeable guilloché-enameled discs in different colors, which could be fastened behind the saw-pierced platinum plaque to match the color of a particular dress (Hinks, 1983). Sometimes the plaque shape would be an elongated lozenge or a drooping triangle, representative of a folded handkerchief.

These handkerchief pendants can be identified by the way the saw-piercing imitates a dainty, lace-edged border (figure 15; Bennett and Mascetti, 1989).

Stomachers, Corsage Ornaments, Brooches, and Pins. The Edwardian lady's bodice, made rigid by the use of corsets, offered a large expanse to accessorize with jewelry for both day and evening wear. For day, brooches were generally smaller and fewer were worn. For evening, in the 1880s and 1890s, the most popular style of adornment for the bodice was to attach many brooches in a random pattern from shoulder to waist. Stars of eight, 10, 12, or 16 points were highly fashionable, preferably set with diamonds, but pearls, opals, or moonstones were also acceptable. These were often worn in multiples of five to eight stars at a time. Other motifs such as flower heads or trefoils could be worn in the same manner. Frequently, these multiple brooches came with fittings so they could be adapted for use as a tiara or on a hairpin. Crescent brooches were also popular, although as a rule they were not worn in multiples. Typically, crescent brooches were single, double, or triple rows of gems with the stones graduating in size from large at the center to smaller at the tips (see figure 6). Again, diamonds were the preferred gem, but crescents were also set with sapphires, rubies, opals, pearls, or, quite naturally, moonstones. Combined with a bird or a trefoil, the brooch became symbolic of the honeymoon, making it an ideal wedding gift (Bennett and Mascetti, 1989). Bows and ribbons, ubiquitous elements of the garland style, were rendered into beautiful brooches of platinum and diamonds. The bow, which had been a recurring motif in jewelry since the late 17th century, was given a new, more relaxed character (again, see figure 10)—in contrast to its earlier stiff, more symmetric representations—to reflect the Edwardian lifestyle of ease (Hinks, 1983).

Around 1900, it was fashionable for evening to wear clouds of tulle, chiffon, or lace at the low neckline of the bodice. This gauzy fabric would be held in place by numerous pins and brooches of every type, randomly scattered among the folds (see cover). The style or period of these brooches was unimportant; all that mattered was quantity (Bennett and Mascetti, 1989). During the Edwardian era, such brooches were often made with whimsical subjects or of unusual gems. Bright green demantoid lizards, frogs, snakes, turtles, and parrots were a common novelty pin. Also common was anything related to hunting, fishing, horse racing, yachting, or motoring, all favorite Edwardian pastimes (see figure 14); lucky charms such as wishbones (also known as merrythoughts), horseshoes,

Figure 15. Finely saw-pierced platinum plaque pendants, set with diamonds and pearls, were the height of fashion by 1910. Classic examples are the radiating design (top right) and the handkerchief design (lower right), which imitates a folded, lace-edged handkerchief. The pendant of nesting tear drops is suspended from a spectacle-set diamond sautoir. The center ring and the garland brooch at bottom show the type of pierced platinum mountings that came into vogue at about the same time. Jewelry courtesy of Frances Klein Antique and Estate Jewels; photo © Harold & Erica Van Pelt.

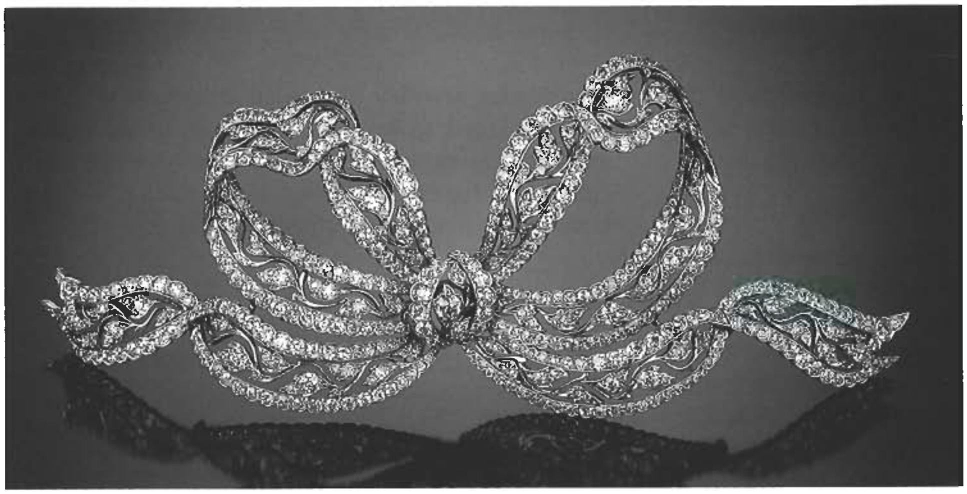

Figure 16. Corsage ornaments, like this exquisite 1905 Tiffany bow, was one way to dress up a décolletage for evening. Made of diamonds set in a 6-in. (15-cm) mounting of platinum on gold, this jeweled bow has a detachable brooch fitting to allow its use as a hair ornament. Courtesy of Neil Lane Jewelry; photo © GIA and Tino Hammid.

or clovers; cherubs, kittens, ducks, chickens, pigs, and monkeys anthropomorphically portrayed playing together; and bugs, particularly butterflies, set in jeweled pins. The swallow and the dove were the most popular bird motifs with the Edwardian set. These pins also sported an eclectic mix of anchors (symbolic of hope), arrows (symbolic of Cupid or Diana), the caduceus (symbolic of Mercury), feathers, daggers, violins, harps, and lyres (Bennett and Mascetti, 1989; Hinks, 1983). A heart surmounted by a coronet or a ribbon bow is a signature motif of the garland style, and was frequently used in brooches, as well as in bracelets and rings (see figure 6). Quite versatile, such novelty jewels could be worn in lesser amounts during the day.

The bar brooch, introduced in the 1890s, was another success for both day and evening wear. A straight line of millegrain platinum set with calibrated rubies, emeralds, or sapphires with diamonds was the most elegant version. However, simple bar brooches of gold with rounded terminals embellished at the center with novelty or sporting motifs were commonly worn with day attire (see figure 14). Women were also becoming more active in outdoor activities, and this was reflected in many of the novelty brooches they wore: bicycles, riding crops, golf clubs, or tennis racquets, for example (Armstrong, 1973).

The Juliet brooch—two gemstones on either end of a stick pin with a chain loop to connect the two ends—was introduced by the Association of Diamond Merchants in 1906. This popular jabot pin (i.e., one used to secure lace or a scarf wrapped around the throat) often incorporated diamonds or baroque-shaped pearls or other fine single colored stones (again, see figure 6; Hinks, 1983).

Between 1900 and 1910, women wore a lot of jewelry, especially for evening. In addition to the tiaras, dog collars, rivières, and sautoirs that were customary for dress occasions, women usually wore large, elaborate bodice ornaments which were often sewn directly to the dress rather than fastened with a conventional clasp. These bodice ornaments were of three types: corsage ornaments (also known as *devant de corsages*), stomachers, and epaulettes. Corsage ornaments, the smallest of the three, were generally worn to embellish the low neckline of the dress, either centered or attached to one side (figure 16). Sometimes they took the guise of a fringe of platinum and diamonds that spanned the neckline from shoulder to shoulder (Scarisbrick, 1989). The stomacher, a jewel borrowed from the 18th-century rococo style, covered the area from the décolletage to the waist. Also known as a *sevigné*, this type of jewel was usually wide at the top and tapered down toward the waistline (Bury, 1991). Epaulettes were commonly worn on the shoulders and usually had long, narrow, drop-shaped pendants called *aiguillettes*. Sometimes epaulettes were connected to each other by diamond rivières. These might be worn with one epaulette pinned to a shoulder and the other at the waist, with the rivières draped across the breast like a sash. However, bodice ornaments were quite heavy and depended on the clothing for support. As clothing fashions relaxed after 1910 and the rigid bodice was replaced by a softer, looser garment, most of these heavy jewels were put away or broken up and remade to suit the new, less confining styles (Nadelhoffer, 1984).

Earrings, Buckles, Bracelets, and Rings. For the Edwardian lady, both day- and evening-wear earrings were more subdued than they had been earlier

Figure 17. Earrings during the Edwardian period were small but still rich in nature, like this pair of pear-shaped fancy yellow diamond drop earrings. The diamonds and demantoid garnet set in a navette-shaped ring, and the 3-ct Burmese ruby set in a platinum, diamond, and calibrated ruby ring by J. E. Caldwell, are excellent examples of ring designs prevalent after 1900. The delicate diamond and platinum-on-gold bow necklace exemplifies the lace-like character of many Edwardian jewels. Jewelry courtesy of Neil Lane Jewelry; photo © GIA and Tino Hammid.

in the 19th century. The preferred combination was of pearls and diamonds set in platinum as simple drops or studs; the gems could be large, but the settings were minimal. In the 1890s, the invention of screw-back fittings for earrings eliminated the painful necessity of having one's ears pierced to follow fashion. After 1910, the vogue for longer, dangling earrings for evening returned, although they were still discreet (Hinks, 1983; figure 17). Tassels of pearls, briolette diamonds, or pear-shaped stones hanging from ribbon bows, and delicate chains of small diamonds suspending laurel wreaths or other garland motifs, became favored styles (Bennett and Mascetti, 1989).

The narrow-waisted silhouette of the hourglass figure in style at the turn of the century was complemented by wide belts that were sometimes boned like a corset. As a result, buckles became a popular jewelry accessory. Decorative buckles could be worn either in front, in back, or in both places (Hinks, 1983). For day wear, buckles might be made of chased gold or enameled silver. For evening, they were often diamond-studded platinum. The buckles were usually quite wide, up to three or four inches. Some of the wealthier Edwardians had entire belts made of diamonds and platinum (figure 18). A photo taken of the Duchess of Marlborough shows her robed for the 1902 coronation wearing a 3-in. (7.5-cm) belt of diamonds (again, see figure 9; Kunz, 1908).

Bracelets were worn in multiples, as many as four at a time. Bangles, which were usually wide in the 1880s, narrowed and became more delicate as the century closed. The half-hoop bangle with a gem-set top was very stylish throughout the period. Sometimes these bracelets would have initials or names spelled out on them. "Semaine" bracelets were a variation on the single-hoop bangle: Three to seven narrow bands would be held together at the top by a center motif, which was often a good-luck charm such as a horseshoe or a clover. Serpent bracelets were introduced in the mid-19th century, became the high fashion of the 1880s, and continued to be popular through 1910. Alexandra had a

Figure 18. The diamond belt was a particularly grand evening accessory during the Edwardian era. This example from around 1890 shows the use of the floral garland that became a signature of this period. The belt itself is 22 ins. (60 cm) long, and has a detachable knot 7 ins. (17.5 cm) high that can be worn as a corsage ornament. The diamonds are set in silver on gold, demonstrating that platinum was not yet accepted fully as a precious metal. Photo courtesy of Sotheby's, Geneva.

favorite snake bracelet that she often wore over gloves for evening. She is portrayed wearing it in several photos and portraits (see cover). Link bracelets of gold or diamond-set platinum were also fashionable (again, see figure 1). Wristwatches, developed by Cartier as early as 1888, were commercially available after 1910, although they were something of a novelty (Nadelhoffer, 1984). Some early examples were in platinum with bands of pavé diamonds or black moiré ribbon.

Like bracelets, rings were also worn several at a time, and the gem-set half-hoop rings were as popular as their bangle-bracelet counterpart. The cross-over ring was introduced in the 1890s and has remained popular to this day. Cross-over rings were designed with two fine stones, usually a diamond and a fine ruby, emerald, or sapphire, set on a diagonal opposing one another on the shank. Marquise or navette-shaped rings were very fashionable during the Edwardian period. Sometimes round stones studded a marquise-shaped mounting (again, see figure 17); in other examples, the stone itself was marquise or navette shaped. Another favorite style of the time was one or two pear-shaped stones mounted to look as if they were tied with a heart-shaped ribbon bow surmounted by a crown (Bennett and Mascetti, 1989). Gypsy-set rings, with the gems set flush with the domed metal shank, continued to be stylish for both men and women (Flower, 1951). After 1900, rings became more substantial, and a vertical row of gemstones set in pierced platinum mountings was very popular. These rings often covered the finger from knuckle to knuckle; sometimes the mounting was further augmented by small diamonds, hand engraving, and millegrain work (again, see figure 15).

Men's Jewelry. Edward VII took matters of dress very seriously, giving the impression that society was held together by a strict observance of the protocol governing the wear of clothes and jewelry (Scarisbrick, 1989). As a leader in society, he was nevertheless innovative and set many fashion trends for clothing, such as the Norfolk jacket and "plus-fours" for casual wear, and shorter tails on the dress coat for evening. Although there are no direct references to show that Edward also set trends in jewelry, it is probable that his lead was followed. In any case, the Edwardian gentleman wore a lot of jewelry. Many of these pieces are still in occasional use today, but at that time they could be considered indispensable to the wardrobe of a well-dressed man. Stickpins, for example, used to secure the necktie or cravat, were the perfect way to display special gemstones such as a spectacular pearl or a cat's-eye chrysoberyl. They could also demonstrate the wearer's sporting tastes or special interests, just like for women (figure 19).

Cuff links, first introduced in the 18th century, were a necessity by the late 19th century (figure 20). Edwardian gentlemen owned a wide variety of cuff links for both casual and formal wear; these were an ideal forum for colored stones. Among the favorites were aquamarines with blue or green shirts, topaz with yellow or brown, garnets or spinels with red, andalusite with plaids, rutilated quartz with beige, and amethyst with lavender (Jonas and Nissenson, 1991). Cuff links also incorporated sporting motifs and whimsical subjects. Formal evening dress required complete, matching dress sets of cuff links, shirt studs, and waistcoat buttons. King Edward is known to have had a dress set of rubies and diamonds made by Fabergé (Jonas and Nissenson, 1991).

Pocket watches were another essential jewelry item. Both the watch and the chain by which it was secured to the waistcoat allowed the man to be discreetly decorative, or to indulge his fancy by attaching charms, medals, or seals to the fob (Bury, 1991).

Popular ring styles for men were gypsy-set diamonds, rubies, or sapphires. Seal rings made of engraved gold or carved carnelian, bloodstone, or other chalcedonies engraved with family seals were an ideal way to exhibit the owner's lineage.

Other Jewels and Jeweled Objects. Gift giving was an integral part of Edwardian society. Presents were often obligatory for state occasions, and they were

Figure 19. Stickpins for Edwardian men, like novelty brooches for their female counterparts, enabled the wearer to exhibit particular interests or whimsies. From left: a platinum cube set with calibrated rubies; a pavé-diamond platinum bulldog with ruby eyes; an enameled gold yachting flag; a ruby and diamond platinum-on-gold horseshoe; a marquise-cut diamond set in platinum with calibrated demantoids and pavé diamonds; a yachting flag painted on mother-of-pearl and capped with a quartz cabochon; a diamond-set platinum motorcar with red enameled seat (the wheels turn), and a pavé diamond platinum-on-gold bulldog head with ruby eyes. Jewelry courtesy of Neil Lane Jewelry; photo © GIA and Tino Hammid.

Figure 20. Cuff links were an important accessory for Edwardian men, most of whom had several sets for both day and evening. Here are two sets of cuff links suitable for evening: mother-of-pearl "buttons" with a diamond border and cross-stitch detail of platinum on gold (left), and (right) dark gray agate cuff links with diamond centers and diamond scrolled borders. Jewelry courtesy of Neil Lane Jewelry; photo © GIA and Tino Hammid.

exchanged freely in many social situations beyond the usual birthdays, holidays, and personal anniversaries. Jewelers catering to the Edwardian upper class supplied an enormous variety of jeweled objects that were suitable for virtually every occasion: cigarette and card cases, scent bottles, fans, picture frames, walking-cane and parasol handles, as well gemstone carvings and jeweled clocks.

Most men carried cigarette cases, which were considered very masculine. These cases could be hand-engraved silver or gold, but they were frequently made using guilloché enamel. Cigarette cases were often additionally decorated with rose-cut diamonds, cabochon sapphires, rubies, and/or emeralds. Many of the other objects mentioned above were also made using guilloché enamel, and often the decorative touches would be motifs typical of the garland style.

Where the jewelers Cartier and Garrard's, for example, excelled in the fabrication of magnificent tiaras, necklaces, and corsage ornaments, the workshops of Fabergé were best known for their enameled objects, their gem carvings, and their ability to make mechanized jeweled toys such as glittering birds that chirped, miniature gold and platinum trains that actually ran, and small silver elephants that waved their trunks as they walked. Queen Alexandra particularly loved Fabergé animals. For her birthday one year, King Edward commissioned Fabergé to carve replicas of the animals at Sandringham—not just the prize horses and favorite dogs, but also the entire barnyard, including ducks, pigs, and chickens. In subsequent years, friends and family added to this menagerie until there were over 350 animals; the British Royal Collection is the largest collection of Fabergé carvings still in private hands (Habsburg-Lothringen and Solodkoff, 1979).

Perhaps the object for which Fabergé is most famous, however, is the jeweled Easter egg: This royal tradition began in Russia in 1884, when Tsar Alexander III commissioned a jeweled egg to give to his wife. In all, Fabergé's workshops made an estimated 57 imperial Easter eggs between 1884 and 1917, of which all but 11 are accounted for. Besides the imperial eggs, Fabergé made literally thousands of miniature jeweled eggs in amazing variety; rarely were two alike. These diminutive eggs were considered ideal gifts for Edwardian ladies and gentlemen alike. Ladies could suspend them from a sautoir necklace or chain-link bracelet, and new ones could be added each year. Men could hang them from a watch chain or wear them as a stickpin (Habsburg-Lothringen and Solodkoff, 1979).

THE END OF AN ERA

Nothing as superficially exquisite as the Edwardian lifestyle could possibly last. The luxurious, leisurely dream was shattered by the onset of the First World War. Economies, philosophies, and lifestyles changed virtually overnight; gone were the gala dinners, formal receptions, and lighthearted theme parties. Society went through a dramatic metamorphosis in a mere four years. With the absence of occasions to wear them, jewels were locked away or sold.

War had other effects on the jewelry industry in addition to its impact on the social structure. Platinum was declared a strategic metal for its use as an engine magneto and as a catalyst for the manufacture of nitric acid, an essential component in explosives. The government restricted the use of platinum, and commandeered all stocks of it for the war effort. The gem trade was paralyzed as well. In 1915, De Beers closed down production until diamond prices, which had dropped by more than 20%, stabilized (Hinks, 1983). Jewelers enlisted in the armed forces, or converted their skills to military applications. As a result, little or no jewelry was produced in England and most of Europe during the war years (Bennett and Mascetti, 1989).

When the war was over, it was impossible for society to revert to the leisurely self-indulgent lifestyle of the Belle Époque. The exigencies of wartime had drastically changed perceptions of life for society as a whole, and the horrors that many people experienced made it inconceivable for them to view the world with the same attitude. Jewelry fashioned in the Art Deco period that followed World War I reflects this change in view by its use of sharp geometrics and contrasting primary color combinations. Gone were the muted pastels, gaily triumphant garlands, splendid wreaths and innocently enchanting lace motifs that we attribute to jewels of the Edwardian elite. We are fortunate to have been left with a few exquisite examples of these Edwardian jewels that are both majestic and formal, yet charming and lighthearted in character. They are as distinctive and beautiful as the period they represent.

REFERENCES

Armstrong N. (1973) *Jewellery: An Historical Survey of British Styles and Jewels.* Lutterworth Press, London.

Balfour I. (1992) *Famous Diamonds*, 2nd ed. Gemological Institute of America, Santa Monica, CA.

Becker V. (1987) *Antique and Twentieth Century Jewellery*, 2nd ed. N.A.G. Press, Colchester, Essex, England.

Bennett D., Mascetti D. (1989) *Understanding Jewelry.* Antique Collectors' Club, Woodbridge, Suffolk, England.

Bruton E. (1978) *Diamonds,* 2nd ed. Chilton Book Company, Radnor, PA.

Bury S. (1991) *Jewellery 1789–1910.* Antique Collectors' Club, Woodbridge, Suffolk, England.

Debrett's Peerage: Baronetage, Knightage and Companionage (1952) Oldham's Press, London.

Field L. (1987) *The Queen's Jewels: The Personal Collection of Elizabeth II.* Harry N. Abrams, New York.

Flower M. (1951) *Victorian Jewellery.* Cassell & Co., London.

Habsburg-Lothringen G. Von, Solodkoff A. Von (1979) *Fabergé: Court Jeweler to the Tsars.* Tabard Press, New York.

Harkness S., McCleery J.G., with Shor R., Shuster W.G., Spencer S., Thompson M., Weldon R. (1992) The heritage jewelry market: Uncharted territory *Jeweler's Circular-Keystone,* Vol. 163, No. 8, pp. 92–109.

Hinks P. (1983) *Twentieth Century British Jewellery 1900–1980.* Faber and Faber, London.

Hinks P. (1989) Victoriana and Belle Époque, 1827–1914. In Chesshyre M., Ed., *Jewellery: Makers, Motifs, History, Techniques.* Thames and Hudson, London, pp. 85–107.

Jonas S., Nissenson M. (1991) *Cuff Links.* Harry N. Abrams, Inc., New York.

Krashes L. (1988) *Harry Winston: The Ultimate Jeweler.* Harry Winston, Inc., and Gemological Institute of America, New York and Santa Monica.

Kunz G.F., Stevenson C.H. (1908) *The Book of the Pearl.* The Century Co., New York.

Magnus P. (1964) *King Edward VII.* E. P. Dutton & Co., New York.

Marvels of the nineteenth century (1899) *Keystone Magazine.* November, Vol. 20, No. 11, pp. 1096a–1096e.

Menkes S. (1989) *The Royal Jewels.* Grafton Books, London.

Minney R.J. (1964) *The Edwardian Age.* Little, Brown & Co., Boston.

Misiorowski E.B., Dirlam D.M. (1986) Art Nouveau: Jewels and jewelers. *Gems & Gemology,* Vol. 22, No. 4, pp. 209–228.

Nadelhoffer H. (1984) *Cartier: Jewelers Extraordinary.* Harry N. Abrams, New York.

Neret G. (1988) *Boucheron.* Rizzoli, New York.

Newman H. (1981) *An Illustrated Dictionary of Jewelry.* Thames and Hudson, London.

Scarisbrick D. (1989) *Ancestral Jewels.* Vendome Press, New York.

Vever H. (1908) *La Bijouterie Française au XIX^e Siècle, Vol. III: Troisième République 1870–1900.* H. Floury, Paris.

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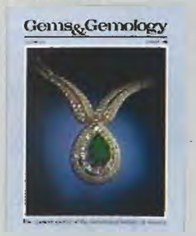

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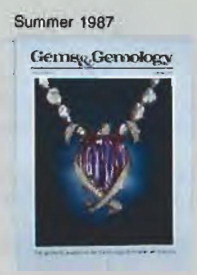

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A PROSPECTORS' GUIDE MAP TO THE GEM DEPOSITS OF SRI LANKA

By C. B. Dissanayake and M. S. Rupasinghe

Sri Lanka is world famous for its gem wealth, but the actual extent of the deposits has never been determined. Recently, a geologic survey team gathered field data in order to compile the first gem prospectors' guide map of Sri Lanka. Using the criteria of lithology and topography, stream-drainage density, presence of alluvium, and the nature and abundance of heavy minerals, this team determined that approximately 20% of the land mass of Sri Lanka may be gem bearing. They also characterized the potential of specific regions.

Sri Lanka may have the greatest proportion of land surface underlain by gem deposits, as well as the widest variety of gem minerals (figure 1), of any country in the world. Yet there has been little scientific study of the true gem potential of this island nation. Most "prospecting" in Sri Lanka to date has been by independent miners who search broad areas, using only shovels and washing baskets (figure 2). The chance discovery of a gem by one miner will bring others into the region, and thus the haphazard exploration of the area continues. Although the number of fine gems produced in Sri Lanka over the course of more than 2,000 years supports the general effectiveness of these methods, the need to compile an inventory of the natural resources of the country cannot be disputed. In fact, gem minerals as a group are by far the most valuable mineral resource in Sri Lanka. According to the 1990 Central Bank *Annual Report*, gems represent 84% of the total value of minerals exported from this island nation. To meet the need for a more systematic assessment of the nation's gem resources, the senior author (CBD) led a research study to characterize known gem-producing regions and identify potential new areas. This article reviews that study and introduces the Prospectors' Guide Map that was compiled from the semiquantitative data gathered.

ABOUT THE AUTHORS

Prof. Dissanayake is director of the Institute of Fundamental Studies, Kandy, Sri Lanka, and senior professor of geology at the University of Peradeniya, Sri Lanka. Dr. Rupasinghe is a senior research fellow and head of the Earth and Space Science Department at the Institute of Fundamental Studies, Kandy.

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GEOLOGIC SETTING

Sri Lanka, with an area of 25,325 square miles (65,845 km^2), is physically the southern continuation of the Indian subcontinent and geologically part of the Indian shield. More than 90% of the island is made up of Precambrian metamorphic rocks and can be divided into four major divisions: the Highland Group, Southwest Group, Eastern Vijayan Complex, and Western Vijayan Complex (figure 3). The Highland Group occupies the entire

Figure 1. Impressive in its variety and quality is this array of colored gems from Sri Lanka (top to bottom, from left): 30.77-ct yellow-green chrysoberyl, 1.37-ct cobalt spinel ring, orangy pink spinel (about 13 ct) and sapphire brooch, 1.12-ct purple sapphire ring, 11.90-ct pink spinel, 3.36-ct pink sapphire ring, 12.53-ct red spinel, 3.45-ct blue sapphire, 1.07-ct yellow sapphire, and 4.02-ct purple spinel. Courtesy of David Humphrey, Pacific Palisades, California; Mayer & Watt, Maysville, Kentucky; and Elise Misiorowski, Los Angeles, California. Photo by Shane F. McClure.

hill country of the island and is comprised of granulite facies (i.e., rocks formed under high pressure and high temperature) metamorphosed sediments. The Southwest Group is also made up of granulite facies rocks, but these probably formed under different pressure-temperature conditions. The Vijayan Complexes are composed of granitoids, migmatites, and migmatitic gneisses. Sri Lanka's gem deposits are located primarily in the Highland Group, within an area of approximately 6,000 square miles (15,540 km^2; again, see figure 3).

Over the past few million years, intense weathering and rapid erosion have given rise to thick and extensive accumulations of sediments in the flood plains of rivers, in lakes, and in now-buried river channels. It is within these weathering products that significant secondary—alluvial—gem deposits collected.

DETERMINING GEM POTENTIAL: CRITERIA AND METHODOLOGY

Four criteria were used to determine the gem potential of the various regions of Sri Lanka: lithology and topography, drainage density, presence of alluvium, and heavy-mineral concentrations in stream sediments.

Except for a few alluvial occurrences in the Eastern Vijayan Complex, virtually all Sri Lankan gem deposits have been found within the Highland and (to a lesser extent) Southwest Groups; in fact, it is presumed that the Eastern Vijayan gems originated from rocks in these two groups. Therefore, this investigation was conducted primarily within the Highland and Southwest Groups, in the areas indicated by the topographic sheets in figure 3. The topography of each of these areas was studied before field investigations, using existing aerial photographs and topographic sheets. The drainage basins were outlined, and the areas covered by alluvium were identified.

Because few gem minerals have been found in situ in Sri Lanka (to date, only corundum in the Bakamuna, Matara, and Rupaha areas; moonstone in Meetiyagoda; and aquamarine in Kegalle), this survey was limited to placer deposits.

Within the areas noted on figure 3, samples were taken from stream sediments at intervals of approximately one location per square mile. Each sample typically consisted of 2–3 kg of "pay gravel," that is, rounded or subangular pebbles or boulders of quartz and heavy minerals, including gemstones. A few samples were also taken at different stratigraphic levels at the same locality for comparison; analysis of these data showed that the heavy minerals generally are enriched in the lower stratigraphic levels. Some samples were obtained from existing gem pits, particularly in the gem-producing areas around Ratnapura and Elahera. The survey team collected about 1,450 stream sediment samples in total.

The samples were first washed to remove the clay, and then subjected to grain-size analysis using a sieve shaker. A mesh fraction of 0.177–0.125 mm was selected for this analysis, with bromoform (S.G. 2.90) used to separate out the heavy minerals. The magnetic bromoform sink products were removed with a hand magnet; the nonmagnetic residue was processed with a Frantz isodynamic separator to obtain different mineral concentrates. The nonmagnetic products were weighed and split using a multiple cone separator to obtain about 500 grains. The individual mineral grains were then identified and counted using a binocular microscope, after which the percentages of each mineral were computed. We believe that the distribution of these grain-size minerals represents the distribution of their larger counterparts.

ANALYSIS OF THE CRITERIA

For the final Prospectors' Guide Map (figure 4), we established five categories of gem potential: (1) highly probable, (2) probable, (3) moderate, (4) poor, and (5) no deposits. Classification of the various areas into one of the five categories was based on our analyses of all four criteria: lithology and topography, drainage density, presence of alluvium, and heavy-mineral concentrations. For instance, an area with abundant heavy minerals but without sites of accumulation was not classified as highly probable because it lacked the mechanism whereby economic deposits of alluvial gem materials could form. Following is a summary of the key considerations within each criterion that determined the probability assignments to the various regions.

Figure 2. A miner examines river gravel for various types of rough. Most "prospecting" in Sri Lanka to date has been by independent miners, who search broad areas using only shovels and washing baskets. Photo by Robert C. Kammerling.

Lithology and Topography. The Highland Group of rocks is particularly conducive to the formation of gem minerals (Hapuarachchi, 1975; Munasinghe and Dissanayake, 1979, 1982; Rupasinghe and Dissanayake 1985). However, even if the source rocks for the gem minerals are available in a certain area, the wrong topography may result in a paucity of gem deposits. A relatively flat topography—drained by wide, meandering streams—is most conducive to the formation of gem-bearing alluvial deposits.

Drainage Density. A good network of streams is prerequisite for the transportation and deposition of sediments derived from the weathering of the gem-mineral source rocks. The central and southern regions of the gem-bearing Highland and Southwest Groups are all supplied by a network of radial drainage systems.

Presence of Alluvium. Large expanses of alluvial deposits have been extensively mined in the main Ratnapura and Elahera gem fields. Consequently, particular emphasis was placed on areas with thick layers of alluvium, either at sites adjacent to present streams or in the flood plains of ancient rivers.

Heavy-Mineral Concentrations. Heavy minerals in the sediments of streams draining source areas are the best indicators of gem potential. Our analyses of the approximately 1,450 sediment samples revealed the presence of garnet, spinel, zircon, corundum, beryl, topaz, tourmaline, sillimanite, and rutile, among other heavy minerals. Garnets, spinels, and zircon, in particular, were the most useful indicators of gem potential because of their abundance relative to other important gem minerals with which they are associated, such as corundum, topaz, and beryl. The latter often occur in such low concentrations that their presence or absence from a particular sample has no statistical value. To classify an area as at least probable, we required a minimum of 25% heavy minerals, including indicator minerals; samples from some areas were nearly 75% heavy minerals.

CLASSIFICATION OF GEM POTENTIAL

Areas were initially delineated on the basis of qualitative descriptions made during the field surveys. Suitable flat-lying topographic terrains with good

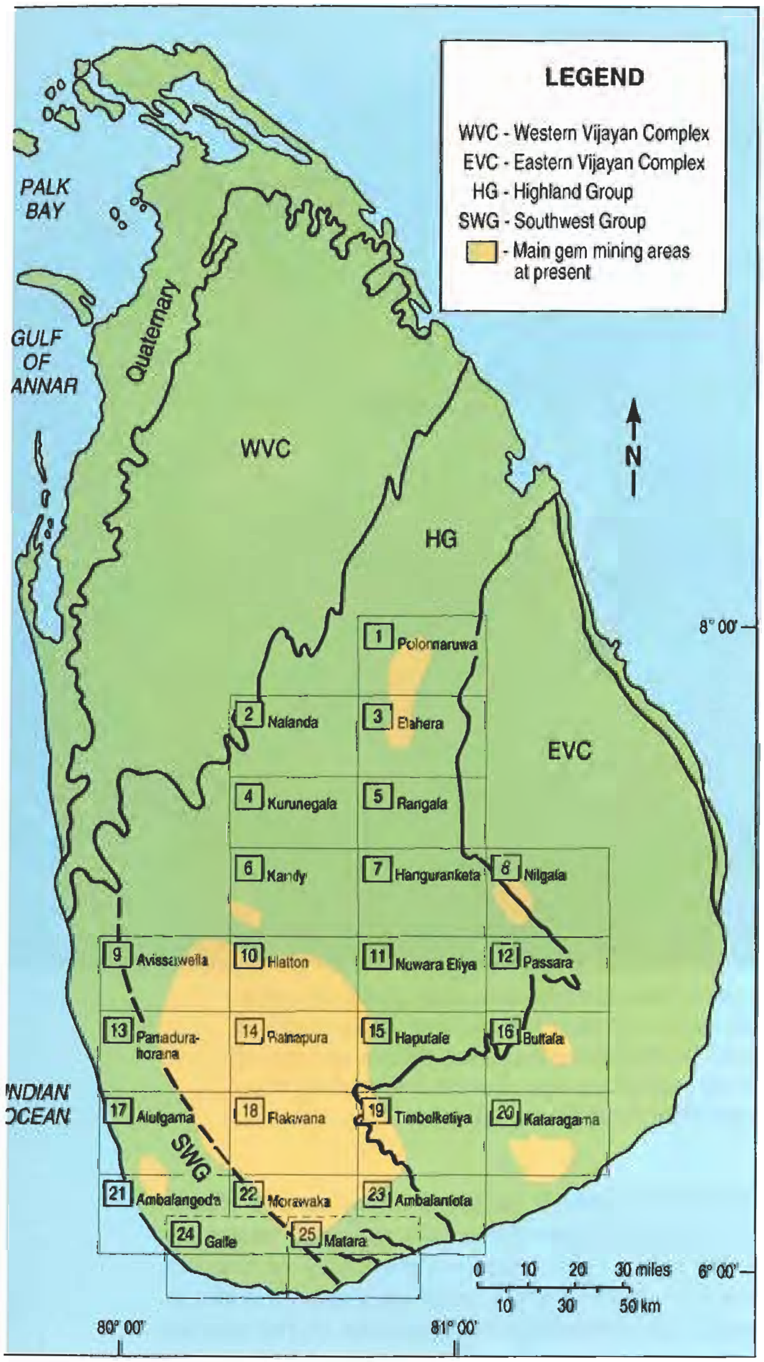
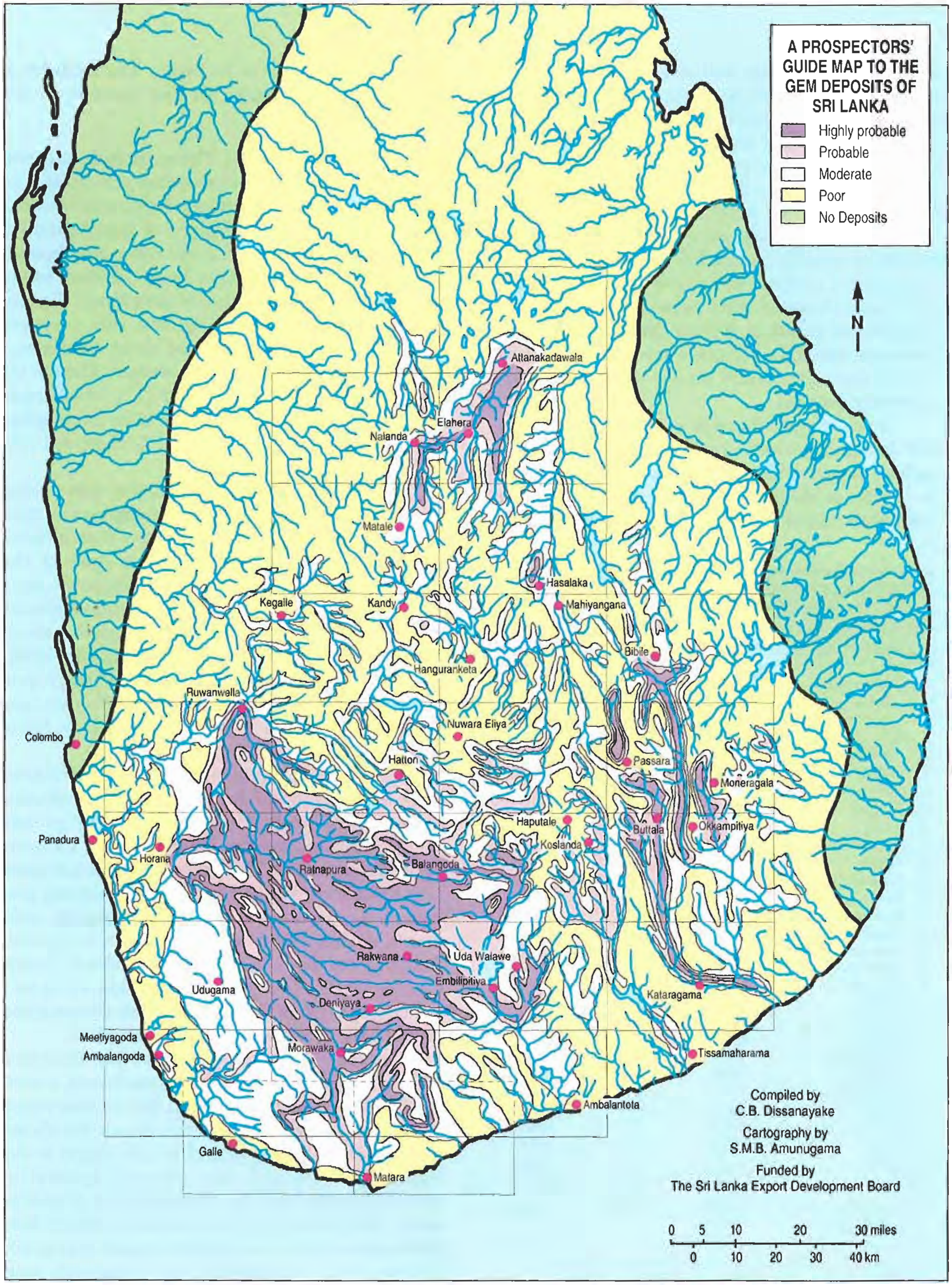


Figure 3. The Precambrian rocks that comprise most of Sri Lanka are divided into four groups: the Highland Group, Southwest Group, Eastern Vijayan Complex, and Western Vijayan Complex. To date, virtually all gem deposits have been found in the Highland and Southwest Groups. The boxed numbers on this simplified geologic map of Sri Lanka show which 1-inch (2.5-cm) topographic sheets correspond to study areas in tables 1 and 2, and figure 4. Artwork by Carol Silver.

Figure 4. This Prospectors' Guide Map to the Gem Deposits of Sri Lanka was compiled by the senior author on the basis of the study discussed in the text. Areas are categorized as "highly probable," "probable," "moderate," "poor," and "no deposits" on the basis of their gem potential. An estimated 20% of Sri Lanka's land mass contains viable gem deposits. Artwork by Carol Silver.


A PROSPECTORS' GUIDE MAP TO THE GEM DEPOSITS OF SRI LANKA
Highly probable
Probable
Moderate
Poor
No Deposits
N
Attanakadawala
Elahera
Nalanda
Matale
Hasalaka
Mahiyangana
Kegalle
Kandy
Bibile
Hanguranketa
Ruwanwella
Nuwara Eliya
Colombo
Hatton
Passara
Moneragala
Haputale
Buttala
Okkampitiya
Koslanda
Panadura
Horana
Ratnapura
Balangoda
Rakwana
Uda Walawe
Embilipitiya
Udugama
Kataragama
Deniyaya
Meetiyagoda
Ambalangoda
Morawaka
Tissamaharama
Ambalantota
Galle
Matara
Compiled by C.B. Dissanayake
Cartography by S.M.B. Amunugama
Funded by The Sri Lanka Export Development Board
0 5 10 20 30 miles
0 10 20 30 40 km

networks of drainage and alluvial deposits were mapped, and the corresponding heavy-mineral concentrates of the stream sediments were analyzed. Areas that satisfied all of the above criteria were classified as "highly probable"; those that did not adequately satisfy at least some criteria were classified as "poor" or as having "no deposits." The intermediate categories of "probable" and "moderate" were assigned somewhat arbitrarily, since full quantitative analysis was not within the scope of this study. However, areas were classified as being of moderate potential if their lithology could produce gem minerals, but other factors (such as inadequate drainage) would hinder the formation of economic deposits.

Table 1 shows the areas in square miles classified as highly probable, probable, and moderate, as well as the percentage of land mass in each category relative to the total area of the island. Note that these three classifications together comprise about 20% of the land area of Sri Lanka. This probably is the highest percentage for any country in the world.

TABLE 1. Land surface (in square miles) of key areas in Sri Lanka found to be highly probable, probable, and of moderate probability for gem occurrences. Topographic sheet numbers are keyed to those shown on figure 3[a].

Topographic sheet		Highly probable	Probable	Moderate
No.	Name			
1	Polonnaruwa	7.9	21.9	14.9
2	Nalanda	9.9	9.9	54.7
3	Elahera	63.6	39.8	109.3
4	Kurunegala	9.9	7.9	79.0
5	Rangala	4.9	12.9	127.2
6	Kandy	—	5.0	149.0
7	Hanguranketa	—	—	157.2
8	Nilgala	14.9	14.9	79.5
9	Avissawella	79.5	49.7	99.4
10	Hatton	11.8	39.7	59.6
11	Nuwara Eliya	—	49.7	168.9
12	Passara	36.8	49.7	74.5
13	Panadura-horana	119.3	110.6	61.2
14	Ratnapura	248.0	164.0	60.0
15	Haputale	71.6	139.1	129.2
16	Buttala	54.7	84.5	208.7
17	Alutgama	49.7	29.8	198.8
18	Rakwana	367.0	100.0	5.0
19	Timbolketiya	79.5	129.2	159.0
20	Kataragama	14.9	39.8	59.6
21	Ambalangoda	—	19.9	159.0
22	Morawaka	94.4	49.7	308.4
23	Ambalantota	1.4	1.9	169.5
24	Galle	1.0	9.9	79.5
25	Matara	—	19.9	29.8
Total		1340.7	1199.4	2800.9
	Percentage relative to total land area	5.29	4.74	11.06

[a] *The total area of Sri Lanka is 25,325 square miles (about 65,845 km²). A 1-inch topographic sheet = 472 square miles (about 1,222 km²).*

Highly Probable Areas. These include present, newly discovered, and rediscovered gem fields. The areas described as new and not being mined at present are mostly at the periphery of existing mining regions. Rediscovered areas are those that historical records show to have been worked many decades ago and subsequently abandoned. Current mining regions that fall within this category include (relevant topographic sheet numbers—from figure 3—given in parentheses): Elahera (3), Hasalaka (5), Bibile (8), Passara (12), Moneragala (12), Buttala (16), Okkampitiya (16), Kataragama (20), Ratnapura (14), Rakwana (18), Deniyaya (18), and Morawaka (22).

Even though much of the current gem-mining activity is centered in the Elahera region, the main gem field covers an area much larger than hitherto anticipated—from the southern part of the Attanakadawala area in the Polonnaruwa topographic sheet (no. 1) and southwest and southward into the Kurunegala and Rangala topographic sheets (nos. 4 and 5; Gunawardene and Rupasinghe, 1986).

The Hasalaka area has a much larger gem potential than previously had been known, and detailed exploration is warranted along the tributaries of the Mahaweli River.

Bibile is a relatively unexplored area surrounded by known gem fields. The presence of euhedral (well-formed) crystals in the gravel samples indicates a source region nearby. The Passara, Moneragala, Buttala, Okkampitiya, and Kataragama gem fields form a major north-south trending gem belt along eastern Sri Lanka. Gem-bearing sediments in this region were brought in by streams draining the boundary of the Highland Group-Eastern Vijayan Complex, which is known to be a mineralized terrain (Munasinghe and Dissanayake, 1979; Dissanayake and Weerasooriya, 1986).

The Ratnapura (figure 5), Rakwana, Deniyaya, and Morawaka gem fields, in the southwest, constitute the largest and best-known gem mining region of Sri Lanka. The gem-minerals survey has shown that the actual gem potential of this region is also significantly broader than current exploitation would indicate, with good prospects in peripheral areas. The main gem field appears to stretch from Embilipitiya in the Uda Walawe region (topographic sheet 19) to Ruwanwella (on Avissawella topographic sheet 9) and south almost to the coast in the Imaduwa and Matara regions (sheets 24 and 25). Because the source rocks for many of the gem minerals are believed to be in this region, both the mountains and the alluvial plains should be explored, especially the weathered rock formations.

Probable Areas. Most of these "new" areas surround known gem deposits and the other "highly probable" areas (again, see figure 4). Large probable areas occur in the vicinity of the Elahera (around Attanakadawala and Pallegama) and Rakwana-Ratnapura gem fields. The latter include the southeast-trending river system that stretches from Koslanda (topographic sheet 15) through the western portion of topographic sheets 16 and 20 to Tissamaharama, near the southeast coast; the hills and valleys around Hatton (sheet 10) and eastward through sheet 11, including the towns (not shown in figure 4) of Welimada, Boralanda, and Bandarawela; and the upper catchment areas of the Walawe River, particularly around Godakawela and Uda Walawe (sheets 18 and 19, respectively).

Moderate Areas. The areas classified as "moderate" may yield viable gem deposits, especially with the aid of better exploration techniques. In general, the moderate areas border the more "probable" ones or occur where geomorphic conditions are suitable for the accumulation of gemstones. They include the stretch from Ruwanwella (topographic sheet 9) to Matara (sheet 25), in southwestern Sri Lanka, encompassing Agalawatta, Hiniduma, and Udugama; the regions south of the gem fields at Okkampitiya and Buttala (sheet 16); and the tributaries of Menik River as well as those of Mahaweli River in the Hanguranketa and Mahiyangana (sheet 7) regions.

Poor and No Deposit Areas. Areas classified as "poor" on figure 4 are within general geologic regions that have produced gem minerals, but to date have yielded no significant deposits. Those areas classified as "no deposit" are located well outside the Highland Group and are believed to be devoid of gems. It should be noted that samples were not taken from those areas classified as "no deposit," since these regions had not yielded gems in the past.

DISTRIBUTION OF GEM MINERALS IN SRI LANKA

Known Deposits. Table 2 indicates the distribution of gem minerals found thus far in Sri Lanka, some of which are illustrated in figure 6. Zwaan (1982) provided a general account of the gem fields of Sri Lanka, and Gunawardene and Rupasinghe (1986) gave a very detailed account of the mineralogy of gems in the Elahera gem field. Silva and Siriwardena (1988) described the corundum-bearing skarns in the Bakamuna area, near Elahera (topographic sheet 3). The two main gem fields—Ratnapura and Elahera—contain a wide variety of gem minerals, including corundum, chrysoberyl, zircon, tourmaline, kornerupine, garnet, spinel, and taaffeite, among others.

Topaz is abundant in Polwatta and elsewhere in the Rattota-Matale area (topographic sheet 4). Identified by this study as fluoride-rich, this gem field has also yielded significant amounts of other

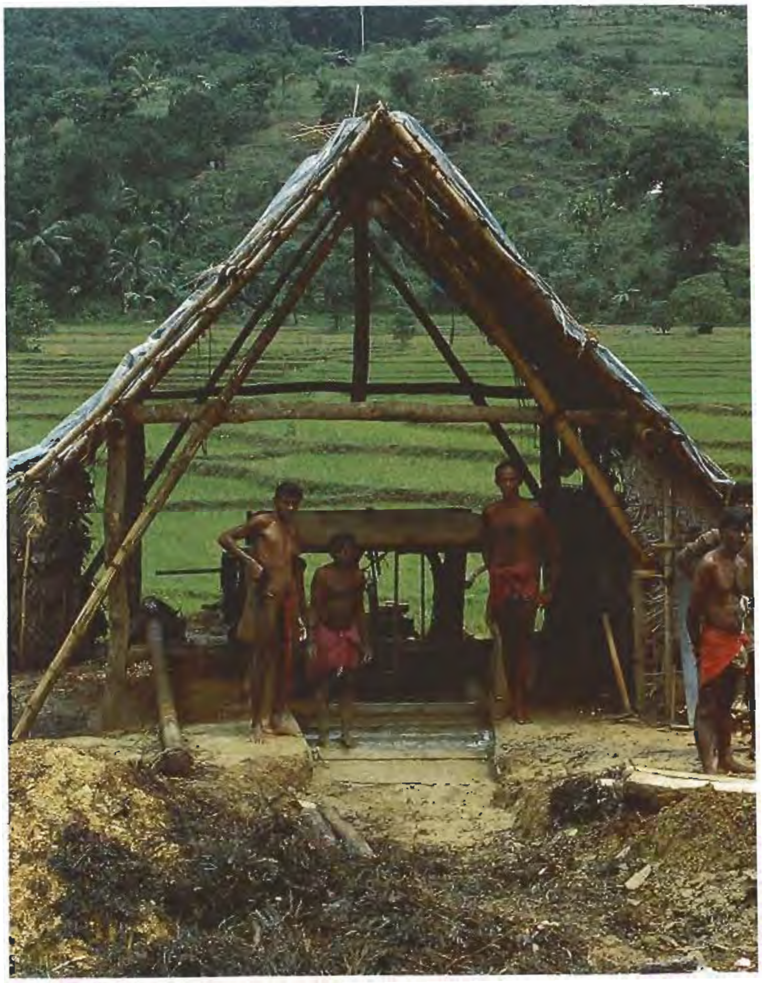


Figure 5. Dozens of thatched canopies dot the countryside around the mining center of Ratnapura. The canopies cover alluvial mining pits that are worked by local miners. Photo by Robert C. Kammerling.

TABLE 2. Key gem minerals of Sri Lanka listed by locality[1]. Topographic sheet numbers are keyed to those shown on figure 3.

Topographic sheet No.	Name	Gem minerals
1	Polonnaruwa	Corundum, garnet
2	Nalanda	Apatite
3	Elahera	Chrysoberyl, corundum, garnet, iolite, kornerupine, sinhalite, sphene, spinel, zircon
4	Kurunegala	Amethyst, apatite, citrine, fluorite, iolite, topaz, tourmaline
5	Rangala	No known deposits
6	Kandy	Amethyst, aquamarine
7	Hanguranketa	Corundum
8	Nilgala	Corundum, garnet, spinel, tourmaline, zircon
9	Avissawella	Amethyst, andalusite, beryl, chrysoberyl, corundum, diopside, epidote, iolite, kornerupine, garnet, sinhalite, spinel, tourmaline, zircon
10	Hatton	Andalusite, corundum, garnet, iolite, spinel, topaz
11	Nuwara Eliya	Amethyst, corundum, spinel, zircon
12	Passara	Corundum, ekanite, garnet, kornerupine, spinel, taaffeite, topaz, tourmaline, zircon
13	Panadura-horana	Aquamarine, axinite, beryl, chrysoberyl, corundum, garnet, idocrase, phenakite, scapolite, sillimanite, spinel, taaffeite, topaz, tourmaline, zircon
14	Ratnapura	Amethyst, andalusite, apatite, beryl, chrysoberyl, citrine, corundum, diamond, danburite, diopside, ekanite, garnet, iolite, kornerupine, scapolite, sillimanite, sinhalite, spinel, taaffeite, topaz, tourmaline, zircon
15	Haputale	Andalusite, axinite, beryl, chrysoberyl, corundum, diopside, garnet, idocrase, spinel, topaz, tourmaline, zircon
16	Buttala	Corundum, ekanite, garnet, spinel, tourmaline
17	Alutgama	Chrysoberyl, corundum, spinel, zircon
18	Rakwana	Apatite, aquamarine, axinite, beryl, chrysoberyl, corundum, danburite, diopside, ekanite, enstatite, fluorite, garnet, kornerupine, spinel, tourmaline, zircon
19	Timbolketiya	Garnet
20	Kataragama	Corundum, hiddenite, sphene, spinel
21	Ambalangoda	Moonstone
22	Morawaka	Aquamarine, beryl, chrysoberyl, corundum, danburite, diopside, garnet, sillimanite, sphene, spinel, tourmaline, zircon
23	Ambalantota	Beryl, chrysoberyl, corundum, garnet, idocrase, iolite, scapolite, sillimanite, sinhalite, spinel, tourmaline, zircon
24	Galle	Beryl, chrysoberyl, corundum, sphene
25	Matara	Aquamarine, chrysoberyl, corundum, garnet, zircon

[1] *All data compiled by the authors and the State Gem Corporation of Sri Lanka.*

fluoride-bearing minerals such as fluorspar (fluorite), apatite, and tourmaline. Note that both topaz and fluorite have been found in primary pegmatite deposits (Rupasinghe et al., 1984; Dissanayake et al., 1992). The areas along the Highland-Vijayan boundary are also known to be fluoride-rich (Dissanayake and Weerasooriya, 1986).

Iolite is common in the Elahera and nearby Matale gem fields, whereas andalusite and scapolite are frequently found in the gem fields around Ratnapura. Meetiyagoda (topographic sheet 21) has an important deposit of moonstone; garnets are found in abundance in the region around Embilipitiya and Uda Walawe (sheet 19; Cooray, 1984).

Future Prospects. A comparison of the highly probable, probable, and moderate land masses (figure 4) with the present mining areas (figure 3) indicates the potential for identifying new colored gem deposits in Sri Lanka. In addition, recent reports of the discovery of alluvial diamonds within the granulite belt of the Highland Group have created interest in diamond exploration. As early as 1965, Gunaratne mentioned the occurrence of diamond in Sri Lanka. Subsequent reports of diamond finds, such as at Polonnaruwa and at Balangoda (Dissanayake and Rupasinghe, 1986), indicate the need for a thorough investigation into the geologic occurrence of diamond on this island.

In addition, the many rivers that drain the gem fields undoubtedly have transported large quantities of gem minerals mixed with sediments into the sea, particularly in the southwestern regions. Thus, the mouths of rivers and their near-shore regions are obvious targets for future gem prospecting.

CONCLUSIONS

Although government figures indicate that gem exports account for more than 80% of Sri Lanka's mineral export industry, they represent only 4% of the total foreign exchange earnings. Yet, as reported in this article, the vast gem potential of the country has been underexplored and underexploited. Present gem mining and prospecting are based largely on chance discoveries and subsequent "word-of-mouth" exploration. Scientific methods could significantly improve the accuracy of locating target areas. The Prospectors' Guide Map (figure 4) discussed in this article takes the first step toward further exploration by identifying new and expanded areas with gem potential.

Figure 6. Illustrating some of the many gems from Sri Lanka are these rough and faceted stones (top to bottom, from left): blue and yellow sapphire crystal, moonstone rough, 2.92-ct purple sapphire, pink spinel crystal, 1.79-ct orangy brown enstatite, yellow sapphire crystal, 5.50-ct moonstone cabochon, 1.02-ct yellow sapphire, purplish pink spinel crystal, hiddenite crystal, 1.65-ct green zircon, 1.23-ct brown sinhalite, yellow chrysoberyl crystal, 2.30-ct pink sapphire, 1.42-ct yellow zircon, pink sapphire crystal, 1.14-ct purplish pink spinel, pink sapphire crystal, pink spinel crystal, 1.26-ct orangy pink sapphire, 0.70-ct orange sapphire, moonstone beads, yellow sapphire crystal, 0.78-ct yellow sillimanite. Courtesy of David Humphrey and N. D. International, both of Pacific Palisades, California; and Evan Caplan & Co., Los Angeles, California; photo by Shane F. McClure.

REFERENCES

Cooray P.G. (1984) *An Introduction to the Geology of Sri Lanka (Ceylon).* National Museums Publication, Colombo, Sri Lanka.

Dissanayake C.B., Rupasinghe M.S. (1986) Possibilities for diamond occurrences in Sri Lanka. *Journal of the Gemmologists Association of Sri Lanka,* No. 3, pp. 2–6.

Dissanayake C.B., Rupasinghe M.S., Dharmaratne T. (1992) Fluorine hydrochemistry in a topaz-rich area in Sri Lanka. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 41, No. 2/3, pp. 111–116.

Dissanayake C.B., Weerasooriya S.V.R. (1986) Fluoride as an indicator of mineralization—Hydrogeochemistry of a Precambrian mineralized belt in Sri Lanka. *Chemical Geology,* Vol. 56, pp. 257–270.

Gunaratne H.S. (1965) The discovery of a diamond from Ceylon. *Spolia Zeylanica,* Vol. 30, No. 2, pp. 51–52.

Gunawardene M., Rupasinghe M.S. (1986) The Elahera gem field in central Sri Lanka. *Gems & Gemology,* Vol. 22, No. 2, pp. 80–95.

Hapuarachchi D.J.A.C. (1975) *The Granulite Facies of Sri Lanka.* Geological Survey Department of Sri Lanka, Professional Paper No. 5.

Munasinghe T., Dissanayake C.B. (1979) Is the Highland—Eastern Vijayan boundary in Sri Lanka a possible mineralized belt? *Economic Geology,* Vol. 74, pp. 1495–1496.

Munasinghe T., Dissanayake C.B. (1982) A plate tectonic model for the geologic evolution of Sri Lanka. *Journal of the Geological Society of India,* Vol. 23, pp. 369–380.

Rupasinghe M.S., Banerjee A., Pense J., Dissanayake C.B. (1984) The geochemistry of beryllium and fluorine in the gem fields of Sri Lanka. *Mineralium Deposita,* Vol. 19, pp. 86–93.

Rupasinghe M.S., Dissanayake C.B. (1985) Charnockites and the genesis of gem minerals. *Chemical Geology,* Vol. 53, pp. 1–16.

Silva K.K.M.W., Siriwardena C.H.E.R. (1988) Geology and the origin of the corundum-bearing skarn at Bakamuna, Sri Lanka. *Mineralium Deposita,* Vol. 23, pp. 186–190.

Zwaan P.C. (1982) Sri Lanka: The gem island. *Gems & Gemology,* Vol. 18, No. 2, pp 62–71.

TWO TREATED-COLOR SYNTHETIC RED DIAMONDS SEEN IN THE TRADE

By Thomas M. Moses, Ilene Reinitz, Emmanuel Fritsch, and James E. Shigley

Two dark brownish red faceted stones, recently submitted to the GIA Gem Trade Laboratory for standard origin-of-color reports, were found to be treated synthetic diamonds. This conclusion was based on observations of: patterns of zoned color, U.V. luminescence, and graining; metallic inclusions; and certain bands in the visible- and infrared-range absorption spectra. We believe that this is one of the first published reports of treated-color synthetic diamonds seen as faceted gems. For some of the gemological features described here, such as visible-range spectra with sharp absorption bands, this is one of the first reported occurrences in gem-quality synthetic diamonds.

In early July 1993, a diamond dealer submitted a 0.55-ct dark brownish orangy red diamond (figure 1, left) to the New York office of the GIA Gem Trade Laboratory (GIA GTL) for a standard origin-of-color report. According to the client, this round brilliant-cut stone had been obtained on memo from a dealer in Bombay, India. In September, a 0.43-ct dark brownish red "radiant"-cut diamond (figure 1, right) was submitted in New York for a similar report by a separate client. Given the very high market value and the great rarity of natural-color "red" diamonds (see, e.g., Federman, 1992), these two stones were undoubtedly submitted to GIA GTL in hopes of receiving a favorable color description on a laboratory report. However, standard gemological examination quickly revealed that both stones were synthetic diamonds. In addition, their gemological properties indicated that both had been color enhanced subsequent to synthesis.

To date, the GIA Gem Trade Laboratory has examined only a very few faceted synthetic diamonds that were submitted by members of the jewelry industry for a laboratory report (see also the brief mention of GIA GTL's examination of a 0.23-ct faceted Sumitomo synthetic yellow diamond in Fryer, 1987). With the announced commercial offering of Russian gem-quality synthetic diamonds for jewelry use (Catalano, 1993), however, it is likely that this situation will occur more frequently. Notification of the 0.55-ct faceted synthetic diamond and its gemological properties to other gem-testing laboratories was made through International Colored Gemstone Association (ICA) Laboratory Alert No. 74, dated August 9, 1993 (this alert also mentioned an untreated, 0.74-ct yellow synthetic diamond crystal examined by GIA GTL at a client's request at about the same time). The present article reports on the gemological properties of these two treated synthetic red diamonds and discusses how they compare with other synthetic diamonds examined to date.

BACKGROUND

The possibility of gem-quality synthetic diamonds entering the jewelry trade has been a concern ever since the first diamonds of a size and quality suitable for faceting were synthesized by General Electric in 1970. For more than two decades, researchers at GIA and elsewhere have been reporting regularly on the

ABOUT THE AUTHORS

Mr. Moses is director of identification and research, and Dr. Reinitz is a research scientist, at the GIA Gem Trade Laboratory in New York. Dr. Fritsch is manager of research, and Dr. Shigley is director of research, at the Gemological Institute of America, Santa Monica, California.

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Figure 1. Standard gemological testing at the GIA Gem Trade Laboratory in New York revealed that this 0.55-ct brownish orangy-red round brilliant cut (left) and this 0.43-ct brownish red "radiant" cut (right) are synthetic diamonds that have been treated to produce the red color. Photos by Shane F. McClure.

properties of gem-quality synthetic diamonds to address this industry concern (Crowningshield, 1971; Woods and Lang, 1975; Koivula and Fryer, 1984; Shigley et al., 1986, 1987, 1992, 1993a, 1993b; Burns et al., 1990; Kanda, 1990; Ponahlo, 1992; Burns and Davies, 1992; Clark et al., 1992; Rooney et al., 1993; Fritsch and Shigley, 1993). These articles have described various means for recognizing gem-quality synthetic diamonds using both standard gem-testing equipment and more advanced instrumentation. Although synthetic diamonds with a red color have not been described in the gemological literature, there has been some scientific work on synthetic diamonds that are pink or red due to treatment by irradiation followed by annealing (see Collins, 1978; Collins, 1991, p. 667). The information on synthetic and treated synthetic diamonds reported in these articles, and our examination over many years of numerous natural-color diamonds, made possible the identification of the two synthetic diamonds reported here.

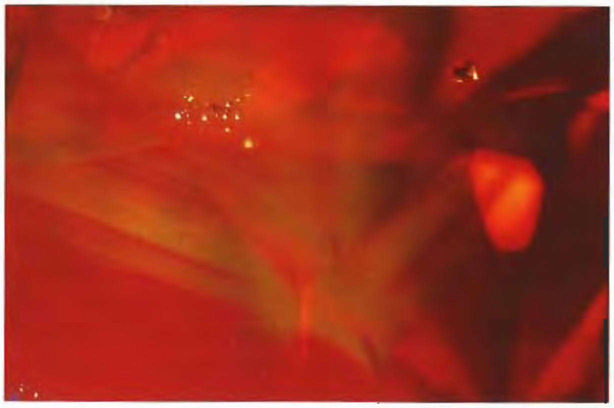
MATERIALS AND METHODS

We used standard gemological testing equipment as well as other laboratory instrumentation to characterize these faceted stones. The former included a gemological microscope, a long-wave (366 nm) and short-wave (254 nm) ultraviolet lamp unit (used in a darkened room), and a Beck prism spectroscope as well as a Discan digital-scanning diffraction-grating spectroscope (with the diamonds cooled using a spray refrigerant). We used a Pye-Unicam 8800 spectrophotometer to record absorption spectra at liquid-nitrogen temperature over the range 250–850 nm, and Nicolet 510 and 60SX Fourier-transform infrared spectrometers to record infrared spectra over the range 400–10,500 cm^{-1}. Qualitative chemical analysis was carried out using a Tracor X-Ray energy-dispersive X-ray fluorescence (EDXRF) system.

RESULTS

Microscopy. *Color Zoning.* When examined with 10× magnification, both samples exhibited very distinct color zoning (figures 2–4). Through the crown facets of the 0.55-ct stone, we observed the outlines of both square-shaped and superimposed cross-shaped light yellow areas surrounded by much larger areas of red color (figure 2 shows a portion of this color-zoning pattern). The cross-shaped pattern was approximately centered under the table facet. In general, the areas of yellow color were tabular, and they were much narrower than the red areas. When viewed through the pavilion facets of this stone, the color zoning was manifest, at four locations around the girdle (separated by 90°), as narrow light yellow zones surrounded by larger red areas (figure 3); this corresponds to looking down one of the four "arms" of the cross-shaped pat-

Figure 2. This view through the crown facets of the 0.55-ct red synthetic diamond shows the intersecting red and yellow zones. The latter appear slightly greenish due to their luminescence to visible light. Several groups of small metallic inclusions can also be seen. Photomicrograph by John I. Koivula; transmitted light, magnified 35×.



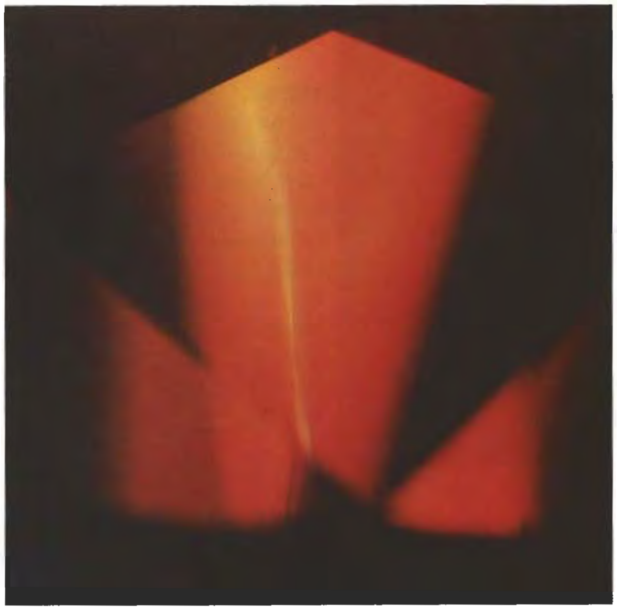


Figure 3. When the 0.55-ct stone was viewed through the pavilion facets parallel to the girdle, a narrow light yellow zone surrounded by larger red areas could be seen at four locations (separated by 90°) around the girdle. Photomicrograph by John I. Koivula; transmitted light, magnified 40×.

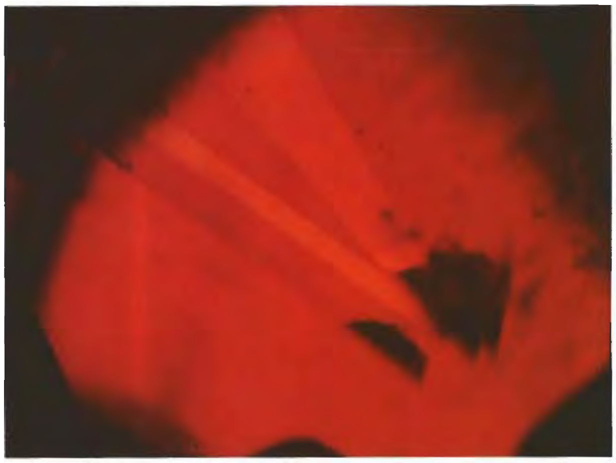


Figure 4. With magnification, the 0.43-ct red synthetic diamond showed a pattern of distinct red and narrow yellow zones separated by planar internal graining. Photomicrograph by John I. Koivula; transmitted light, magnified 40×.

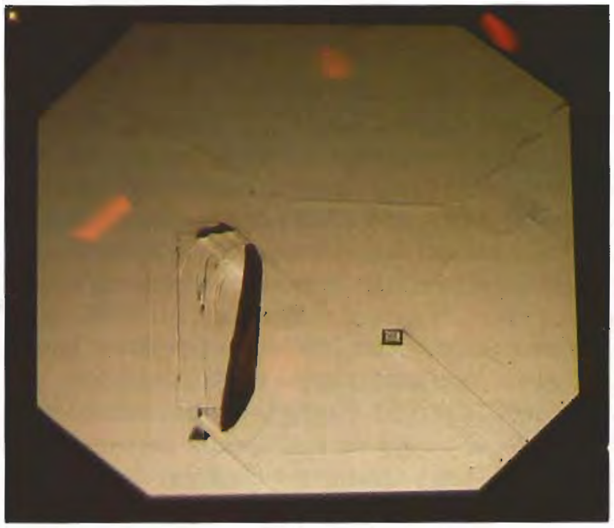
tern mentioned above. Similar kinds of red-yellow color zoning could also be seen through the crown and pavilion facets of the 0.43-ct stone (figure 4).

Graining. Using reflected light, we saw only one faint graining line on the table facet of the 0.55-ct stone. In contrast, we saw a faint pattern of surface graining and some parallel polishing "drag" lines on the table of the 0.43-ct stone (figure 5). In both stones, the color zones mentioned above were separated by planar boundaries marked by slight internal graining.

Inclusions. A large, rounded, opaque inclusion with a metallic (or reflective) appearance was readily visible beneath the table facet of the 0.55-ct stone (figure 6). It was accompanied by many smaller inclusions of similar appearance (again, see figure 2). Small metallic inclusions were also visible in the 0.43-ct stone, as was a large open cavity and an unusual square-shaped inclusion of uncertain identity seen through the table facet (figure 5). Because of these inclusions, both synthetic diamonds were attracted by a simple magnet. EDXRF chemical analysis of both stones revealed the presence of nickel and smaller amounts of iron (figure 7), presumably in large part from these metallic inclusions. Although GIA GTL does not issue quality-grading reports on synthetic diamonds, a natural diamond with eye-visible inclusions (such as the ones found in these synthetics) would receive an "Imperfect" clarity grade.

Ultraviolet Luminescence. The luminescence reaction visible from the crown facets of the 0.55-ct diamond to *both* long- and short-wave ultraviolet radiation was striking. In both cases, we saw two unevenly distributed colors of fluorescence: a very intense green and a moderately intense reddish orange.

Figure 5. A faint pattern of intersecting surface grain lines and some parallel polishing "drag" lines can be seen on the table facet of the 0.43-ct stone. Also visible is a large, open cavity and an unusual square-shaped inclusion. Photomicrograph by John I. Koivula; reflected light, magnified 15×.



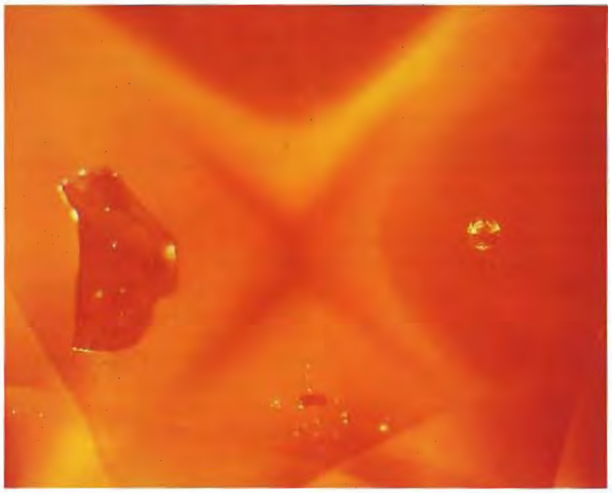


Figure 6. One large—and several smaller—opaque inclusions of flux metal lie beneath the table facet of the 0.55-ct red synthetic diamond. This photomicrograph also shows the distinctive pattern of color zones, with four yellow areas forming a "cross shape" that is surrounded by red areas. When the stone is illuminated by a strong visible light source, the yellow areas are seen to emit green luminescence. Photomicrograph by John I. Koivula; transmitted light, magnified 35×.

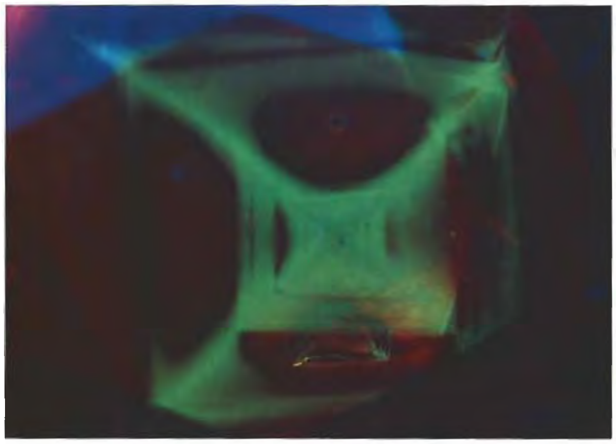
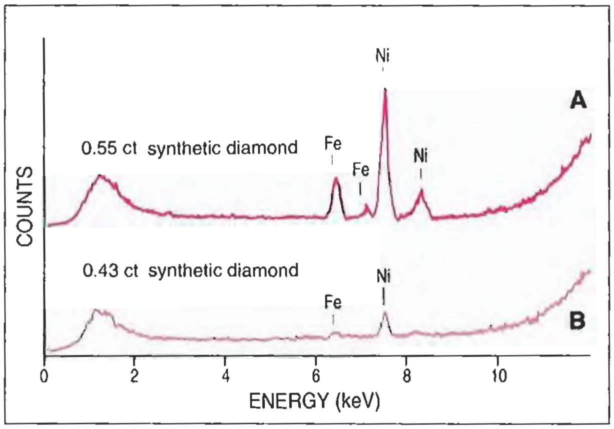


Figure 8. The crown facets of the 0.55-ct red synthetic diamond reveal an uneven, intense fluorescence to short-wave U.V. radiation. The combined square- and cross-shaped pattern of green fluorescence corresponds to the light yellow zones in the diamond; the moderate reddish orange fluorescence to the red areas in the stone. Photomicrograph by John I. Koivula; magnified 5×.

The pattern of green fluorescence was identical to that of the narrow yellow color zones described above (figure 6)—a combination of square and cross shapes (see figure 8). When the short-wave U.V. lamp was turned off, the green fluorescing regions continued to phosphoresce the same color briefly for several seconds. The moderately intense reddish orange fluorescence corresponded to only one small isolated point near the girdle under long-wave U.V., but to all the large, dark red areas under short-wave U.V (again, see figure 8).

Figure 7. These EDXRF spectra show the presence of both nickel (Ni) and iron (Fe) from the metallic inclusions in these two synthetic diamonds.



The 0.43-ct stone also exhibited uneven U.V. luminescence, but in a different spatial pattern from that described above. The overall long-wave U.V. fluorescence was moderately intense, and the short-wave U.V. fluorescence was intense. In both cases, when the stone was viewed through the crown facets, there was a very small area of red fluorescence near the center of the table facet, which was surrounded by a narrow zone of green fluorescence. From the latter, narrow bands of moderate orange fluorescence pointed toward the four corners of the table facet, where there were square areas of stronger orange fluorescence. The remainder of the stone exhibited weaker orangy red fluorescence. When the U.V. lamp was turned off, we did not see any phosphorescence from the 0.43-ct stone.

We also observed moderate-intensity green luminescence in the yellow areas when the 0.55-ct diamond was illuminated with a strong visible light source (such as that provided by fiber-optic light with reflected or transmitted illumination; see figure 2). We did not see a similar luminescence in the 0.43-ct stone.

Spectroscopy. The visible-range absorption spectra of the two synthetic diamonds are shown in figure 9. Numerous sharp absorption bands occur between 400 and 800 nm in the spectrum of the 0.55-ct stone (figure 9A, table 1). Several of the bands between 500 and 660 nm were intense enough to be seen with a

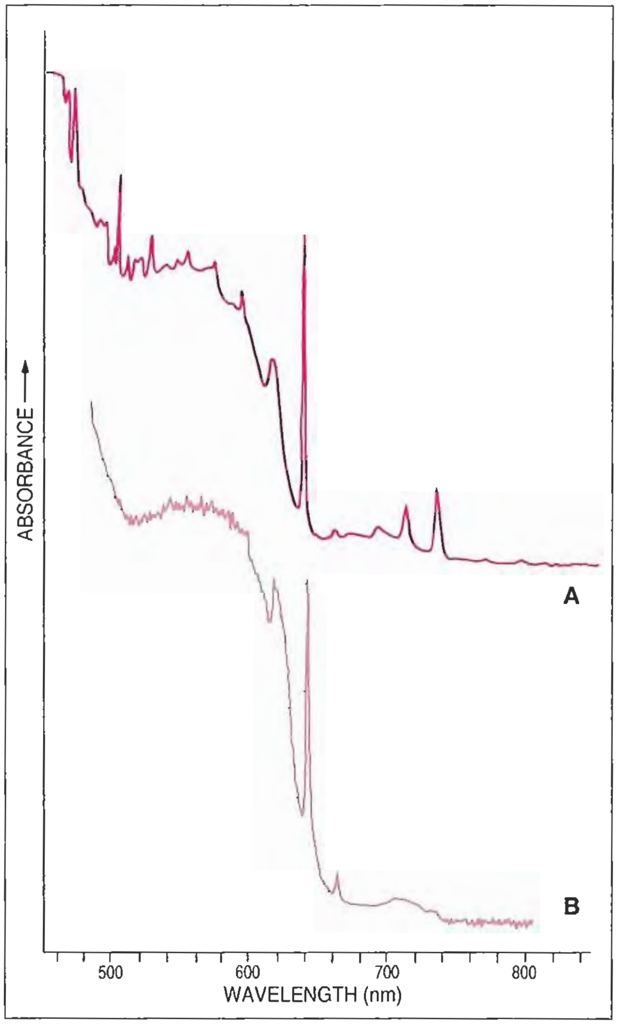


Figure 9. These visible-range absorption spectra were recorded at liquid-nitrogen temperatures for the 0.55-ct (A) and 0.43-ct (B) treated synthetic diamonds. A list of the bands present in both spectra, and their causes, are given in table 1. In the spectrum of the 0.55-ct stone, numerous sharp absorption bands can be seen between 460 and 800 nm; many of these were sufficiently intense to appear as sharp bands in a handheld spectroscope (i.e., at about 503, 527, 553, 595, 617, 637, and 658 nm), especially when the sample was cooled by use of spray refrigerant. No spectral features could be recorded below 460 nm because virtually all incident light was absorbed by the diamond itself. In the 0.43-ct synthetic diamond, only a few sharp bands are visible; the two at 637 and 658 nm are also present in the spectrum of the other diamond. No spectral features could be recorded below about 600 nm for the same reason as cited above.

handheld spectroscope, especially when the diamond was cooled.

TABLE 1. Absorption bands present in the visible and near-infrared ranges of the spectrum of the 0.55-ct treated red synthetic diamond (with those seen in the 0.43-ct red synthetic diamond marked by an asterisk [*]), listed by decreasing wavelength.

Wavelength (rounded to closest nm)	Seen in handheld spectroscope (at low temperature)	Comments[a]
809		Visible in published spectrum but not discussed in [a]
792		Ni-related [a]
767		Visible in published spectrum but not discussed in [a]
732		Ni- and N-related [a]
711		Ni- and N-related [a]
691		Ni- and N-related [a]
671		Ni- and N-related [a]
658*	Yes	Ni-related [b]
637*	Yes	"N-V" center typical of treated pink diamonds [c]
617	Yes	"N-V" center, typical of treated pink diamonds [c]
614	Yes	"N-V" center, typical of treated pink diamonds [c]
595	Yes	Typical of treated diamonds [c]
575	Yes	Typical of treated pink diamonds [c]
553	Yes	Ni- and N-related [a]
547	Yes	Ni- and N-related [a]
540		Ni- and N-related [a]
527	Yes	Ni- and N-related [a]
520		Ni- and N-related [a]
518	Yes	Ni- and N-related [a]
516		Ni- and N-related [a]
511		Ni- and N-related [a]
503	Yes	Ni- and N-related [a] and H3 center (always seen in treated pink diamonds) [c]
502		Ni- and N-related [a]
494		Ni-related [b]
491		Ni- and N-related [a]
478		Ni- and N-related [a]
473		Ni- and N-related [a]
468		Ni- and N-related [a]

[a] *References: [a] observed by Lawson and Kanda (1993a, 1993b) in nitrogen-containing synthetic diamonds, grown in Ni and subsequently annealed to 1600°–1990° C; [b] Collins and Spear, 1982; [c] Collins, 1982.*

Although the visible spectrum of the 0.43-ct stone (figure 9B) exhibited far fewer sharp absorption bands, those observed are in wavelength positions similar to those seen in the other stone—in particular, at 637 and 658 nm. Besides sharp absorption bands, the visible spectra of both stones exhibited two additional features: an increasing absorption toward the violet, and a broad region of absorption extending from about 500 to 640 nm.

The mid-infrared absorption spectra (figure 10) reveal that both of these synthetic diamonds are a mixture of types. The 0.55-ct stone is type Ib + IaA + IaB (with IaA >> IaB, and Ia > Ib), while the 0.43-ct stone is type Ib + IaA +IaB (with IaA >> IaB, and Ib > Ia). For details on diamond types, see Fritsch and Scarratt (1992).

In addition, both stones showed absorption bands at 1050, 1450, and 1502 cm^{-1} in their mid-infrared spectra (figure 10). Both also displayed a band at 4935 cm^{-1} in their near-infrared spectra (which are not illustrated here). The 1450 and 4935 cm^{-1} bands are referred to as H1a and H1b, respectively (Clark et al., 1956; Woods, 1984).

DISCUSSION

Comparison to Other Synthetic Diamonds. Certain gemological properties of synthetic diamonds differ from those of natural diamonds because of their different conditions of formation (for a recent review, see Burns and Davies, 1992). The observed zoning of color and U.V. luminescence, the pattern of graining, and the presence of metallic inclusions in these two stones are all typical of gem-quality colored synthetic diamonds described to date.

Conversely, these two synthetic diamonds displayed some features that are different from those that have been reported, not least of which is their red color. Thus far, the only commercially available gem-quality synthetic diamonds have been yellow, type-Ib material. They have been inert to long-wave U.V. radiation, and have lacked sharp absorption bands in their visible-range spectra (Shigley et al., 1986). The infrared spectra of these two red synthetic diamonds indicate that neither stone is a pure type-Ib diamond; both exhibit some type-Ia character. In addition, both fluoresced not only to short-wave but also, more importantly, to long-wave U.V. radiation, with a pattern of both green and orange colors that corresponds to the arrangement of internal growth sectors. Finally, both stones displayed sharp absorption bands between 500 and 660 nm, some of which were visible in a handheld spectroscope. None of these features has previously been reported for synthetic diamonds in the gemological literature.

We have examined two pieces of Sumitomo synthetic diamond that, after known irradiation and annealing, turned from yellow to orangy red. After treatment, they exhibited orange fluorescence to both long- and short-wave U.V. radiation (with the short-wave reaction more intense than the long-wave reaction). Their visible-range absorption spectra revealed sharp bands at about 575, 595, and 637 nm. Even after treatment, the infrared spectra indicated that one sample was still a pure type Ib, while the other was a mixture of Ib and minor IaB. The mid- and near-infrared spectra of both Sumitomo samples exhibited sharp bands at 1450 and 4935 cm^{-1} after treatment.

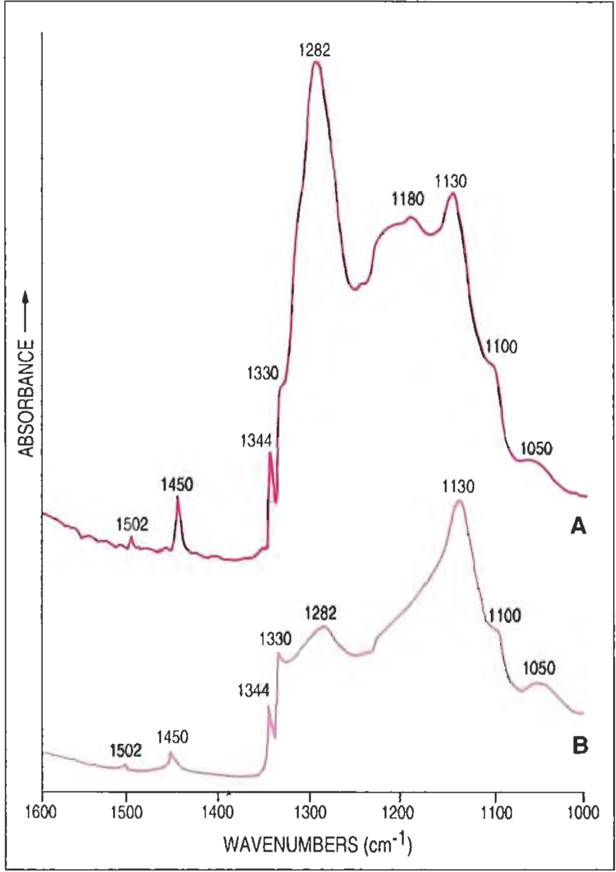


Figure 10. The "nitrogen region" (between 1344 and about 1000 cm^{-1}) of the mid-infrared absorption spectra of these two synthetic diamonds reveals that, unlike most synthetic yellow diamonds tested to date, they are not a pure type Ib. Type-Ib diamonds are characterized by a sharp band at about 1344 cm^{-1}, and a broader band at about 1130 cm^{-1}. Type-IaA diamonds have a band at approximately 1282 cm^{-1}, while type-IaB diamonds have bands at about 1330 and 1180 cm^{-1} (see Field, 1992, p. 683). Thus, the 0.55-ct stone (spectrum A) is a mixture of type Ib + IaA + IaB (with IaA >> IaB, and Ia > Ib), and the 0.43-ct stone (spectrum B) is a type Ib + IaA + IaB (with IaA >> IaB, and Ib > Ia). The bands at 1502 and 1450 cm^{-1} in both spectra are the result of annealing of these two irradiated synthetic diamonds (Clark et al., 1992, p. 43). The broad band at about 1050 cm-1 is due to a nitrogen-related defect (with N in a positive charge state) in the crystal structure of these diamonds that has been found only in synthetic diamonds (Lawson and Kanda, 1993a).

Visible- and Infrared-Range Absorption Spectra. As shown in table 1, the sharp absorption bands present in the visible-range spectra of these two synthetic diamonds arise from several different causes.

Scientific studies have shown that only nickel, of the several transition metals that have been used as a flux for synthetic diamond growth, can give rise to sharp absorption bands in the visible-range spectrum of diamond (Collins and Spear, 1982; Lawson and Kanda, 1993a, 1993b). These Ni-related bands fall into two groups. The first group includes bands at 494 and 658 nm, which are present in the spectra of the as-grown Ni-containing synthetic diamond crystals (Collins and Spear, 1982; Collins et al., 1990). The second group contains a large number of bands between 460 and 800 nm, which are found in nitrogen-containing synthetic diamonds (grown in Ni) that have been annealed to 1600°–1900°C (Lawson and Kanda, 1993a, 1993b; again, see table 1).

Apart from those that are Ni-related, other sharp bands in the visible range result from laboratory treatment. The 503-nm (H3) band is known to result from irradiation and annealing (to 1400°–1700°C) of synthetic type-Ib diamonds, and is thought to be due to a vacancy trapped at a nitrogen A aggregate (two nearest neighbor substitutional N atoms; Collins, 1978, 1982, 1991). The 595-nm band is found in type-Ia and Ib diamonds that have been irradiated and then annealed to 800°–1000°C (Collins, 1982). Finally, there are several sharp bands that are typically seen in type-Ib diamonds that, after irradiation and annealing (to 800°C or more), turn from yellow to pink. These include the 575-nm band as well as the 637-nm band (with sidebands at 614 and 617 nm, all superimposed on a broad region of absorption between about 450 and 650 nm) produced by a defect known as the "N-V" center (a vacancy "V" trapped at a substitutional N atom; Davies and Hamer, 1976; Collins, 1978, 1982, 1991).

In the infrared spectra, the H1a and H1b bands (1450 and 4935 cm^{-1})—as well as the band at 1502 cm^{-1}—are produced in type-Ib diamonds by irradiation and annealing above 800°C (Woods, 1984; Collins and Stanley, 1985; Collins, 1991; Clark et al., 1992, p. 43).

The presence of some or all of these spectral features in the two synthetic red diamonds allows us to make some inferences regarding their origin and treatment history. The presence of Ni-related sharp absorption bands confirms the results of EDXRF analysis that both samples are synthetic and were grown using a Ni-containing flux, since most of the sharp bands between 460 and 800 nm have no other known causes.

In the 0.55-ct stone, the bands indicative of irradiation and annealing include those at 503, 575, 595, and 637 nm in the visible spectrum, and those at 1450, 1502, and 4935 cm^{-1} in the infrared spectrum. The 503-nm and 4935-cm^{-1} features, along with the other bands in the mid-infrared spectrum, are evidence of some degree of nitrogen aggregation in this synthetic diamond. The numerous Ni-related sharp absorption bands in the visible spectrum suggest that this diamond either has a relatively high nickel content or, if it has a lower Ni content, it was heated after growth to temperatures above 1600°C, so these bands are especially prominent (A. T. Collins, pers. comm., 1993).

In the 0.43-ct stone, in contrast, only the 637-nm band seen in the visible spectrum, along with the bands at 1450, 1502, and 4935 cm^{-1} in the infrared, are evidence of irradiation and annealing. Again, the 4935-cm^{-1} feature, along with the other bands in the mid-infrared spectrum, are evidence of some degree of nitrogen aggregation (mainly A aggregates). The lack of the numerous, Ni-related sharp bands suggests that this synthetic diamond either contains relatively smaller amounts of nickel or was not annealed to such high temperatures (1600°–1900°C) as was the 0.55-ct stone.

Other bands in the mid-infrared revealed that the two stones exhibit some type-Ia character (mainly IaA; see caption, figure 10), which indicates that some nitrogen aggregates formed during treatment. In the spectra of both synthetic diamonds, the weak type-IaB features in the mid-infrared, and the lack of an H1c band (5165 cm^{-1}) in the near-infrared, confirm that only a limited number of nitrogen B aggregates (an even number of nearest-neighbor substitutional N atoms of undetermined structure; Woods, 1984; Collins and Stanley, 1985) formed during treatment in both stones (A. T. Collins, pers. comm., 1993). Aggregation of nitrogen atoms in a synthetic diamond has been documented during crystal growth (Kanda et al., 1990, for crystals produced in cobalt metal at temperatures of 1400°–1500°C) and during post-growth treatment (either by annealing alone at temperatures of 1700°–2400°C [Collins, 1980; Collins and Stanley, 1985], or by irradiation followed by annealing at temperatures of about 800°C [Collins, 1978]). From our data, we cannot conclude whether the observed N aggregation in these two stones resulted during crystal growth or post-growth treatment.

Cause of Color. Yellow-to-brown type-Ib diamonds, whether natural or synthetic, will turn pink to red (or purple) when subjected to treatment by irradiation and annealing (Collins, 1982; and our own experience—see previous Discussion section above). As grown, synthetic diamond crystals do not exhibit a red color that results from impurities. This color is due to post-growth irradiation and annealing, as proved in these treated synthetic diamonds by certain spectral bands present.

Untreated natural pink-to-red diamonds are either type Ia or IIa (those that are treated are always partially type-Ib; Collins, 1982, and our own observations). The visible-range spectra of type-Ia diamonds of these colors show increasing absorption toward the ultraviolet (due to nitrogen). Superimposed on this are one or more sharp absorption bands of the "Cape series" (mainly the 415-nm band due to the N3 center, which consists of three nearest-neighbor substitutional N atoms). In addition, there is a broad absorption band centered at about 550 nm (Collins, 1982; Kane, 1987; Shigley and Fritsch, 1993). This latter broad band is thought to be due to a defect produced by plastic deformation (a small displacement of the carbon atoms along gliding planes in the diamond crystal structure) that can occur while the diamond is still in the earth (Collins, 1982).

Similarly, the visible-range spectra of untreated, natural type IIa diamonds of these colors exhibit a broad band between 500 and 600 nm, but lack the increasing absorption toward the ultraviolet and the sharp bands, both of which are due to nitrogen (Collins, 1982).

Except for the sharp bands (which make little contribution to the color), the visible spectra of the two treated red synthetic diamonds described here are similar in appearance to those of treated-color pink-to-red natural diamonds. There is increasing absorption toward the ultraviolet (due again to the singly substitutional nitrogen), and a broad absorption band between about 450 and 650 nm (due to the "N-V" center). This broad band, here the result of laboratory treatment, also gives rise to a pink-to-red color, since it reaches a maximum near 550 nm (similar in location to the broad absorption band in the spectra of untreated pink-to-red natural diamonds, which results from a different process; Collins, 1982).

Cause of U.V. Luminescence. The green fluorescence observed to correspond to the narrow yellow zones probably is due to the H3 center (503 nm), while the orange fluorescence from the more extensive red areas is probably due to the 575-nm absorption band (these observations have been confirmed by A. T. Collins, pers. comm., 1993).

Previous descriptions of yellow (untreated) synthetic diamonds reported a yellow or greenish yellow fluorescence to short-wave U.V. radiation (Shigley et al., 1986, 1987). In all cases, these synthetic diamonds were pure type Ib with no evidence of a type-Ia character. In contrast, natural type-Ib yellow diamonds: (1) rarely react to U.V. radiation, but when they do, it is usually orange fluorescence to both long- and short-wave U.V. (Shigley et al., 1986); and (2) always exhibit some type-Ia character (again, observations confirmed by A. T. Collins, pers. comm., 1993). GIA and GIA GTL researchers are currently examining some yellow and greenish yellow, untreated and treated (annealing only), mixed type Ib + IaA synthetic diamonds from Russia that reveal only yellow to greenish yellow U.V. fluorescence. Thus, the orange U.V. luminescence observed in the two stones described here is almost certainly the result of irradiation and annealing, not of their mixed type Ib + IaA character. This possibility is supported by the orange fluorescence to both long- and short-wave U.V. of the two irradiated and annealed Sumitomo synthetic diamonds we examined. Furthermore, we have observed orange U.V. fluorescence in all treated-pink natural diamonds examined to date.

Comparison to Natural Diamonds. Some natural-color pink diamonds are type IIa (i.e., essentially lacking in nitrogen) and have an orange U.V. fluorescence (Collins, 1982). We have never seen a known treated pink diamond that is a type IIa. An increasing number of the pink-to-red natural-color diamonds that we have documented are type Ia and have a blue U.V. fluorescence. The color is primarily due to the broad absorption band centered at 550 nm (Collins, 1982; Shigley and Fritsch, 1993). None of these type-Ia natural diamonds has exhibited any type-Ib character. Thus, all known natural-color pink-to-red diamonds are readily distinguishable from the two stones described here (mainly on the basis of the distinctive features of the latter).

We have also documented some treated pink-to-red type-Ib natural diamonds. They usually have evenly distributed color, and all exhibit the 575-, 595-, and 637-nm bands typical of treatment by irradiation and annealing. Although we examined two treated natural diamonds that were a mixed type Ib + IaA and exhibited uneven (pink/yellow) coloration and moderately strong orange fluorescence (to long- and short-wave U.V.), they did not display the pattern of color zoning, nor the nickel-related absorption bands, that were shown by the two stones described here and prove their synthetic origin.

CONCLUSION

These two red stones are the first treated-color synthetic diamonds that have been submitted to the GIA Gem Trade Laboratory by members of the trade. Although we do not know precisely where these synthetic diamonds were manufactured, their color zoning, U.V. luminescence behavior, and visible and infrared absorption spectra are very similar to those we have observed in synthetic diamonds grown in Russia (see, e.g., p. 207 of the Gem News section in this issue). We have no evidence of, or information on, where they might have been treated.

Because such encounters with synthetic diamonds will undoubtedly increase in the future, colored diamonds must be examined with greater care than has been previously necessary. All those involved with selling or grading gem diamonds must know how to identify synthetic, and now treated synthetic, diamonds.

REFERENCES

Burns R.C., Cvetkovic V., Dodge C.N., Evans D.J.F., Rooney M-L.T., Spear P.M., Welbourn C.M. (1990) Growth-sector dependence of optical features in large synthetic diamonds. *Journal of Crystal Growth*, Vol. 104, pp. 257–279.

Burns R.C., Davies G.J. (1992) Growth of synthetic diamond. In J.E. Field, Ed., *The Properties of Natural and Synthetic Diamond*, Academic Press, London, pp. 395–422.

Catalano D.A. (1993) Chatham is entering the diamond business. *National Jeweler, JA Hotline*, July 25–28, pp. 1, 6.

Clark C.D., Collins A.T., Woods G.S. (1992) Absorption and luminescence spectroscopy. In J.E. Field, Ed., *The Properties of Natural and Synthetic Diamond*, Academic Press, London, pp. 35–79.

Clark C.D., Ditchburn R.W., Dyer H.B. (1956) The absorption spectra of irradiated diamonds after heat treatment. *Procedures of the Royal Society*, Vol. A237, pp.75–89.

Collins A.T. (1978) Migration of nitrogen in electron-irradiated type Ib diamond. *Journal of Physics C: Solid State Physics*, Vol. 11, pp. L417–L422.

Collins A.T. (1980) Vacancy enhanced aggregation of nitrogen in diamond. *Journal of Physics C: Solid State Physics*, Vol. 13, pp. 2641–2650

Collins A.T. (1982) Colour centres in diamond. *Journal of Gemmology*, Vol. 18, No. 1, pp. 37–75.

Collins A.T. (1991) Optical centers in synthetic diamond—a review. In R. Messier, J.T. Glass, J.E. Butler, R. Roy, Eds., *Proceedings of the Second International Conference on New Diamond Science and Technology*, Washington, DC, 23–27 September 1990, pp. 659–670.

Collins A.T., Kanda H., Burns R.C. (1990) The segregation of nickel-related optical centers in the octahedral growth sectors of synthetic diamond. *Philosophical Magazine B*, Vol. 61, No. 5, pp. 797–810.

Collins A.T., Spear P.M. (1982) Optically active nickel in synthetic diamond. *Journal of Physics D: Applied Physics*, Vol. 15, pp. L183–L187.

Collins A.T., Stanley M. (1985) Absorption and luminescence studies of synthetic diamond in which the nitrogen has been aggregated. *Journal of Physics D: Applied Physics*, Vol. 18, pp. 2537–2545.

Crowningshield R. (1971) General Electric's cuttable synthetic diamonds. *Gems & Gemology*, Vol. 13, No. 10, pp. 302–314.

Davies G., Hamer M.F. (1976) Optical studies of the 1.945 eV vibronic band in diamond. *Proceedings of the Royal Society of London*, Vol. A348, pp 285–298.

Federman D. (1992) The Hancock red diamond: Per-carat champion. *Modern Jeweler*, Vol. 91, No. 4, p. 34.

Field J.E. (1992) *The Properties of Natural and Synthetic Diamond.* Academic Press, London, 710 pp.

Fritsch E., Scarratt K. (1992) Natural-color nonconductive gray-to-blue diamonds. *Gems & Gemology*, Vol. 28, No. 1, pp. 35–42.

Fritsch E., Shigley J.E. (1993) The separation of natural from synthetic gem-quality diamonds on the basis of crystal growth criteria. *Journal of Crystal Growth*, Vol. 128, pp. 425–428.

Fryer C.W. (1987) Gem trade lab notes: Synthetic diamond. *Gems & Gemology*, Vol. 23, No. 1, p. 44.

Kanda H. (1990) Patterns observed in the cross sections of high pressure synthetic diamonds. *New Diamond*, pp. 58–62.

Kanda H., Ohsawa T., Yamaoka S. (1990) Formation of nitrogen pairs in synthetic diamond during growth. In S. Saito, O. Fukunaga, M. Yoshikawa, Eds., *Science and Technology of New Diamond*, Terra Scientific Publishing Co., Tokyo, Japan, pp. 339–344.

Kane R.E. (1987) Three notable fancy-color diamonds: Purplish red, purple-pink, and reddish purple. *Gems & Gemology*, Vol. 23, No. 2, pp. 90–95.

Koivula J.I., Fryer C.W. (1984) Identifying gem-quality synthetic diamonds: An update. *Gems & Gemology*, Vol. 20, No. 3, pp. 146–158.

Lawson S.C., Kanda H. (1993a) Nickel in diamond: An annealing study. *Diamond and Related Materials*, Vol. 2, pp. 130–135.

Lawson S.C., Kanda H. (1993b) An annealing study of nickel point defects in high-pressure synthetic diamonds. *Journal of Applied Physics*, Vol. 73, No. 8, pp. 3967–3973.

Ponahlo J. (1992) Cathodoluminescence (CL) and CL spectra of De Beers' experimental synthetic diamonds. *Journal of Gemmology*, Vol. 23, No. 1, pp. 3–17.

Rooney M-L.T., Welbourn C.M., Shigley J.E., Fritsch E., Reinitz I. (1993) De Beers near colorless-to-blue experimental gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 29, No. 1, pp. 38–45.

Shigley J.E., Fritsch E. (1993) A notable red-brown diamond. *Journal of Gemmology*, Vol. 23, No. 5, pp. 259–266.

Shigley J.E., Fritsch E., Kammerling R.C., Koivula J.E., Moses T.M. (1993a) Identifying faceted gem-quality synthetic diamonds. *Rapaport Diamond Report*, Vol. 16, No. 26, pp. 10–13.

Shigley J.E., Fritsch E., Reinitz I. (1993b) Two near-colorless General Electric type-IIa synthetic diamond crystals. *Gems & Gemology*, Vol. 29, No. 3, pp. 191-197.

Shigley J.E., Fritsch E., Reinitz I., Moon M. (1992) An update on Sumitomo gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 28, No. 2, pp. 116–122.

Shigley J.E., Fritsch E., Stockton C.M., Koivula J.I., Fryer C.W., Kane R.E. (1986) The gemological properties of the Sumitomo gem-quality synthetic yellow diamonds. *Gems & Gemology*, Vol. 22, No. 4, pp. 192–208.

Shigley J.E., Fritsch E., Stockton C.M., Koivula J.I., Fryer C.W., Kane R.E., Hargett D.R., Welch C.W. (1987) Gemological properties of the De Beers gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 23, No. 4, pp. 187–206.

Woods G.S. (1984) Infrared absorption studies of the annealing of irradiated diamonds. *Philosophical Magazine B*, Vol. 50, No. 6, pp. 673–688.

Woods G.S., Lang A.R. (1975) Cathodoluminescence, optical absorption, and X-ray topographic studies of synthetic diamonds. *Journal of Crystal Growth*, Vol. 28, pp. 215–226.

TWO NEAR-COLORLESS GENERAL ELECTRIC TYPE-IIA SYNTHETIC DIAMOND CRYSTALS

By James E. Shigley, Emmanuel Fritsch, and Ilene Reinitz

Gemological examination of two near-colorless, isotopically pure, carbon-12 synthetic diamonds grown recently by General Electric reveals short-wave ultraviolet luminescence behavior, a cathodoluminescence pattern, and small metallic inclusions that are typical of other gem-quality synthetic diamonds. These characteristics also help separate them from natural type-IIa diamonds. Study of additional near-colorless synthetic diamonds is needed to confirm these preliminary observations.

Of all the gem-quality synthetic diamonds that could potentially enter the jewelry trade, faceted near-colorless synthetic diamonds are the greatest concern. Not only do near-colorless diamonds represent the vast majority of stones in the jewelry industry, but the techniques the jeweler typically uses to quality grade these stones are different from those needed to separate natural from synthetic diamonds. Yet relatively few near-colorless gem-quality synthetic diamonds have been made available for gemological examination, so practical means for identifying them have not been well documented.

In 1990, scientists at the GE (General Electric) Research and Development Center in Schenectady, New York, announced the production of a new, isotopically pure carbon-12 (^{12}C) synthetic diamond (press releases issued by General Electric Company, 10 July 1990 and 18 October 1991). Carbon in nature consists of a mixture of carbon atoms that have different masses (weights), called isotopes: 98.89% of carbon has 12 atomic mass units (usually written ^{12}C), and 1.11% of carbon has 13 atomic mass units (^{13}C). This applies to carbon found in natural and most synthetic diamonds as well. Using isotope enrichment, one can make carbon that is almost pure ^{12}C or ^{13}C. Such enrichment processes are both difficult and expensive. However, the resulting isotopically pure diamond crystals have advanced technological applications related to their exceptional ability to disperse heat (Anthony et al., 1990; Banholzer and Anthony, 1992).

The very few GE ^{12}C diamond crystals grown so far are only available for scientific studies; to date, none has been sold or faceted (R. D'Angelo, pers. comm., 1993). This article reports on the gemological properties and identification of two of these new GE near-colorless ^{12}C synthetic diamond crystals (figure 1), and discusses how their properties compare to those of other near-colorless GE synthetic diamonds produced in the 1970s and examined by GIA at that time (Crowningshield, 1971; Koivula and Fryer, 1984). While we do not expect these near-colorless GE synthetic diamonds to appear in the jewelry industry, those from other

ABOUT THE AUTHORS

Dr. Shigley is director of research, and Dr. Fritsch is manager of research, at the Gemological Institute of America, Santa Monica, California. Dr. Reinitz is a research scientist at the Gemological Institute of America, New York.

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Figure 1. These two near-colorless synthetic diamond crystals, grown by the new GE process, were loaned to GIA by GE Superabrasives in Worthington, Ohio. Some crystal faces of these 0.91- and 1.04-ct (respectively) cuboctahedral crystals have been polished. Photo by Maha DeMaggio.

sources, grown from carbon with the standard isotopic composition or with impurities removed, could eventually become available.

THE SYNTHESIS PROCEDURE

As with the first gem-quality GE synthetic diamonds reported in 1970, these newer crystals are grown using the standard high temperature/high pressure flux technique in what is referred to as a "belt" apparatus (figure 2; Strong and Chrenko, 1971; Bundy et al., 1973; Strong and Wentorf, 1991). A tiny (about 0.001 ct) synthetic diamond "seed crystal" (with a carbon isotope ratio of 99% ^{12}C and 1% ^{13}C) is positioned in the growth vessel to initiate crystal growth. However, the synthetic diamond used as carbon-source material for this new production is quite different from the carbon (with a standard isotopic composition) that was used earlier at General Electric. The carbon-source material for this new production of large (up to about 1 ct) single crystals is actually a thin, polycrystalline layer of synthetic diamond—grown using isotopically enriched ^{12}C methane gas by a low-pressure, chemical vapor deposition (CVD) technique (Anthony et al., 1990; also see Fritsch et al., 1989)—that has been crushed and powdered. In addition, the new procedure uses a transition metal flux that removes nitrogen and boron impurities, thus resulting in the crystallization of type-IIa crystals. Synthetic diamond crystals produced by this technique have ranged up to 99.9% ^{12}C (with other crystals grown by this method having up to 99% ^{13}C).

A small quantity of these new ^{12}C diamond crystals have been grown, initially at the GE research facility in Schenectady, New York, and most recently at GE's commercial production facility (GE Superabrasives) in Worthington, Ohio. This research program is designed to explore the fundamentals of diamond growth and the physical-performance characteristics of this particular diamond material. Because of their isotopic purity, the thermal conductivity of the ^{12}C synthetic diamonds is reportedly superior to that of natural diamonds. They are apparently also more resistant to laser damage. GE representatives are exploring the use of this new type of synthetic diamond (when cut into thin wafers—see figure 3) as heat sinks for telecommunications equipment, computers, and integrated circuits. They also envision their use as windows or mirrors in laser equipment. Manufacturing and marketing of these costly crystals for specialized, high-technology applications will be handled through GE Superabrasives in Worthington.

Figure 2. A General Electric scientist prepares the high temperature/high pressure "belt" apparatus for growing synthetic diamond crystals. Photo courtesy of General Electric.

Figure 3. One of the new GE ^{12}C synthetic diamond crystals is shown here cut into slices for use in various high-technology applications. Photo courtesy of General Electric.

MATERIALS AND METHODS

Following a visit to the GE facilities in Worthington by one of the authors (EF), representatives of GE Superabrasives loaned GIA the two ^{12}C diamond crystals shown in figure 1 (as noted above, to date none of this material has been faceted). These two crystals weigh 1.04 ct and 0.91 ct.

Our examination was conducted using standard gemological testing equipment as well as more sophisticated instruments. The former included a GIA GEM Instruments binocular microscope, a long-wave (366-nm) and short-wave (254-nm) ultraviolet (U.V.) lamp unit (used in a darkened room), a Beck prism spectroscope, and a DISCAN digital-scanning, diffraction-grating spectroscope. Also used were a Pye-Unicam 8800 ultraviolet-visible spectrophotometer and a Nicolet 60SX Fourier-Transform infrared spectrometer. Observations of cathodoluminescence were made with a Nuclide ELM-2B luminoscope. Qualitative chemical analysis was carried out by the energy-dispersive X-ray fluorescence (EDXRF) method using a Tracor X-Ray Spectrace 5000 instrument.

RESULTS

Crystal Morphology. Both crystals are cuboctahedra with octahedral, cube, and other crystal faces of varying relative size and arrangement. The surface attached to the seed crystal had been polished on both crystals; on the smaller crystal, all the faces had been polished.

The octahedral faces of both crystals have the largest surface area. On the larger crystal, the trapezohedral faces are larger than the cube faces, while the reverse situation prevails on the smaller crystal. The larger crystal exhibits very small dodecahedral faces.

Some surface markings, such as trigons on octahedral faces, could be seen on the larger crystal. These two crystals are similar in morphology to the yellow synthetic diamonds described previously (Shigley et al., 1986, 1987).

Color. For research purposes only (inasmuch as the GIA Gem Trade Laboratory does not color or clarity grade rough diamonds, either natural or synthetic), GIA GTL staff members determined that the approximate color grade of the two samples is in the "L–M" range; that is, they both exhibit a faint yellow color. No color zoning was observed. According to published reports (Anthony et al., 1990; Shor, 1990), some other new GE crystals (apparently earlier crystals, presumably grown at the GE research facility in Schenectady) have higher color grades, in the "E–G" range.

Microscopy. Using a gemological microscope at low to moderate magnification (10–40×), we saw several interesting features. The larger crystal revealed a few small, rod-like metallic inclusions (figure 4), similar to those we have seen in other synthetic diamonds. Both crystals also contained clusters or "clouds" of tiny, triangular or lozenge-shaped, tabular inclusions in areas beneath the octahedral crystal faces, as well as tiny pinpoint inclusions scattered throughout. In transmitted

Figure 4. This small, elongate, metallic inclusion was seen in the larger of the two GE ^{12}C synthetic diamond crystals. Photomicrograph by John I. Koivula; magnified 40×.

light, these tabular inclusions had low relief and a brownish appearance. In reflected light, however, they had higher relief and a bright, white or metallic, reflective appearance (figure 5). When suspended from a string, both crystals were attracted to a simple magnet, undoubtedly because of these flux metal inclusions. EDXRF analysis of the smaller crystal failed to reveal the chemical composition of these inclusions.

We did not see any graining (or fractures or cleavages) in either crystal.

While examining the two crystals between crossed polarizing filters with a gemological microscope, we saw anomalous birefringence ("strain") present as a weak, banded or clustered pattern of gray or blue (first-order and some second-order) interference colors. We also observed a weak strain pattern related to the occurrence of the large flux inclusions (see figure 6) in the larger specimen, and a weak banding of strain parallel to the cube faces of both crystals. The general absence of strain in synthetic diamonds was first reported by Crowningshield (1971) and has been routinely noted in subsequent GIA articles on the gemological properties of synthetic diamonds.

Luminescence. Both crystals were inert to long-wave ultraviolet radiation, but fluoresced a weak yellowish orange to short-wave U.V. The latter appeared to increase in intensity for a short period when the U.V. lamp was turned on, and then to stabilize at a certain level. One of the distinctive gemological characteristics of gem-quality synthetic diamonds is that they typically have a more intense response to short-wave U.V. than to long-wave U.V. (Crowningshield, 1971; Koivula and Fryer, 1984; Shigley et al., 1986, 1987; Scarratt, 1987; Rooney et al., 1993).

Figure 5. Both of the GE ^{12}C synthetic diamonds revealed clusters of tiny triangular or lozenge-shaped tabular inclusions of flux metal beneath the octahedral faces of the crystal. In reflected light, these inclusions appear metallic and reflective. Photomicrograph by John I. Koivula; magnified 40×.

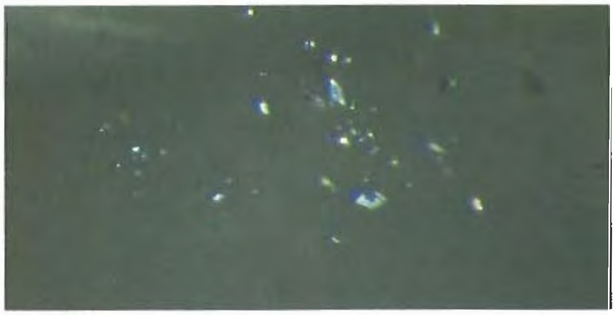


Figure 6. A weak pattern of anomalous birefringence ("strain") can be seen in the smaller crystal when it is examined between crossed polarizing filters. The black, bluish gray, and light gray are low-order interference colors indicative of weak strain. The birefringence occurs around inclusions and in a pattern related to the arrangement of internal growth sectors. Photo by John I. Koivula.

However, the zoning of short-wave U.V. fluorescence seen in the yellow and blue synthetic diamonds we have examined to date was not evident in either of these new GE crystals. When the short-wave lamp was turned off, both crystals continued to luminesce. This moderate greenish yellow phosphorescence persisted for more than two minutes.

We also observed the cathodoluminescence of the two crystals, that is, their luminescence when exposed to a beam of electrons in a vacuum chamber. Under these conditions, we clearly saw a zoned pattern of luminescence corresponding to the arrangement of different internal growth sectors (as has been reported in yellow synthetic diamonds; see Shigley et al., 1987).

There was, however, some difference in cathodoluminescence pattern between the two GE crystals. When viewed with its base upward, the smaller crystal exhibited large areas of slightly greenish blue luminescence just below (and with some banding parallel to) the four octahedral faces (figure 7). Beneath the four cube faces, we observed narrow areas that formed a cross-shaped pattern with a weaker reddish luminescence (not visible in figure 7). In the larger crystal, the areas of bluish luminescence, again beneath the octahedral faces, were smaller, but the areas of weak reddish luminescence beneath the cube faces were larger. There was also a small area of bright blue luminescence in the center of this crystal. These luminescence patterns are related to the relative sizes, differences in impurity content, and different geometric arrangements of the internal growth sectors. We were surprised, however, to see stronger luminescence from the octahedral growth sectors of these crystals than from their cube sectors (in contrast to previous observations; see Shigley et al., 1987). Regardless, this zoning geometry clearly indicates the presence of different types of growth sectors, which identifies the crystals as synthetic.

When exposed to a beam of X-rays, both crystals luminesced yellow. When the X-rays were turned off, both crystals exhibited very persistent yellow phosphorescence—the larger crystal for about two minutes, and the smaller crystal for about 10 minutes.

Electrical Conductivity. Neither crystal proved to be electrically conductive. This directly contrasts with data reported on the near-colorless GE synthetic diamonds produced in the early 1970s (Crowningshield, 1971; Koivula and Fryer, 1984), which we determined—on the basis of their mid-infrared spectra—to be a mixed type IIa/IIb. As a result, electrical conductivity is no longer as diagnostic an identification property for near-colorless synthetic diamonds as was suggested in these articles.

Spectroscopy. We saw no sharp absorption bands in the visible spectra of either crystal, although we did observe a very slight increase in absorption toward the ultraviolet in both. This broad absorption at the blue end of the spectrum accounts for the faint yellow color of these crystals.

The infrared spectra of these two crystals confirmed that they are type-IIa diamonds; none of the impurity-related absorption bands that are characteristic of other diamond types were present (for information on diamond types, see Fritsch and Scarratt, 1992). This is consistent with the high-purity crystal-growth method used. Therefore, neither visible-range nor infrared spectroscopy is useful in identifying the synthetic character of these crystals.

Figure 7. The uneven cathodoluminescence of the smaller GE ^{12}C synthetic diamond results from the conditions of crystal growth, which produced an arrangement of octahedral and cube internal growth sectors that are revealed by their differing luminescence behavior. Photo by Maha DeMaggio.

DISCUSSION

The gemological reports on earlier GE synthetic diamonds noted that they contained flattened or rod-like dark metallic inclusions or tiny dust-like pinpoints, exhibited no sharp bands in their visible-range absorption spectrum, and were remarkably free of "strain." Two of the faceted stones examined for these reports were color graded in the "I–J" range. In addition, these synthetic diamonds fluoresced and phosphoresced yellow to short-wave (but not to long-wave) U.V. radiation and to X-rays, and they were slightly electrically conductive. Tests such as infrared spectroscopy and EDXRF chemical analysis that are now routinely performed in gemological research were not done at that time because the instrumentation was not readily available.

The two crystals documented here have both similarities to, and differences from, early GE near-colorless synthetic diamonds—as reported by

Crowningshield (1971) and Koivula and Fryer (1984), and with information provided by three crystals (0.20 to 0.75 ct) and four faceted stones (0.29 to 0.78 ct; "F–G" and "H" color grades) subsequently examined in GIA Research. Both the older and the newer GE gem-quality synthetic diamonds have weak-to-strong yellow short-wave U.V. fluorescence (but no long-wave U.V. fluorescence), little or no "strain," metallic flux inclusions, and a visible-range absorption spectrum with no sharp bands. However, the earlier GE material is electrically conductive type-IIa/IIb diamond while, in contrast, the newer GE crystals are type-IIa diamonds, which do not conduct electricity. We are certain that these features result from differences in the growth process and are not related to the carbon isotope composition.

As part of GIA's ongoing research into synthetic diamonds, we have also begun to document type-IIa natural diamonds to help identify their distinguishing characteristics. Although to date we have studied only 30 rough and faceted type-IIa diamonds, some preliminary observations can be drawn.

These "near-colorless" natural type-IIa diamonds appeared to fall into two categories: (1) those that are slightly brownish or grayish (five of the 30), and (2) those that are essentially colorless ("D to F" color grades; 25 of the 30). Of the 30 samples, 20 were inert to both long- and short-wave U.V. radiation, and 10 exhibited a very weak or weak blue, yellow, or orange fluorescence to both wavelengths (with the long-wave reaction equal to or greater than the short-wave reaction). Although very weak U.V. fluorescence in a diamond may be difficult to see (even in a darkened room), we saw a very weak yellow or blue fluorescence to short-wave U.V.—with no fluorescence to long-wave U.V.—in only two of these natural diamonds. Only one of the 30 samples displayed any phosphorescence: a weak yellow luminescence that persisted for only a few seconds. Weak octahedral graining could be seen in almost all faceted samples, and they all exhibited a corresponding weak, cross-hatched "strain" pattern of blue and yellow or gray interference colors (with the cross-hatched pattern representing planes parallel to octahedral crystal faces). Metal inclusions are virtually unknown in natural gem diamonds (although Sobolev et al., 1981, reported the presence of metallic iron as inclusions in some natural diamonds). Nor have we ever seen triangular tabular inclusions, like those in the two GE crystals described here, in a natural diamond. Last, the visible-range absorption spectra of the natural samples lacked strong sharp absorption bands, but two samples displayed one or more weak sharp bands (such as at 503, 515, and 575 nm). We observed no distinctive features in the infrared spectra of these 30 natural diamonds.

In general, the most useful properties to identify near-colorless GE synthetic diamonds include short-wave U.V. fluorescence and phosphorescence, metallic inclusions, yellow X-ray luminescence and phosphorescence, and zoned cathodoluminescence. The absence of anomalous birefringence is only an indication of synthetic origin, as is the observation of a visible spectrum with no sharp absorption bands. However, because we have been able to examine only a very few near-colorless gem-quality synthetic diamonds to date, we urge caution in overgeneralizing from these few observations.

When testing an unknown near-colorless diamond, a practical approach would be to check the short-wave U.V. luminescence, and to look for the presence of metallic inclusions and for the absence of both anomalous birefringence and sharp bands in the visible absorption spectrum. Since most near-colorless natural gem diamonds are type Ia, they will likely have U.V. luminescence (to both long- and short-wave radiation, with long-wave more intense than short-wave) and a visible-range absorption spectrum exhibiting one or more sharp bands ("Cape lines"). Although natural type-IIa diamonds will not show these features, they can display graining and anomalous birefringence related to their growth as octahedral crystals. In testing an unknown near-colorless diamond, it may be more useful to check for features that prove the stone is a natural diamond than to look for those that indicate that the diamond is synthetic. Use of advanced techniques such as cathodoluminescence or possibly EDXRF chemical analysis may help confirm an identification in difficult cases.

CONCLUSION

Examination of two near-colorless, isotopically pure, ^{12}C type-IIa synthetic diamond crystals grown by General Electric using a new method has revealed that they have several distinctive gemological properties. Most diagnostic are luminescence to short-wave U.V. radiation (as for most synthetic diamonds reported to date), and the presence of metallic inclusions and very small triangular tabular inclusions. Further study of natural and synthetic type-IIa diamonds is needed to confirm these preliminary identification criteria. Although colored synthetic diamonds have some obvious distinctive properties, the identifying characteristics of near-colorless synthetic diamonds appear to be more subtle. While there is little possibility that these GE synthetic diamonds will be sold for jewelry use, the diamond industry must anticipate the challenge of identifying near-colorless synthetic diamonds produced by other manufacturers.

REFERENCES

Anthony T.R., Banholzer W.F., Fleischer J.F., Wei L., Kuo P.K., Thomas R.L., Pryor R.W. (1990) Thermal diffusivity of isotopically enriched ^{12}C diamond. *Physical Review B (Condensed Matter)*, Vol. 42, Third Series, No. 2, pp. 1104–1111.

Banholzer W.F., Anthony T.R. (1992) Isotope enrichment during diamond growth. *Diamond and Related Materials*, Vol. 1, No. 12, pp. 1157–1160.

Bundy F.P., Strong H.M., Wentorf R.H. Jr. (1973) Methods and mechanisms of synthetic diamond growth. *Chemistry and Physics of Carbon*, Vol. 10, pp. 213–263.

Crowningshield R. (1971) General Electric's cuttable synthetic diamonds. *Gems & Gemology*, Vol. 13, No. 10, pp. 302–314.

Fritsch E., Conner L., Koivula J.I. (1989) A preliminary gemological study of synthetic diamond thin films. *Gems & Gemology*, Vol. 25, No. 2, pp. 84–90.

Fritsch E., Scarratt K. (1992) Natural-color, nonconductive gray-to-blue diamonds. *Gems & Gemology*, Vol. 28, No.1, pp. 35–42.

Koivula J.I., Fryer C.W. (1984) Identifying gem-quality synthetic diamonds: An update. *Gems & Gemology*, Vol. 20, No. 3, pp. 146–158.

Rooney M.L-T., Welbourn C.M., Shigley J.E., Fritsch E., Reinitz I. (1993) De Beers near colorless-to-blue experimental gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 29, No. 1, pp. 38–45.

Scarratt K. (1987) Notes from the laboratory—11. *Journal of Gemmology*, Vol. 20, Nos. 7/8, pp. 406–409.

Shigley J.E., Fritsch E., Stockton C.M., Koivula J.I., Fryer C.W., Kane R.E. (1986) The gemological properties of the Sumitomo gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 22, No. 4, pp. 192–208.

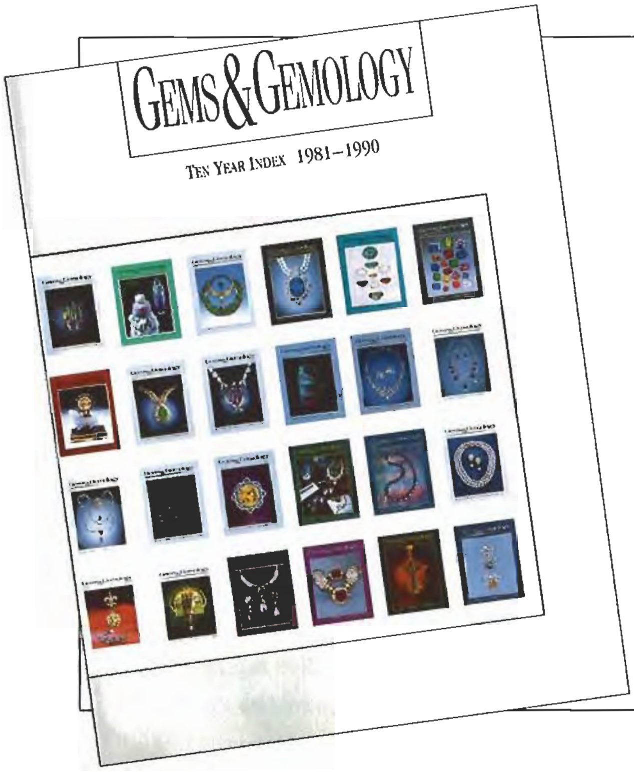
Shigley J.E., Fritsch E., Stockton C.M., Koivula J.I., Fryer C.W., Kane R.E., Hargett D.R., Welch C.W. (1987) The gemological properties of the De Beers gem-quality synthetic diamonds. *Gems & Gemology*, Vol. 23, No. 4, pp. 187–206.

Shor R. (1990) GE's new synthetics are 'costly beauties.' *Jewelers Circular Keystone*, September, Vol. 161, No. 9, pp. 62–63.

Sobolev N.V., Efimova E.S., Pospelova L.N. (1981) Native iron in diamonds of Yakutia and its paragenesis. *Soviet Geology and Geophysics*, Vol. 22, No. 12, pp. 18–21.

Strong H.M., Chrenko R.M. (1971) Further studies on diamond growth rates and physical properties of laboratory-made diamonds. *Journal of Physical Chemistry*, Vol. 75, No. 12, pp. 1838–1843.

Strong H.M., Wentorf R.H. Jr. (1991) Growth of large, high-quality diamond crystals at General Electric. *American Journal of Physics*, Vol. 59, No. 11, pp. 1005–1008.



GEM TRADE LAB NOTES

Clarified AMBER Beads

While we were working on the mystery of the fading amber cabochons described in the Summer 1993 Lab Notes section (pp. 122–123), we received a necklace of baroque amber "nuggets" (figure 1) that had many of the characteristics of the previously described specimens. Specifically, the "nuggets" also fluoresced orange to long-wave U.V. radiation in the brown areas and blue in the near-colorless areas. A few beads had planes of tiny bubbles near the surface, and many showed heat-induced "sun spangles." As with the cabochons, the color of these beads also appeared to be confined to the surface, although wherever a stress "spangle" broke the surface, the brown color had penetrated it, contrasting markedly with the colorless appearance of those spangles that were completely enclosed (figure 2). Because the fluorescence, near-surface bubbles, and stress spangles are typical of clarified material, it would appear that the original material from which most, if not all, of the beads were fashioned was cloudy.

Figure 1. Prolonged exposure to strong light did not change the color of the amber beads (largest is 2.4 × 15.25 × 7.80 mm) in this 40-cm (16-inch) long necklace of amber beads.

Figure 2. The heat-induced "spangles" that reach the surface of this amber bead are dark; those that are totally enclosed within the bead are not.

Since these beads had properties similar to those of the cabochons described in the last issue, which faded when exposed to light, we fade tested one by placing it about 7.5 cm (3 inches) from the bulb of a 12-watt Tensor lamp for seven days. (Neighboring beads were carefully shielded from the light.) The selected bead failed to fade, which indicates that the material was not surface treated in the same manner as were the cabochons described in the Summer issue.

At the time we tested the "fading" amber cabochons, we also exposed one each of five pairs of closely matched, untreated Dominican amber cabochons to the Tensor lamp for a seven-day period. The control sample of each pair was kept in the dark during the exposure period. All but one of the exposed cabochons actually *darkened*. This reaction was not unexpected, since untreated amber typically darkens with time due to oxidation. Exposure to strong light apparently accelerates the process.

GRC

DIAMOND

Brown-Pink Diamond with "Green Graining"

"Green graining" (colorless or brown graining that appears green because of transmission luminescence) is most commonly associated with brown, orange, and yellow diamonds, and has been seen in some green and near-colorless stones. Recently, the West Coast lab received a 0.52-ct brown-pink round brilliant for grading and determination of its color origin. Magnification showed green graining

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

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Figure 3. This 0.52-ct natural-color brown-pink diamond is unusual because it exhibits brownish pink graining that luminesces green. Magnified 15×.

throughout the pavilion; when used in conjunction with fiber-optic illumination, it revealed that the green graining was actually brownish pink graining that was luminescing green (figure 3).

When examined with fiber-optic illumination, the diamond also exhibited a moderate overall green transmission luminescence. With a desk-model spectroscope, we observed absorption lines at 498 and 504 nm (but no 594-nm line), which is typical of stones that exhibit green graining. We also observed an absorption line at 415.5 nm, as well as the weak bands centered at about 500 and 580 nm that are commonly seen in natural-color pink diamonds. The observed spectrum, plus the presence of pink graining, proved that the stone was of natural color. Such "green graining" is extremely rare in natural-color pink diamonds.

Patricia Maddison and RCK

Light Violet-Gray Diamond

Figure 4 shows the unusual color of a 27.89-ct pear-shaped diamond next to a 7.14-ct D-color stone for comparison. This internally flawless, light violet-gray diamond—cut by a New York dealer from a 60+-ct piece of South African rough—exhibited some unusual characteristics.

During routine examination with the DiamondLite (the stone positioned table down), we noticed two well-defined zones of gray. One was wedge shaped and located toward the head of the stone; the other was more rectangular and in the center, just below the culet. When we viewed the diamond (still table down) parallel to the girdle plane and in the direction of the length, we saw a pale pink color that was even more apparent in the pointed end of this pear-shaped stone when it was examined table up.

Testing for electrical conductivity revealed a weak conduction, with the zones of conductivity correlating to the gray areas—thus indicating that they are type IIb. The diamond did not react to long-wave U.V. radiation, but it fluoresced weak orangy red to short-wave U.V., with phosphorescence of the same color lasting about three minutes. This is consistent with some other type IIb diamonds.

No absorption features were visible with a desk-model prism spectroscope. Nor did the U.V.-visible spectrum recorded with a Pye Unicam SP8-400 spectrometer show any distinct features. The mid-infrared spectrum, recorded with a Nicolet 510 FTIR spectrophotometer, showed features associated with both type IIb and IIa diamonds. The absence of any spectral features that would indicate treatment, together with the electrical conductivity of this stone, proved that it was natural color. In addition, type IIa natural-color pale pink diamonds have been documented by the GIA Gem Trade Laboratory many times, as well as reported in the literature (see, e.g., *Journal of Gemmology*, Vol. 20, No. 6, 1987, pp. 358–361).

The violet-gray color can be explained as an optical combination of the gray and pink zones. Although this is a good example of the mixture of two diamond types, it is the first of this combination (IIa and IIb) that we have recorded. (For more information on diamond types, see, e.g., *Gems & Gemology*, Spring 1992, pp. 38–39.)

Ilene Reinitz and TM

Strain Phantom in Diamond

Phantom crystals are one of the more interesting internal features in gems. Although generally associated with single-crystal quartz, they are also encountered in other materials, including diamond. In the latter, they are typically defined by clouds of pinpoint inclusions and/or various types of graining, both of which usually can be resolved with darkfield illumination.

Recently, the West Coast lab was asked to determine origin of color for a 3.01-ct modified emerald-cut light-yellow diamond. Microscopic examination with darkfield conditions revealed nothing unusual. However, when crossed polarizers were used in

Figure 4. Note the subtle color difference between the light violet-gray 27.89-ct pear-shaped diamond on the right and its D-color 7.14-ct counterpart on the left.

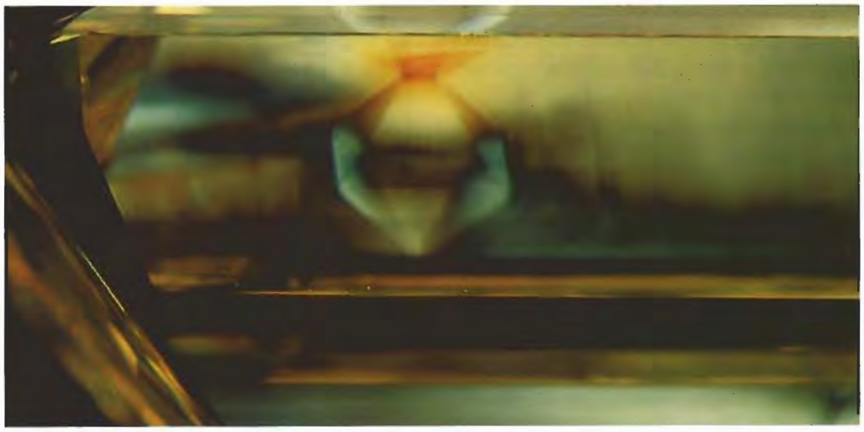


Figure 5. Crossed polarizers clearly reveal a "strain phantom" in this 3.01-ct light-yellow diamond. Magnified 8×.

conjunction with magnification, we were surprised to see a well-formed phantom with a distinctive octahedral shape that was very clearly defined by first-order interference colors (figure 5). Although such phantoms are not unknown in diamond, this one is exceptional for the sharpness of its delineation. *RCK*

Synthetic Yellow Diamond Crystal

Last summer, the East Coast laboratory received a 0.74-ct orangy yellow crystal for routine identification. Measuring 4.83 × 4.75 × 3.62 mm, the crystal displayed a predominantly cubic form with minor octahedral and dodecahedral faces.

Magnification revealed fairly large inclusions with metallic luster; when suspended by a thread, the crystal was attracted to a magnet, actually attaching to it. With magnification, we also noted a square pattern of ultraviolet fluorescence and color zoning centered roughly in the middle of the crystal's base. This fluorescence was a moderate green to short-wave U.V. radiation and a weaker green to long-wave U.V.

Infrared spectroscopy helped further characterize the specimen, showing it to be essentially type Ib with some IaA character. In the visible range, we noted rising absorption from 400 to about 480 nm, with distinct, sharp absorptions at 495, 628, 637, 648, and 659 nm. Weaker features were seen at about 609, 615, 618, 630, 642, 651, 684, 711, and 733 nm.

The crystal morphology, metallic inclusions, magnetic reaction, color zoning, and stronger reaction to short-wave than long-wave U.V., clearly identified the crystal as synthetic diamond. The absorptions at 659 and 733 nm, and a weak feature in the mid-infrared at about 1050 cm^{-1} (attributed in the scientific literature to Ni-related defects), are also consistent with synthetic diamond that has been grown in a Ni-containing metallic flux. The absorption at 637 nm suggests that the crystal had been subjected to annealing. We noted with interest that some of these properties are slightly different from those observed in yellow gem-quality synthetic diamonds produced by General Electric, Sumitomo, or De Beers (see, e.g., related articles in the Fall 1984 [pp. 146–158], Winter 1986 [pp. 192–208], and Winter 1987 [pp. 187–206] issues of *Gems & Gemology*). However, all features are consistent with those of some Russian yellow synthetic diamonds currently being studied by GIA Research and the GIA Gem Trade Laboratory (see the Gem News section of this issue; a detailed report on these investigations is also scheduled for an upcoming issue of *Gems & Gemology*).

Soon after receiving the above crystal for examination, the lab was asked to identify, first, a predominantly red round brilliant-cut stone and, some weeks later, a predominantly red radiant cut. These items, described elsewhere in this issue (pp. 182–190), were also determined to be synthetic diamonds, with features similar to those of the Russian synthetics we have examined. The color was the result of irradiation followed by annealing.

TM, RCK, and Emmanuel Fritsch

Treated Green Diamond with a Blue Color Zone

Determining origin of color for some light green diamonds still poses a great challenge for the gemologist. The green color is usually caused by irradiation, but the source of the radiation may be either natural or the product of a laboratory. The criteria used to identify the sources of radiation remain few, but over the years we have documented certain characteristics in known treated stones that do reveal laboratory enhancement. One identifying characteristic is a small blue zone close to the culet (see, e.g., E. Fritsch and J. E. Shigley, *Gems & Gemology*, Summer 1989, pp. 95–101). This feature was very obvious in a 0.75-ct oval, brilliant-cut diamond sent to the West Coast lab for an origin-of-color report. The stone was an attractive light bluish green. No green or brown radiation stains were visible that could impart the green color; nor were there any prominent internal features, except for some graining that appeared brown. In addition, the stone appeared to have a brownish body color when viewed table down in the diamond tray. The visible absorption spectrum did not reveal any distinct lines other than a faint smudge around 500 nm that is usually seen in brown diamonds. The diamond fluoresced a weak yellowish green to both long- and short-wave U.V. radiation.

However, when the stone was viewed table up over a diffused light source, a bluish zone on only one side

Figure 6. A small blue color zone, present on only one side of the culet of this 0.75-ct oval diamond, not only strongly influences the stone's faceup color, but also proves that it has been treated.

Figure 7. The unidentified "coating" on the table of the stone in figure 6 is the first such feature encountered on a diamond in the GIA Gem Trade Laboratory. Magnified 8×.

of the pavilion became visible (figure 6). (We have found that a white color-grading tray placed above the light well in a microscope can make color zones stand out quite prominently.) Although this blue zone at the culet proved (with immersion in methylene iodide) to be quite small and appeared on only one side of the pavilion, its location was such that it imparted enough blue color to make the otherwise light brown diamond appear bluish green. We also noticed on the table of this stone a feature that we had never before encountered on *any* diamond: a whitish, irregularly shaped "coating" of unknown origin (figure 7). KH

Devitrified GLASS, Resembling Actinolite

Among the less commonly seen gem imitations are devitrified glasses. These result from the alteration of a substance from a glassy, noncrystalline structure to one of partial or total crystallization. The trade is probably most familiar with the green devitrified glasses, which are used as jade simulants and marketed under such trade names as "Meta jade" and "Imori stone." The lab has also examined a cobalt-bearing black partially devitrified glass represented as dyed black "onyx" (Lab Notes, Summer 1986, p. 108). Other devitrified glasses reported in *Gems & Gemology* include those that resemble lapis lazuli (G. Bosshart, "Cobalt Glass as a Lapis Lazuli Imitation," Winter 1983, pp. 228–231) and one that was reminiscent of the distinctive blue pectolite from the Dominican Republic (Gem News, Winter 1990, p. 309).

Recently, the West Coast lab received for identification the 12.25-ct tapered, somewhat trapezoidal, tablet shown in figure 8. The dark green color, low diaphaneity, and prominent, eye-visible planes of coarse fibers reminded us of similar features seen in masses of actinolite crystals. Gemological testing revealed a refractive index of 1.60 and a specific gravity of 2.72. Examination with a desk-model spectroscope showed strong absorption increasing toward both ends of the spectrum, with a transmission window from about 540 to 580 nm. Magnification revealed a roiled or swirled effect throughout, as well as the fern-like structure typical of devitrified glass. Our client subsequently told us that this unusual material had been found in a rock quarry in Michigan, where it occurred as irregular lumps. How this manufactured glass got there is not known. RCK

Figure 8. This unusual 12.25-ct tablet, which is reminiscent of a mass of actinolite crystals, proved to be devitrified glass.

Bleached/Polymerized JADEITE Update

Both figures 1 and 3 of the article "Identification of Bleached and Polymer-Impregnated Jadeite" (*Gems & Gemology*, Fall 1992, pp. 176–187)

Figure 9. The beads (8.7–10.0 mm) in this variegated jadeite necklace are representative of the quality of most of the bleached and polymer-impregnated jadeite seen thus far in the East Coast laboratory.

Figure 10. This fine 34.82 ct (39.36 × 17.52 × 6.20 mm) jadeite pendant also proved to have been bleached and polymer impregnated.

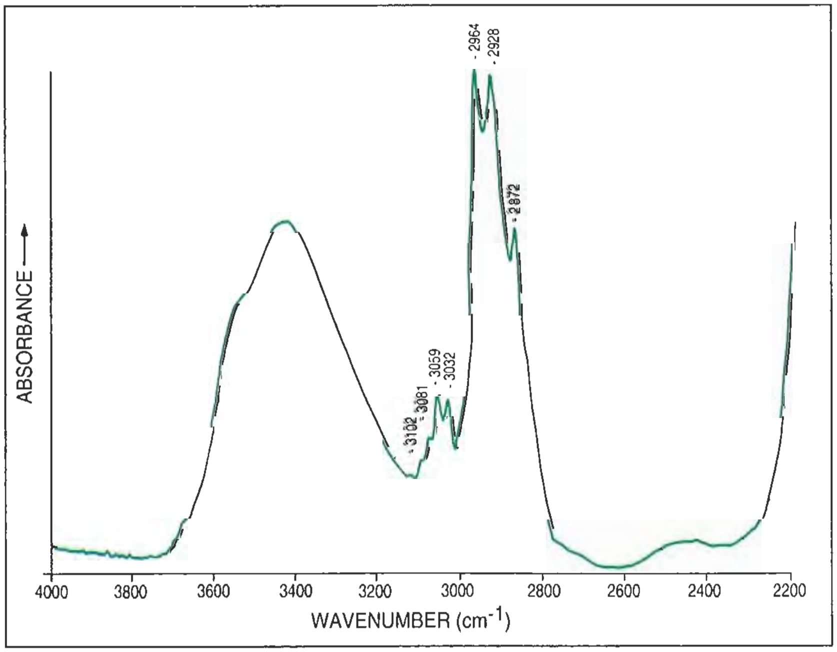
showed high-end treated jadeite. In the months after that article appeared, however, only variegated material (figure 9; similar to the mottled necklace of "B-jade" pictured in the same article) was seen in the East Coast lab.

Recently, however, a New York dealer submitted carvings suitable for pendants (see, e.g., figure 10), stating that he had been informed that the stones had had "the treatment." However, because he had not seen this quality and color for many years, he needed to know if color had been added as well. We were happy to assure him (based on the visible spectrum) that the green color was natural, although there were enormous polymer peaks in the infrared region of the spectrum (figure 11).

By coincidence, we received a jadeite ring and matching earrings at the same time that we were testing the pendants. To the unaided eye, they appeared to be equal in quality to the pendants, but they did not show the presence of any polymer.

GRC

Figure 11. The infrared absorption spectrum of the pendant in figure 10, produced with a Nicolet 510 DX infrared spectrometer, shows strong peaks in the mid-infrared range that are diagnostic of a polymer.



PEARLS

Cultured Pearl, Unusual "Twin"

Throughout history, pearls with unique shapes occasionally have been used creatively in jewelry to simulate flora or fauna. First popularized during the Renaissance era, these were particularly prevalent in jewelry from the late 1800s and early 1900s (see, e.g., Dirlam et al., "Pearl Fashion Through the Ages," *Gems & Gemology*, Summer 1985, pp. 63–78). These unusual shapes were made into *objets d'art*, a practice that continues today.

The East Coast lab recently received for identification a gray pearl that was set in a brooch with a bird motif (figure 12). Not only did X-radiography prove this to be a cul-

Figure 12. This brooch (approximately 29.0 × 25.4 × 6.7 mm) is set with a natural-color cultured pearl that was found to contain two beads.

Figure 13. An X-radiograph of the brooch in figure 12 proves that the pearl is cultured and has two separate beads.

tured pearl, but it also revealed two beads (figure 13). It was not so readily apparent from the X-radiograph whether this was one whole piece or a doublet. However, closer inspection, with a binocular microscope, revealed a continuation of nacreous structure between the head and the body. In addition, the brown-orange long-wave U.V. fluorescence, which is diagnostic of natural color (similar to pearls from French Polynesia), was uniform over the pearl—further proof that it was not an assemblage but rather one piece, essentially a twin cultured pearl. *Nicholas DelRe*

Eroded Cultured Pearls

Figure 14 shows a section of a relatively old (as suggested by the small nuclei and the amount of wear evident) double-strand cultured pearl necklace received by the East Coast lab. Note the area of each pearl that eroded, leaving a "cap" at either end, after repeated contact with the wearer's skin. This erosion affected the first dozen or so pearls at both ends of each strand, where they would be in constant contact with the neck. It would appear that this necklace did not receive proper care, that is, wiping with a damp cloth after each wearing. *GRC*

Figure 14. The central areas of these pearls (5.6–10.4 mm in diameter) have been eroded by contact with the acidic skin of the wearer. Magnified 10×.

Color-Zoned Pink QUARTZ

Last year, a gem dealer from Teófilo Otoni, Brazil, showed us some curious faceted colorless quartz with vivid pink banding, reportedly from the Araçuaí region of Minas Gerais. Later, at the February Tucson gem shows, we saw limited quantities of this gemological curiosity in the form of faceted stones weighing up to a few carats.

More recently, the West Coast lab inspected a highly transparent 4.55-ct modified brilliant-cut oval stone that, face up, appeared to be a fairly uniform vivid pink (figure 15). However, further examination showed color zoning—densely packed thin pink bands in an otherwise colorless stone (figure 16). The gemological properties were consistent with those of quartz.

Although identification of the species was straightforward, the stone presented a nomenclature problem. Should a recognized variety name (i.e., rose quartz or amethyst) be used? To help answer that question, additional testing was carried out at GIA Research.

EDXRF analysis revealed—besides silicon—only traces of iron. Yet U.V.-visible absorption spectroscopy showed absorption features more similar to those of amethyst (color produced by iron) than of rose quartz, which suggests that the coloring agent might be iron.

Still, it did not seem appropriate to call the material amethyst, as it was clearly not purple. In addition, the color banding was very unlike the rhombohedral color zoning typical of this variety. Although the hue was closer to that of rose quartz, rose quartz is usually semi-transparent at best; this stone was more transparent than any specimens of rose quartz we

Figure 15. Table up, this 4.55-ct oval-cut quartz appears a fairly uniform, vivid pink.

Figure 16. Examination at 10× magnification reveals that the pink color of the stone in figure 15 is confined to densely packed bands.

have previously encountered. Also, we have not seen such color zoning in rose quartz. Therefore, we identified the stone simply as "quartz," including the unusual color in its description.

RCK and Emmanuel Fritsch

SYNTHETIC RUBY

Another Imitation Ruby "Crystal"

GIA Gem Trade Laboratory staff are periodically asked to identify what at first glance appear to be natural gem crystals. Gemological testing, however, has exposed a number of these as clever fakes, including cubic zirconia fashioned to resemble diamond octahedra (see, e.g., Lab Notes, Winter 1988, p. 241), flame-fusion synthetic corundum fashioned to imitate natural corundum crystals (Gem News, Winter 1989, pp. 249–250), a glass imitation of tourmaline (Gem News, Summer 1992, pp. 138–139), and irregular pieces of synthetic ruby that have been misrepresented as natural waterworn rough from Vietnam (Gem News, Winter 1991, p. 260). This last imitation appears to have become endemic in the gem trade.

One of the cleverest such imitations ever encountered in the West Coast lab is the 10.85-ct "crystal" shown in figure 17, which resembles a somewhat distorted hexagonal pyramid with a polished base. The "natural" appearance was further enhanced by the waterworn look of the ersatz prism faces, which also exhibited irregularly spaced, parallel "striations," apparently sawn across their widths.

Figure 17. This 10.85-ct imitation of a waterworn ruby crystal is fashioned from melt-grown synthetic ruby.

The gemological properties of this specimen, including R.I. and absorption spectrum, were typical of ruby, either natural or synthetic. However, examination of the specimen's interior through the polished base revealed a network of fractures typical of synthetic corundums that have been quench-crackled to give them a less perfect and more "natural" look. Also noted, near the intersection of some fractures, were minute, highly reflective inclusions that were only tentatively identified as gas bubbles. As these data were inconclusive in proving natural or synthetic origin, the specimen was further examined by GIA Research using EDXRF analysis. This revealed a trace-element composition typical of a melt-produced synthetic ruby.

RCK

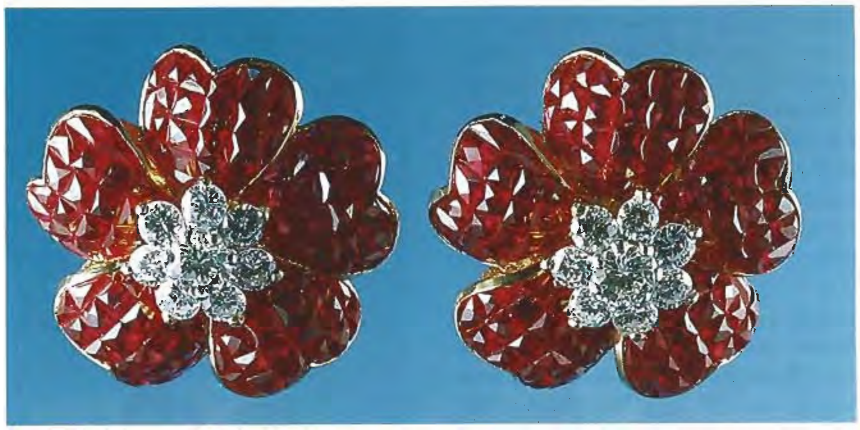


Figure 18. Synthetic rubies (the largest is 1.5 × 1.8 × 2.3 mm) were used in the labor-intensive "invisible" settings of these earrings.

In "Invisible" Mountings

The setting of gemstones so their mountings are "invisible" is an uncluttered and attractive way to use many small stones in a single piece of jewelry. In this process, square-cut (usually) stones are fitted into a gallery of metal tracks. So the stones can "snap" precisely into the metal framework, parallel grooves must be polished on their pavilions (see., e.g., Lab Notes, Spring 1993, p. 48). This labor-intensive "mystery" setting was made popular in the 1930s by Van Cleef & Arpels (see D. Federman, "Invisible Setting," *Modern Jeweler*, February 1993, pp. 51–53).

Until about 10 years ago, virtually all the invisible-mounting ruby-and-sapphire pieces submitted to the lab carried the Van Cleef & Arpels signature and were set with fine-quality natural stones. Over the last decade, however, we have seen a proliferation of lower-quality rubies and sapphires mounted by this costly fabrication method. In general, these pieces do not rival the signature pieces in the workmanship of the mountings or overall quality, but it appears that the execution is cost effective.

Nevertheless, we were quite surprised to determine that the stones set by this labor-intensive process in a pair of flower-motif earrings (figure 18) sent to the East Coast lab were

Figure 19. This asteriated doublet (approximately 13.5 × 11.0 × 7.6 mm) is composed of a synthetic ruby top and an unidentified natural base material.

actually flame-fusion synthetic rubies. Because of the repeated cutting and repolishing necessary to fit the stones in place, the curved striae were difficult to see, although they were visible in most stones when diffused lighting was used. In addition, high magnification with fiber-optic illumination revealed numerous tiny telltale gas bubbles. The stones also fluoresced a strong red to short-wave U.V. radiation, a characteristic of flame-fusion synthetic rubies.

Dan Campbell and TM

As the Top Stone in an Asteriated Doublet

Because the identification of loose assembled stones is usually straightforward, it is not surprising that many of the composite gems seen in the lab are mounted in jewelry. The two types we encounter most often are opal assemblages (including doublets and triplets) and doublets of natural and/or synthetic corundum (occasionally in various combinations with natural or synthetic spinel). On rare occasions, we have also encountered assembled stones that display asterism (e.g., a star sapphire and sapphire doublet, as reported in this section in the Fall 1985 issue, p. 171).

Recently, the West Coast lab received for identification a transparent red cabochon, bezel set in a man's yellow metal ring, that displayed a six-rayed star (figure 19). The spot R.I. reading, characteristic absorption spectrum, and (as seen with magnification) presence of curved striae identified the crown as synthetic ruby. Magnification also revealed numerous round and oval gas bubbles in the cement layer. The reddish purple, semi-translucent base of the cabochon showed pronounced hexagonal growth zoning, partially healed fractures, yellowish brown (limonitic?) staining in fractures, and negative crystals. Although these features are proof that the base is a natural gem material, the mounting prevented a definitive identification. The features noted, however, are consistent with the typically low-transparency, silk-rich natural corundum that is sometimes called "mud ruby" in the trade. The use of such material for the base would also explain the asterism exhibited by the assemblage, as no silk was noted in the synthetic ruby top.

Because we could not conclusively identify the base, the report read "a doublet consisting of a synthetic ruby top with an unidentified bottom, held together with cement," and indicated that the stone would have to be removed from the mounting to identify the bottom material. *RCK*

PHOTO CREDITS

The photos used in figures 1, 2, 4, 9, 10, 12-14, and 18 were taken by Nicholas DelRe. Photomicrographs in figures 3, 5, and 7, and the macro photograph in figure 6, were by John I. Koivula. Maha DeMaggio supplied figures 8, 17, and 19. Ilene Reinitz produced the spectrophotometer curve in figure 11. Shane McClure provided figures 15 and 16.

GEMNEWS

JOHN I. KOIVULA, ROBERT C. KAMMERLING, AND EMMANUEL FRITSCH, EDITORS

DIAMONDS

Argyle production update. Figures for the first six months of 1993 place diamond production by Australia's Argyle mine at 20,013,571 ct from the AK1 pipe primary deposit and 1,060,968 ct from nearby alluvial activity. If production proceeds at this pace, it will undoubtedly exceed the 36,567,849 ct reported for all of 1992. Although the alluvial figure is only a small fraction of Argyle's total output, alluvial diamonds are generally of higher quality than those extracted directly from the pipe. (*Diamond Intelligence Briefs*, August 23, 1993, p. 1031)

Central African Republic has strong reliance on diamonds. The importance of diamonds to a country's economy is well illustrated by figures from the Central African Republic (CAR). According to an August 1993 mining report on Francophone Africa, diamond sales account for 50% of the CAR's gross domestic product and 46% of its export earnings. Annual diamond production is roughly 380,000 ct, of which nearly 80% is reportedly gem quality.

A number of foreign firms have recently started exploration for additional diamond deposits. One, Australia-based Walhalla Mining, has recovered numerous diamonds over 1 ct from alluvium in the firm's 100-km^2 exploration area. Bulk testing of both colluvial and eluvial deposits is scheduled to begin in late 1993. Meanwhile, Canada-based United Reef Petroleum has reported discovering 36 more diamonds, ranging from 0.26 to 7.53 ct, at its Bamingui-Bangoran project in the country's north. (*Mining Magazine*, August 1993, pp. 65, 106; *Diamond Intelligence Briefs*, August 23, 1993, p. 1028)

CSO names first Chinese sightholder. The Central Selling Organisation (CSO) in London has added the first indigenous Chinese firm to its list of sightholders. Located in Shanghai, the China National Pearl, Diamond, Gem & Jewellery Import/Export Corporation is a government-owned entity. It is interesting to note that Gerald L. S. Rothschild, former managing director of I. Hennig brokers, acted as the CSO broker in securing the sight.

The new Chinese sightholder is not the first government-owned operation to be made a sightholder—India and Israel have also had government-owned sightholders. Three more firms, all from India, were also recently added to the list of sightholders. (*Diamond Intelligence Briefs*, July 26, 1993, pp. 1017ff)

Indian polished exports increase. For the one-year period ending March 31, 1993, India reported the purchase of US$2.380 million worth of rough diamonds and the export of polished stones worth $3.240 million, the latter figure representing an added value of 36%, some 10% greater than that recorded for the prior one-year period. The improved export performance was attributed to a move by consumers in recession-hit industrialized nations to the types of smaller stones cut in India. (*Mining Journal*, April 23, 1993, p. 298)

Russian production high but declining. Worldwide revenue from rough diamond sales was US$6.414 billion in 1992, estimates Yorkton Natural Resources, a Canadian stockbrokerage. This figure includes an estimated $1.240 billion for Russia, which places it second only to Botswana ($1.553 billion) in diamond revenue.

Russian production in terms of caratage, however, has declined from a peak of about 20 million carats in 1986 to about 12 million carats in 1991. It is believed that production fell by another 20%–25% in 1992, and De Beers estimates that 1993 output will be around 8 million carats. Continuation of this decline appears likely in the short run. In the eastern Siberian republic of Sakha, production at the Mir pipe is reportedly now negligible, as attempts to move underground have been halted by the presence of huge amounts of methane gas. The Sytykanskaya mine is also reported to be nearing exhaustion, and the Udachnaya mine is expected to be depleted by the year 2000.

Still, there are significant areas with potential for future development if obstacles can be overcome. At least five pipes have been found in the Archangel district of northwest Russia; at least two of these are believed to have economic potential. (For further information on the potential of Russian diamond deposits, see the Levinson et al. article in *Gems & Gemology*, Winter 1992, pp. 234–254.) To develop these, however, an effective way to mine what amounts to a 700-m deep "mud pile"—water-saturated kimberlitic yellow ground—must be found.

Environmentalists are concerned that the outflow from pumping could contaminate local fish-spawning grounds. Dust and material leached from dumps would cause further pollution. Environmentalists, and some of the local populace, are also concerned about possible further damage to the region's swamps and forests. Their position is strengthened by a new national environmental protection law that dictates that development be ecologically sound.

One approach to these potential problems is the use of some alternative mining techniques. For example, Atomredmetzoloto, part of the Russian Nuclear Energy Ministry, has developed a technique by which a grid of wide bore holes (4.6 m or 6.2 m in diameter) is drilled into the diamond-bearing pipes, with the debris then removed in solution for treatment. Design approval for this method has just been granted, and a feasibility study is being conducted. (*Mining Journal,* August 20, 1993, pp. 124–125)

United States sells diamonds from stockpile. The United States Defense National Stockpile Center has sold 932,806.43 ct of industrial and near-gem quality diamonds from a stockpile built up in the 1940s and 1950s for industrial applications. The bidding was reportedly very competitive, with successful bids coming from firms in Antwerp, Chicago, New York, and Ramat Gan, Israel. The U.S. government made a net profit of $77,646,016.94 from the sales. (*Diamond Intelligence Briefs,* July 26, 1993, p. 1022)

Zaire faces severe mining problems. The political crisis in Zaire has led to ongoing problems in that country's mining industry. Diamond production is estimated to have dropped from an estimated 19 million carats in 1991, to about 15 million carats last year. Among the factors accounting for this drop are disruptions in production due to defective operating equipment, shortages of spare parts and fuel, and an influx of illegal miners. (*Mining Magazine,* August 1993, p. 73)

SYNTHETIC DIAMONDS

Chatham proposes commercial production and distribution of Russian synthetic diamonds . . . At the Jewelers of America International Jewelry Show in New York this past July, Thomas H. Chatham announced that his firm, Chatham Created Gems of San Francisco, California, would soon market faceted, gem-quality synthetic diamonds to the jewelry industry. These "Chatham Created Diamonds" reportedly will be produced by Chatham Siberian Gem Company, a firm that Mr. Chatham formed in Russia in June. The production facility, yet to be constructed, will be located in Siberia.

Initially, according to Mr. Chatham, only approximately 100 ct of rough material will be produced monthly and marketed to the trade as faceted stones, the cutting to take place in either Russia or Thailand. He also reported that these stones would be available in a range of qualities and in colors that could include "white" and yellow, among others. Mr. Chatham estimates that the product will sell for approximately 10% of the cost of natural gem-quality diamonds of the same quality.

. . . and GIA says Russian gem-quality synthetic diamonds examined to date can be identified by standard tests. In Spring 1992, GIA received on loan (courtesy of Prof. N. V. Sobolev, director of the Institute of Mineralogy and Petrography, Siberian Branch of the Russian Academy of Science, Novosibirsk) a selection of yellow synthetic diamond crystals and cut stones produced in Novosibirsk. On the basis of separate conversations with Prof. Sobolev and Thomas Chatham, GIA researchers believe that these stones were grown using the same technology that will be used to grow the gem-quality synthetic diamonds that Mr. Chatham proposes to manufacture and distribute. This group of synthetic diamonds is currently being examined by staff members in GIA Research and the GIA Gem Trade Laboratory. The results of this study will be submitted to *Gems & Gemology* for publication in an upcoming issue.

Over the last several years, GIA researchers have reported extensively on synthetic diamonds in this journal, based on their work and on related information in the literature. Articles published in *Gems & Gemology* have described the gemological properties of synthetic diamonds produced experimentally by General Electric and De Beers Diamond Research Laboratory, and those being sold commercially for industrial use by Sumitomo Electric Industries. These reports have covered identification criteria for both colored (i.e., yellow and blue) as well as near-colorless synthetic diamonds. Distinctive features (not seen in natural diamonds) include color zoning (in colored synthetic diamonds), strong fluorescence to short-wave ultraviolet radiation that is often also zoned, rounded metallic flux inclusions, and graining patterns in several geometric shapes. On the basis of this work, GIA researchers have concluded that the gem-quality synthetic diamonds produced to date can be identified by jewelers using standard gem-testing equipment. Further conclusive results may be supplied by advanced testing using, for example, infrared spectroscopy.

This means, however, that gemologists involved in diamond grading must also strengthen their skills in gem identification. Although many of the clues that show that the stone is a synthetic will reveal themselves in the course of standard identification and grading (e.g., metallic inclusions and graining patterns), other tests should be added to ensure that the stone is natural (e.g., stronger luminescence to long-wave than short-wave ultraviolet radiation). Because some of the distinctive visual properties may be subtle, especially in near-colorless synthetic diamonds, gemological identification of this material will probably require more extensive examination of gem diamonds than has been required for diamond grading alone. And, since not every synthetic diamond possesses all the distinctive gemological properties described in past articles, no identification should be based on one gemological property alone.

The Russian synthetic diamonds that GIA is now examining include two cuboctahedral crystals (0.78 and 0.88 ct) and eight faceted stones (0.11–0.51 ct). The two crystals and five of the cut stones are yellow (see, e.g., figure 1). The other three cut stones are greenish yellow; they were reportedly heat treated at high pressure in Novosibirsk during color-enhancement experiments.

The gemological properties of this group exhibit some similarities to, and differences from, what GIA and others have previously reported for yellow synthetic diamonds. The faceted stones were cut from cuboctahedral crystals, so they display internal growth sectors that manifest themselves in several gemological properties (i.e., the distribution of color and U.V. fluorescence, as well as graining). Most of the 10 samples had some kind of uneven color zoning due to differences in impurities between different growth sectors. This color zoning was most apparent when the sample was examined while it was immersed in a heavy liquid such as methylene iodide.

In addition, all responded to short-wave U.V. radiation, although it was surprising to see that all but one also responded to long-wave U.V. However, the long-wave U.V. fluorescence was always less than or equal in strength to the short-wave U.V. response. In all cases, the U.V. fluorescence was unevenly distributed and followed a pattern similar to that of the color zoning.

When examined with a gemological microscope, many of the samples revealed metallic inclusions, weak anomalous birefringence ("strain"), and internal and/or surface graining that marked the boundaries between internal growth sectors. This graining sometimes formed a square, octagonal ("stop sign"), or "hourglass" pattern.

Figure 1. GIA researchers believe that standard gemological tests can identify Russian synthetic diamonds produced to date, like this 0.78-ct crystal and 0.51-ct square step cut. Photo by Nicholas DelRe.

In contrast to what has been observed with other yellow synthetic diamonds, the Russian samples displayed sharp absorption bands in their visible-range spectra that could be seen with a handheld spectroscope. These sharp bands were especially numerous in the three greenish yellow synthetic diamonds that had been heat treated.

On the basis of these features, we believe that the Russian synthetic diamonds produced to date can be identified by standard gemological tests. What impact this material could have on the jewelry industry will depend on how it is marketed, how it is sold, and, ultimately, how it is accepted by consumers. Nonetheless, the ability to identify synthetic diamonds will become increasingly important to insure continued confidence in the diamond market.

Sumitomo Electric synthesizes high-purity diamonds. Sumitomo Electric Industries has successfully synthesized diamond crystals containing less than 0.1 parts per million impurities (and being, therefore, presumably near-colorless), according to *Japan Industrial Journal.* The company has established a purification technology that, during the formation process, adds rare-earth elements to react with impurities. This process can produce diamonds as large as 6 mm on a side, weighing up to 2 ct. The company reportedly plans to market these diamonds for about half the cost of comparable high-purity natural diamonds. Dr. Shuji Yazu, of Sumitomo Electric Industries, has informed GIA researchers that the company does not plan to sell whole crystals and that these synthetic diamonds are not intended for jewelry purposes, but rather for high-tech applications.

COLORED STONES

Significant amethyst find in Maine. In July 1993, three mineral collectors discovered a significant new pocket of amethyst while prospecting a granitic pegmatite on Deer Hill in Stow, Maine, an area known to produce amethyst in the past. Much of the amethyst was found in spaces between large, blocky crystals of altered feldspar, making the crystals easy to remove. Over 2,500 lbs. (about 1,135 kg) of amethyst was reportedly found, although this figure apparently includes massive amethystine quartz as well as single crystals and crystal clusters. A significant number of the crystals are described as being "unblemished"; these range up to 7.4 inches (19 cm) high and 5.9 inches (15 cm) wide. One gem-quality crystal has been cut into a 29.64-ct stone. (*Mineral News,* Vol. 9, No. 8, pp. 1, 4)

Chalcedony colored by large mineral inclusions. Translucent chalcedony colored blue-green by finely disseminated chrysocolla has been known for many years and, in

Figure 2. Concretions of azurite, malachite, and chrysocolla appear to be responsible for the color in this unusual 16.61-ct chalcedony carving. Courtesy of Lehrer Designs; photo by Maha DeMaggio.

the trade, is often called "chrysocolla quartz." Graduate Gemologist Glenn Lehrer, of Lehrer Designs in San Rafael, California, recently sent the Gem News editors a somewhat unusual variation on this material.

Mr. Lehrer had received some rough carving-quality chalcedony from the Baghdad copper mine in Arizona. He noted that distinct blue, blue-green, and green areas were evident in a host rock that was almost transparent. The color in these areas was not caused by finely disseminated mineral matter, but rather by large—up to almost 1 mm in diameter—spherical to hemispherical concretions of what was reported to be azurite, chrysocolla, and malachite. In certain areas, minute yet distinct euhedral crystals with the habit of azurite and malachite were also visible, further contributing to the color of the host chalcedony.

Figure 2 shows a 16.61-ct (54.76-mm-long) free-form carving that Mr. Lehrer fashioned from this material. Note the different colors in this single piece of chalcedony and the eye-visible inclusions.

Massive green grossular garnet from South Africa. At Tucson this past February, Pala International, of Fallbrook, California, offered some exceptional massive green garnets from the Transvaal, South Africa. The color of this material was distinctly brighter and more saturated than that of most massive green garnets that we have seen from this classic locality. The stones they were offering were all cut as oval cabochons, ranging up to about 7 ct. The material is very popular in Asia, no doubt due to its resemblance to fine jadeite, according to Pala International–associate Edward Boehm. However, Pala's Bill Larson indicated that these stones were from an old collection in Germany, not a new source. Only 50 were made available to him.

A 3.31-ct cabochon (figure 3) subsequently examined exhibited the following properties: color—dark, saturated green; diaphaneity—translucent; polariscope reaction—aggregate; spot R.I.—1.74; S.G.—3.60. Examination with a desk-model prism spectroscope revealed a faint absorption line at about 460 nm, a band at 590–610 nm, a fairly sharp line at 630 nm, and another faint line at 670 nm. The stone appeared weak orangy pink when viewed through the Chelsea color filter, and it fluoresced a weak reddish orange to both long- and short-wave U.V. radiation (the short-wave reaction being the stronger of the two), with a strong yellow fluorescence to X-rays. Magnification revealed bands of fluid inclusions and a cloud of small, very dark brown crystals.

The above properties—particularly the relatively high R.I. and S.G.—identified the stone as a massive grossular garnet, not the hydrogrossular type.

"Rainbow" hematite from Brazil. Rock Currier, of Jewel Tunnel Imports in Baldwin Park, California, provided the Gem News editors with samples of an eye-catching iridescent hematite that he has used both for jewelry and as display specimens (figure 4). This fissile (platy) material, called "rainbow hematite," is found in an iron mine near Belo Horizonte, Minas Gerais, Brazil. It fills a very steep, 2+ m (almost 7 ft.) wide vein running about 15 m up a working face in the iron mine, according to Bill Besse, from the same company.

The iridescence is completely natural and appears to be stable to light. Its origin has been researched by Dr. George Rossman of the California Institute of Technology, Pasadena, and by Dr. George Robinson, of the Canadian Museum of Nature in Ottawa. Both detect-

Figure 3. The Transvaal, South Africa, is the reported source of the massive grossular garnet from which this 3.31-ct (9.60 × 6.74 × 5.10 mm) cabochon was fashioned. Courtesy of Pala International; photo by Robert Weldon.

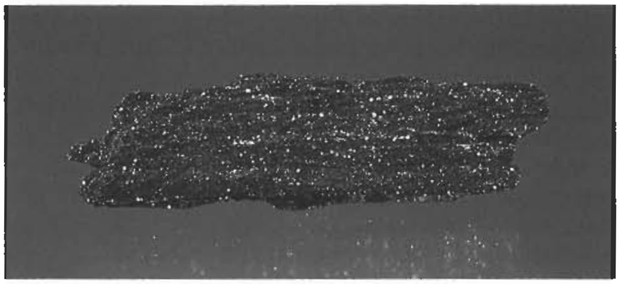


Figure 4. Iridescent hematite, like this 8.73-ct (approximately 35 × 10 mm) specimen, is being recovered in the Belo Horizonte area of Minas Gerais, Brazil. Photo by Maha DeMaggio.

ed a coating, composed of aluminum and phosphorus, on the iridescent surfaces. They hypothesized that this thin film (0.1 micrometer thick in some places) may be responsible for the colorful effect by virtue of an interference phenomenon.

Since the iridescence is confined to this thin film, the surface must be maintained and only the edges worked for jewelry applications.

"Denim" lapis lazuli from Afghanistan. Fine lapis lazuli exhibits a dark, saturated violetish blue color and no white calcite. If pyrite is present, it is in the form of small, dispersed crystals. Such material, associated with the Badakhshan area of Afghanistan, has been readily available in recent years.

This year, however, the editors saw another type of lapis lazuli (figure 5), also reportedly from Afghanistan but with a quite different appearance. This material contained small, medium-to-dark blue areas interspersed with equally small white areas, which produced an overall mottled pale blue appearance. Its resemblance to the color and texture of faded blue denim was not lost on Mahbob Azizi of Liberty Gems and Minerals, Albuquerque, New Mexico, as he was marketing the material as "denim" lapis. Mr. Azizi informed one of the editors (RCK) that the material was being mined in the same general area of Badakhshan that has historically produced lapis lazuli.

Two oval cabochons, 10.39 and 14.02 ct, were purchased for gemological testing. Both were essentially opaque, transmitting only a small amount of light at their edges. Vague spot R.I.'s, obtained at various points on the polished domes of the cabochons, produced values of 1.50 and 1.67, plus a weak "birefringence blink" from about 1.67 to 1.70. The S.G. values (determined hydrostatically) were unexpectedly high—2.98 and 3.02, considering that there was no visual evidence of pyrite. With long-wave U.V. radiation, we noted a mottled fluorescence. The blue areas were inert, and the white areas fluoresced a faint, dull orange. When the samples were exposed to short-wave U.V., the blue areas remained inert, but the white areas fluoresced a moderate greenish yellow. Magnification revealed that the white areas (probably calcite) were interspersed in various combinations with dark blue and lighter greenish blue areas. These areas may be composed of various members of the sodalite group, for example, haüyne, sodalite, nosean, and lazurite, all known components of the complex aggregate gem material called lapis lazuli. Also noted were a few extremely small opaque crystals with a metallic luster, most likely pyrite.

X-ray powder diffraction analyses were performed on minute amounts of material scraped from three areas of one cabochon. All three patterns produced a great number of lines, and we could not conclusively identify any of the individual mineral components. One of the three patterns, however, closely matched one of our standard reference "fingerprint" patterns for lapis lazuli.

Figure 5. This 10.39-ct variegated lapis lazuli cabochon (5.34 × 13.09 × 17.93 mm) from Afghanistan is being marketed as "denim" lapis. Photo by Maha DeMaggio.

Reddish purple mica from New Mexico. Although mica is a common inclusion in gem minerals, it is rarely fashioned for use as a gem material. One exception is pinite, a massive form of muscovite sometimes called agalmatolite (or "Figure Stone") and used as a jade simulant (see, e.g., Gem Trade Lab Notes, Fall 1983, p. 175). At the February Tucson show, however, one of the editors (RCK) spotted the attractive 15.99-ct reddish purple cabochon shown in figure 6. According to Aaron Kuykendall, the material is being recovered in northern New Mexico from a pegmatite that is also rich in white spodumene. Because the material was purple and from a pegmatite, he had tentatively identified it as lepidolite, a lithium-rich mica commonly found in pegmatites in association with such gem materials as tourmaline and spodumene.

Gemological testing of the cabochon revealed: a very vague spot R.I. (due to the poor polish) in the general range 1.55–1.60, an aggregate reaction in the polariscope,

Figure 6. A pegmatite in New Mexico was the source of this 15.99-ct (18.43 × 12.79 × 8.68 mm) mica cabochon. Courtesy of Aaron Kuykendall. Photo by Maha DeMaggio.

a reddish purple appearance through the Chelsea color filter, inert to both long- and short-wave U.V. radiation, a diffused absorption band from about 530 to 580 nm (as seen through a desk-model prism spectroscope), and a 2.85 S.G. (determined hydrostatically). Magnification revealed a pitted surface on a compacted aggregate of micaceous platelets. Also noted was a large, flat break—like the perfect basal cleavage typical of micas.

X-ray powder diffraction analysis revealed a pattern similar to GIA's standard reference patterns for muscovite and pinite. Qualitative analysis by EDXRF revealed a chemical composition consistent with that of micas. Although the chemistry could not help differentiate muscovite from lepidolite, it did reveal the presence of a significant amount of manganese, which could account for the purple color. Because the diffraction pattern did not exactly match that of muscovite, we characterized this material simply as mica.

Nepal update. Gemologist Mark H. Smith of Bangkok, Thailand, reports that on a recent trip to Nepal he was shown numerous local gem materials. Most abundant were specimen-quality, gem-quality, and fashioned elbaite tourmalines, represented as originating from a number of different deposits within Nepal. Large, fine mineral specimens of dravite tourmaline were offered as well. Translucent pink-to-purple corundum was available from mines located at elevations of 3,000–4,500 m (about 10,000–15,000 ft.) above sea level in the Ganesh Himal region. Mr. Smith also saw beryl crystals, some faceted aquamarine, fine blue kyanite crystals, and large quantities of quartz crystals.

Peridot from Vietnam. While visiting the Research Center for Industrial Mineralogy at Hanoi University in November 1992, *Gems & Gemology* Editor Alice S. Keller and one of the Gem News editors (RCK) were shown samples of materials, found throughout Vietnam, that university staff members thought might have commercial gem potential. Among these were what we estimated to be many hundreds of carats of peridot rough.

In July 1993, the Gem News editors learned more about Vietnamese peridot from Saverio Repetto of the Gemological Institute of Vietnam, a joint-venture firm located in Hanoi. According to Mr. Repetto, two deposits were discovered in mid-1993: (1) in Lam Dong Province, southern Vietnam; and (2) in Gia Lai Province, central Vietnam, near the Cambodian border. In their first few weeks of operation, the two localities produced an estimated 100–200 kg of peridot. Production dropped off greatly in August, however, because of the onset of the rainy season.

Mr. Repetto has seen about 60 kg of the peridots from Gia Lai. He described them as averaging about 2–6 ct, with perhaps no more than 5% being larger than 4 ct. The average quality is rather poor, however, as the stones are highly fractured and included, as well as light in color. He estimated that about 15% are suitable for fashioning, with the weight retention being only 5%–10%. Although he has seen significantly less of the Lam Dong material, the rough he has examined to date has generally been of better quality. From the Lam Dong rough, his firm has cut stones up to 7 ct.

Mr. Repetto sent the Gem News editors five faceted Lam Dong peridots (1.60 to 5.56 ct; figure 7) for examination. These transparent stones ranged from yellowish green to brownish green, in medium light to medium dark tones. We measured R.I.'s of $\alpha = 1.650$, $\beta = 1.665$–1.667, $\gamma = 1.687$–1.688, with resulting birefringence

Figure 7. Lam Dong Province in southern Vietnam is the source of these peridots, which range from 1.60 to 5.56 ct. Courtesy of the Gemological Institute of Vietnam; photo by Maha DeMaggio.

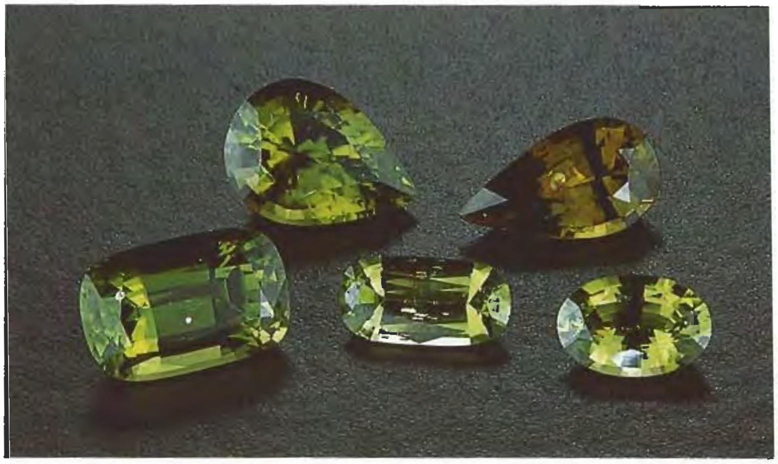


Figure 8. "Lily pad" inclusions like these were seen in all of the Vietnamese peridots shown in figure 7. Photomicrograph by John I. Koivula; magnified 35×.

of 0.037–0.038. S.G. values (determined hydrostatically) ranged from 3.33 to 3.35. With a desk-model prism spectroscope, we saw absorption bands typical of peridot, at approximately 453, 473, and 493 nm. Magnification revealed small, white pinpoint inclusions in association with "lily pads" (figure 8); wispy, whitish planar clouds; partially healed fractures; and occasional dark reddish brown to black crystals that may be chromite or chromian spinel. EDXRF analysis of one specimen indicated the presence of magnesium, iron, and silicon—essential components of peridot—as well as nickel, chromium, manganese, and calcium. These data are consistent with those for peridot from other localities.

Brazilian paragonite mistaken for ruby. Among the more unusual materials seen by one of the editors (RCK) this year was a piece of variegated rough with a dark purplish red core that bore a superficial resemblance to both ruby in zoisite from Tanzania and the pink-purple sapphire in fuchsite from Afghanistan (see, e.g., Gem News, Summer 1991, p. 120). This newest material, reportedly from Brazil, was believed by the vendor to be ruby.

The vendor gave us a 27.75-ct unpolished slab (figure 9) for gemological examination. Testing of the translucent purplish red core revealed: a faint weak red reaction through the Chelsea color filter; a weak red fluorescence to long-wave U.V. radiation (with a similar but slightly weaker reaction to short-wave U.V.); and a visible absorption spectrum consisting of general absorption from about 400 to 480 nm, a band from about 520 to 610 nm, and a series of four fine lines between about 660 and 690 nm. X-ray powder diffraction analysis produced a match with a standard pattern for paragonite—$NaAl_2(Si_3Al)O_{10}(OH)_2$—a member of the mica group; EDXRF analysis supported this identification. These two tests also confirmed that the pale greenish blue layer surrounding the red core was paragonite, too. This is another example of a mica with commercial potential as a gem material (see "reddish purple mica" entry above).

Unusual double star sapphire. Last spring, N-Ter-National Gems of Oklahoma City, Oklahoma, brought to our attention a 38.56-ct translucent, grayish blue sapphire with unusual asterism: two superimposed six-rayed stars, with the rays of one star almost parallel to and just to the side of the other (figure 10).

Magnification revealed that the "silk" that produced the asterism, most likely exsolved rutile, was rather evenly distributed throughout; lamellar polysynthetic twinning, pervasive throughout the stone, was the cause of the unusual effect. The three sets of these needle-like inclusions in one of the orientations of lamellae were not quite parallel to those in the second set of lamellae, so that the rays they produced by light scattering were also not quite parallel. This resulted in two complete, but slightly offset, six-rayed stars when the stone was illuminated with a single point light source.

Black spinel from Mexico. Gray and black gems appear to have regained popularity in recent years. The editors recently obtained a 0.87-ct black faceted material that the dealer, Sri Lanka–based Sally Gems, represented as spinel from Mexico. The stone had a high luster and was opaque throughout; even the thin edges did not transmit the intense light from a fiber-optic illuminator. Both the R.I. of 1.765 and S.G. (determined hydrostatically) of 3.93 were significantly above the mean values for spinel (1.718 and 3.57–3.70, respectively). The stone was inert to both long- and short-wave U.V. radiation, and it had

Figure 9. The purplish red core and greenish blue rim of this specimen (approximately 29.3 × 24.4 × 3.49 mm), which is reportedly from Brazil, are the mica paragonite. Photo by Maha DeMaggio.

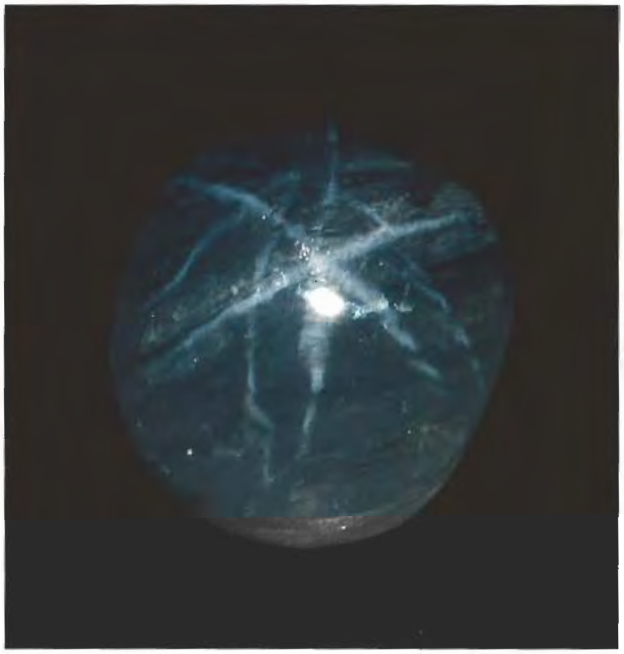


Figure 10. Two distinct, overlapping six-rayed stars can be seen in this 38.56-ct sapphire. Photo by Maha DeMaggio.

no change of appearance through the Chelsea color filter. Examination with a desk-model spectroscope revealed no distinct absorption features.

EDXRF analysis identified magnesium and aluminum in proportions similar to natural spinel, with abundant iron and impurities of titanium, vanadium, chromium, manganese, and zinc. X-ray diffraction analysis showed a standard pattern for hercynite ($FeAl_2O_4$), a member of the spinel group that has a structure similar to that of the spinel species ($MgAl_2O_4$) but a different chemical composition. However, the properties of this stone do not match those reported in the literature for hercynite, that is, R.I. of 1.835 and S.G. of 4.40 (see J. Arem, *Color Encyclopedia of Gems,* second edition, 1987, p. 177).

On the basis of the R.I. and S.G. values measured, we concluded that the material under study is probably a mixture of true spinel and hercynite, approximately halfway between the two species. These properties are, in fact, very close to the material called ceylonite in the gem trade, or pleonaste (R.I.—1.77 to 1.80, S.G.—3.63 to 3.90; again, see Arem, 1987), which is a mixture of both species. According to the *Larousse Encyclopedia of Precious Gems* (P. Bariand and J. -P. Poirot, 1992, p. 178), this black iron-rich spinel is abundant in the gem-bearing gravels of Sri Lanka.

Spinel from Vietnam. Spinel is often found with corundum, for example, in the gem deposits of Sri Lanka and Myanmar (formerly Burma). The corundum deposits of Vietnam are no exception. In fact, gemologist Kenneth Scarratt, who has made a number of trips to the ruby-producing areas of northern Vietnam, was told by a knowledgeable Vietnamese colleague that the discovery of gem spinel in Vietnam (1984) predates the discovery of ruby. Today, significant quantities of spinel—in a broad range of colors and sizes—can be seen in local Vietnamese gem markets, such as the Luc Yen market shown in figure 11.

Saverio Repetto, of the Gemological Institute of Vietnam subsequently loaned one of the Gem News editors (RCK) 11 faceted Vietnamese spinels (0.36 to 4.30 ct) for examination. These stones represented a range of colors, including orangy red to purple, orangy pink to purplish pink, and violet to blue (see, e.g., figure 12). Gemological testing revealed properties consistent with those reported in the literature for spinels, including R.I.'s of 1.714–1.719, an S.G. range (determined hydro-

Figure 11. Spinel is one of the local materials sold at the government gem market at Luc Yen, in northern Vietnam. Photo by Robert C. Kammerling.

Figure 12. These five spinels (1.21–4.30 ct) were fashioned from rough recovered from the same deposits in northern Vietnam that produce rubies. Courtesy of the Gemological Institute of Vietnam; photo by Maha DeMaggio.

statically) of 3.59–3.63, and weak to moderate anomalous birefringence when examined between crossed polarizers. When exposed to long-wave U.V. radiation, the stones that were predominantly red or pink fluoresced a weak to moderate red, and those with more of a purple component exhibited a weaker reaction or were inert. Short-wave reactions were similar in color but of lesser intensity. The blue stones were inert to both wavelengths. Most of the stones with a pink to red component in their body color revealed the "organ pipe" fluorescence spectrum (as described by B. W. Anderson for red spinel) when examined with a desk-model spectroscope. The blue stones displayed spectral features that are attributed to iron.

Magnification revealed internal features that have been noted in spinels from various localities. On the basis of their appearance, these inclusions were tentatively identified as: hexagonal platelets of muscovite mica; apatite crystals; zircons with radiation-induced strain halos; small, black opaque graphite crystals; secondary healing planes, i.e., "fingerprint" inclusions; bundles of parallel and intersecting fine rutile "silk;" decorated intergrowths; and ribbon-like stepped growth planes.

ENHANCEMENTS

World Diamond Congress addresses treatments. The topic of diamond treatments and their disclosure was the focus at the World Diamond Congress this past June in Antwerp, where it was debated by both the International Diamond Manufacturers Association (IDMA) and the World Federation of Diamond Bourses (WFDB). A resolution passed by the latter reinforced and expanded a previous pronouncement on the topic. It reads:

1. The fact that diamonds have been artificially infused with foreign matter, or are coated, or are wholly or partially synthetic, or have been treated by irradiation, must be disclosed as such when offered for sale and in writing on the invoice and memorandum. Any breach of the above rules by a member of an affiliated Bourse shall be regarded as fraudulent.
2. Any violation of the above rule shall be referred to the Bourse for disciplinary action and shall be grounds for suspension, expulsion, fine or such other appropriate disciplinary measure as provided by the by-laws of the Bourse. If the seller alleges that he was not aware of any treatment, he shall bear the burden of proof thereof in order to avoid any sanction.
3. If the seller of a diamond, even in good faith, fails to abide by the above rule, the buyer shall be entitled to cancel the sale, return the diamond, obtain a refund of the purchase price and any direct damage as they, the buyer, may have suffered.

It is particularly interesting that this resolution addresses disclosure not only of such enhancements as fracture filling and irradiation, but also of synthetic diamonds; the wording "wholly or partially synthetic" apparently refers to the possibility of a synthetic diamond thin-film coating on natural diamond, an experimental example of which was described in a Summer 1991 Gem News report. (*Diamond Intelligence Briefs*, June 30, 1993, p. 1009)

Update on ruby enhancement. The Fall 1992 Gem News section (pp. 206–207) contained information from Juan S. Cozar, laboratory director for the Spanish Gemological Institute in Madrid, about what might be a new ruby enhancement, somewhat similar to the glass filling of surface cavities in fashioned corundums.

In response to that entry, Dr. Henry A. Hänni, of SSEF Swiss Gemmological Institute in Zurich, told us of a very similar enhancement that he had encountered in May 1985 in a 9.00-ct East African ruby cabochon. Dr. Hänni reported that he had observed octahedra in the glassy surface layer of a shallow pit on the base of the cabochon. Microprobe analyses of the "glass" and octahedra revealed that the "glass" surrounding the octahedra had the approximate composition of zoisite, while the octahedra had the composition of spinel. A third analysis, taken around the rim of the pit, identified a glass enriched with alumina and calcium oxide. These findings were published the following year in *Zeitschrift der Deutschen Gemmologischen Gesellschaft* (Vol. 35, No. 3/4, pp. 87–96).

On the basis of this research, Dr. Hänni identified the three components found in and around the pit in the ruby cabochon as artificial glass, zoisite, and spinel, the latter two resulting from residual original minerals adhering as devitrification minerals of the glass coating. Since carrying out this examination, however, Dr. Hänni has examined other treated rubies that show microscopic evidence of heat treatment, devitrification, and recrystal-

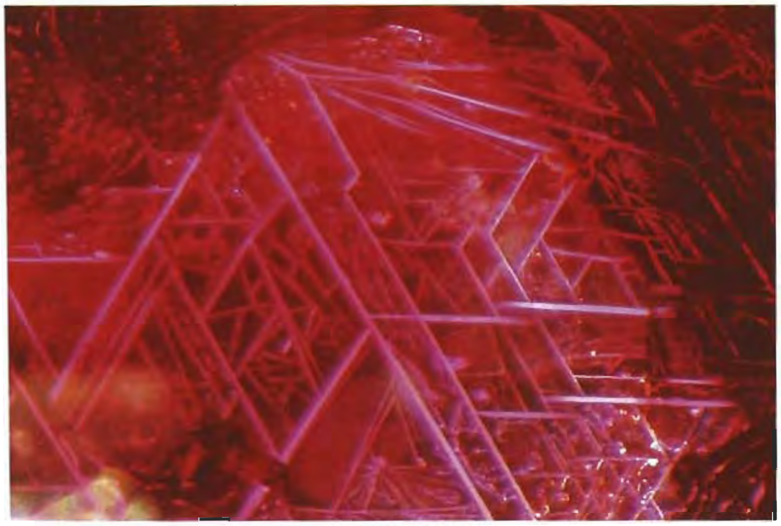


Figure 13. Evidence of recrystallization can be seen in a glass-filled fracture in this treated ruby. Photomicrograph by Dr. H.A. Hänni, courtesy of SSEF Swiss Gemmological Institute; magnified 50×.

lization (see, e.g., figure 13). He theorizes that not every such glassy filling is produced intentionally to fill surface pits and cracks. Rather, corundum is often coated with boron or fluorine compounds to protect the stones during routine heat treatment. As these coatings melt, they can act as a flux, dissolving alumina and other chemicals from the host corundum, and then crystallizing them in pits and surface-reaching fractures.

SYNTHETICS AND SIMULANTS

Glass imitating Vietnamese ruby. Numerous reports in the trade press have discussed episodes of synthetic ruby being misrepresented as natural ruby rough from Vietnam. We recently learned of another unfortunate incident. In this case, the individual purchased a parcel of five "badly waterworn stones" at a mine site in Vietnam; when he subsequently had them tested in the United States, he learned that four of the five were actually flame-fusion synthetic ruby—and the fifth was identified as glass.

The glass specimen was loaned to the editors for examination. It was a very convincing, medium dark purplish red (figure 14), and revealed the following properties: a 1.649 R.I.; a 3.84 S.G.; anomalous double refraction ("strain birefringence") in the polariscope; a red appearance through the Chelsea color filter; inert to long-wave U.V. radiation and a weak, chalky blue fluorescence to short-wave U.V. Magnification revealed two wedge-shaped layers of spherical gas bubbles. Perhaps most interesting gemologically was the absorption spectrum, which included many distinct lines throughout the visible range, with two relatively broader, but still distinct, lines between 570 and 590 nm.

Because of the convincing color and the interesting "rare-earth" type of spectrum, chemical analysis by EDXRF was performed. Among the elements detected were neodymium and lead, which suggests that the material is a lead glass with neodymium producing the ruby-like color.

Dyed magnesite misrepresented as "howlite lapis." Howlite is a mineral species that is usually encountered in its massive form and is occasionally seen in its natural, opaque white color as fashioned beads and cabochons. Because of its neutral body color and porosity, however, it also may be dyed to imitate various other ornamental gems, commonly turquoise.

At a recent gem and mineral show, one of the editors (RCK) spotted some large violetish blue cabochons that were labeled "howlite lapis." The material made a rather convincing imitation of lapis lazuli, as it contained white, dye-resistant veining that resembled the calcite seen in some natural lapis.

A sample was purchased for examination (figure 15). Gemological testing, however, quickly revealed properties inconsistent with those of howlite, including a "birefringence blink," which indicates a high birefringence typical of carbonate minerals. Further testing, including X-ray diffraction analysis, identified the material as magnesite. The presence of dye was confirmed when an acetone-dipped cotton swab produced a blue discoloration when rubbed on the stone. In fact, the dye treatment was so unstable that some of the color was removed by the contact liquid during R.I. testing. Subsequent experimentation showed that even a mild soap solution removed some of the dye.

Figure 14. This convincing 6.41-ct imitation of a waterworn ruby crystal (here with optical flats cut to facilitate testing) was identified as neodymium-doped lead glass. Photo by Maha DeMaggio.

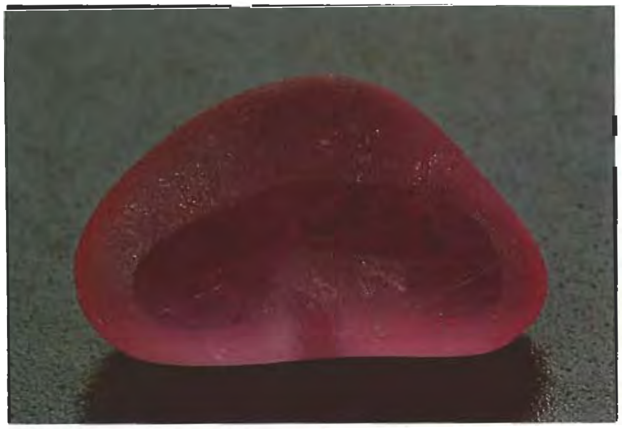


Figure 16. When examined at one orientation, this 24.10-ct synthetic quartz crystal appears a uniform blue (left). Turned 90°, the specimen is seen to consist of synthetic colorless quartz grown on a blue seed crystal wafer (right). Photos by Maha DeMaggio.

Unusual synthetic blue quartz. One pleasure in attending a gem show is discovering the unexpected gemological curiosity. While looking through a dealer's collection of synthetic quartz specimens at one show, one of the editors (RCK) spotted what at first appeared to be an evenly colored light blue crystal (figure 16, left). When examined from the side, however, the true nature of the piece became apparent: Colorless synthetic quartz had been grown on a medium dark blue seed-crystal wafer (figure 16, right). The orientation of the crystal faces was such that the color from the seed crystal was reflected, an effect identical to that seen in synthetic spinel triplets and other assembled stones. Examination of the seed crystal with a desk-model spectroscope revealed the "cobalt" absorption bands that are characteristic of blue synthetic quartz.

Imitation gems from Zaire. Gordon T. Austin, Gemstone Commodity Specialist for the United States Bureau of Mines, has advised the Gem News editors that glass imitations of emerald are still being offered for sale in Africa. While traveling in Zaire, an individual was invited to purchase what was described as a "very fine quality Zambian emerald" (figure 17) for a modest price that negotiations eventually lowered to one-fifth of the original quote.

Figure 15. This 19.41-ct cabochon of dyed magnesite, offered as "howlite lapis," is a rather convincing imitation of lapis lazuli. Photo by Maha DeMaggio.

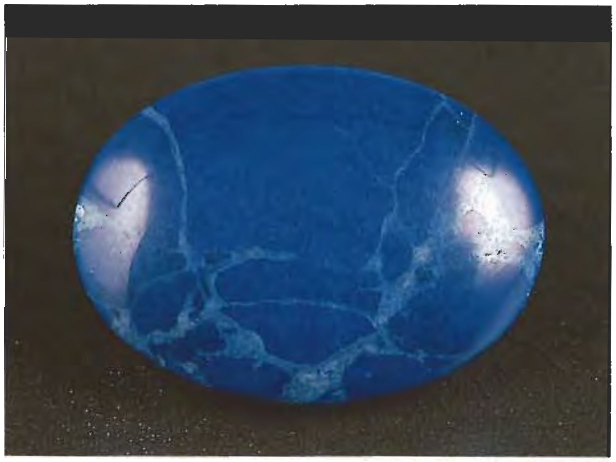


Figure 17. This 33.49-ct (22.89 × 17.38 × 12.19 mm) glass imitation was misrepresented as a Zambian emerald in neighboring Zaire. Courtesy of Gordon T. Austin; photo by Maha DeMaggio.

Subsequent examination by the Gem News editors revealed that the 33.49-ct "emerald" consisted of green glass with a glued-on matrix of pulverized orangy brown limonite and biotite flakes. Microscopic examination of this imitation revealed many spherical gas bubbles.

Mr. Austin informed us that another item purchased at the same time and represented as top-quality ruby was subsequently determined to be cuprite, a dark red copper mineral from Zaire.

Acknowledgments: The editors thank Gustave P. Calderon, Dino DeGhionno, Patricia Maddison, and Cheryl Wentzell, all of the GIA Gem Trade Laboratory, for assistance in testing materials described in this section. Dr. James E. Shigley and Sam Muhlmeister of GIA Research also helped prepare entries for this section. Jo Ellen Cole of the Richard T. Liddicoat Library and Information Center assisted in archival research.

BOOK Reviews

SUSAN B. JOHNSON, EDITOR

GEMSTONES OF EAST AFRICA

*By Peter C. Keller, 144 pp., illus., publ. by Geoscience Press, Phoenix, AZ, 1992. US$50.00**

This is the first comprehensive book on gemstones from a region that has recently become one of the world's prime gem localities. It is well written, interesting, and filled with beautiful illustrations of gems, historical photos of mining developments and deposits, plus many locality maps.

The author briefly reviews the geology of East Africa and then discusses the gemstones—their major deposits, short histories, geologic settings, and gemological properties. Principal chapters cover diamond, ruby and sapphire, emerald and alexandrite, tanzanite, garnets, tourmaline, and prase opal. Also briefly discussed are less important gems, including actinolite-tremolite, agate, amazonite, amethyst, apatite, beryl, diopside, enstatite, euclase, idocrase, kornerupine, moonstone, peridot, phenakite, rhodonite, scapolite, sinhalite, spinel, sunstone, turquoise, and zircon.

Appendix A lists 177 noteworthy East African gem localities, with latitude and longitude for each, organized by gem species. Appendix B lists 21 East African gems in the Los Angeles County Natural History Museum, and Appendix C lists 72 in the Smithsonian Institution. The references, cited in each chapter, constitute an impressive bibliography—242 items out of a total of about 300 that have ever been published on East African gemstones.

The pace of gem discovery and development in East Africa is moving so fast, however, that several important new localities are absent or barely touched on. A major emerald deposit has been discovered at Sumbawanga, just west of Lake Rukwa, in southwestern Tanzania; rubies have turned up both at Naberera, south of Lossogonoi, and near Mbeya, at the north end of Lake Nyasa. It is perhaps unfair to be critical of the outdated and inaccurate information on the Longido ruby mine, because access to that deposit has been so restricted in recent years. Yet, much new progress is not reported. In addition, it is difficult to keep up with the dramatic changes that take place constantly at the Merelani tanzanite mines. To his credit, the author says in the preface: "Given the potential of the region for new gemstones, it is certainly possible that other species will be discovered even before this book is published." This book is a great start, but it is now clear that new deposits will be found every year. No doubt, a revision and update will soon be needed.

Many of the color gem photos are dramatic but unrealistically intense. For example, the pink diamond (figure 2.5) looks almost red, and the impressive carved ruby toad from Longido sits on chrome zoisite the color of imperial jade (figure 3.5). Yet, the ruby in loose blocks of "anyolite" (figure 3.3) looks more like brown rust when it truly is red. It is also disconcerting to have so few carat weights given for pictured gems. The superb Manyara emerald (figure 4.1) could be a world-class 10-ct wonder, or a 10-point stone; there's no indication. It is particularly unfortunate that more-specific locations are not given for a number of pictured gems, especially in a book whose title emphasizes locality. Fascinating historical photos, taken by E. Gübelin, add interest to the brief histories of some of the more famous localities; however, most lack dates. Despite these shortcomings, the many beautiful photographs add drama to the book.

One can sympathize with the author's evasion of the rather complex problem of nomenclature of East African garnets. Still, it would have been appreciated if "malaya" and its relationship to "umbalite" had been discussed, if rhodolite had been treated as an important gem type (instead of being divided between two different locality discussions), and especially if the fascinating Umba Valley color-change garnets had been treated in more depth and illustrated in their different colors. Perhaps the East African garnets merit a separate book or treatise; nearly every known type and variety is found there, and even uvarovite or demantoid may yet be discovered in so chrome-rich an area. On the garnet locality map, the dot for Umba (Tanga Province) is plotted in Kenya rather than Tanzania, and some other localities have been plotted less than accurately. The location maps in general are helpful and important, but many suffer from having no scale, no indication of latitude and longitude, and no roads or towns. Determining exact locations requires a knowledge of the area or an atlas for reference.

Those of us who work in Africa are gratified to see this fine book appear at this time. All gemologists, inevitably aware of the new importance of East Africa, will welcome this addition to their library.

ALLEN M. BASSETT
Tan-Minerals Mining Co., Ltd.
Arusha, Tanzania

HEALTH RISK ASSESSMENT OF IRRADIATED TOPAZ (NUREG/CR-5883BNL-NUREG-52330)

By K. Nelson and J. W. Baum, 141 pp., available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC, 1993.

This technical report, prepared at the Brookhaven National Laboratory for the U.S. Nuclear Regulatory Commission (NRC), documents the neutron irradiation of 51 colorless topazes and the electron-beam (linac) irradiation of 36 other colorless topazes, all reportedly mined in Brazil, India, Nigeria, and Sri Lanka.

The study is fairly thorough. It begins with a discussion of radiation-induced color centers in gemstones, and then focuses on the topaz industry, describing countries of origin for rough material, volume produced, number of people involved in the trade, and so on. Next, various irradiation techniques and previous research on irradiated topaz are discussed, including the effects of radiation on the hardness of topaz. The bulk of the study then concentrates on the radionuclides produced, the treatment processes, and measurement of the radioactivity of the 87 irradiated topazes in the test sample. This is followed by an analysis of radiation doses that would be received by people wearing topaz jewelry with residual radioactivity at NRC release-concentration levels. The authors stick their necks out a bit and claim that the blue color in topaz may be in some way connected to gallium and sodium levels (which has not yet been established by color research).

The report's general conclusions can be summarized as follows: (1) Germanium and sodium-iodide crystal shielded detectors are needed to check for NRC release radionuclide concentrations (bare photographic film can be used, but exposures must exceed 833 hours; Geiger counters are inadequate); and (2) the health risk from irradiated topaz is a small fraction of what the National Council of Radiation Protection considers a negligible individual cancer risk level of one in 10 million. (In other words, irradiated topaz is safe if within the NRC release limits.)

Overall, this is an informative document for anyone who wants to know as much as the U.S. government wants to know about irradiated topaz. It could use some editing, however, to iron out some misquotes, inaccuracies, and omissions that appear throughout. For example, page 33 states that manganese-54 (Mn-54) is produced in topaz by a (n,2n) reaction with Mn-55 rather than by a (n,p) reaction with iron-54 (Fe-54). Also, a substantial portion of the report is devoted to providing data that are not really useful. For example, 28 figures out of 44 (20% of the written report) concern measuring topaz with a Geiger counter. More than four pages of references are provided, and two appendices cover gem and radiation terminology.

CHARLES E. ASHBAUGH, III
Woodland Hills, California

OPAL IDENTIFICATION AND VALUE

*By Paul B. Downing, 210 pp., illus., publ. by Majestic Press, Tallahassee, FL, 1992. US$38.95**

This well-organized and readable book presents key steps in the grading and description of opals. Helpful features include key concepts (highlighted in boxes) throughout, and reviews at the end of each chapter. Stunning photographs by Len Cram and Rudy Weber compliment the text.

Dr. Downing first examines the relationships between opal characteristics and value, stressing that opal is probably the most challenging gem material to evaluate because no two stones are exactly alike. Next, equipment needed for consistent opal grading is listed, including the "opal brightness kit," which he markets. This kit contains three natural opals that are graded faint, bright, and brilliant; Dr. Downing uses this kit to propose a consistent method of determining degree of brightness or "fire." (The opal brightness kit sets practical and consistent parameters for the brightness of a specific opal; in essence, it equates brightness grading of opals to color grading of diamonds, according to Dr. Downing.) He maintains that most people tend to include too many colors in a description. The superb color photographs in this section provide a visual benchmark for determining the "fire color" of a stone. The photographs that accompany the section on fire-pattern types and terms are equally magnificent and helpful. Dr. Downing also provides definitions of the more common fire-pattern terms.

Cut (including proportions and qualities of polish), inclusions, and weight factors are then detailed, as is the effect of cracks and crazing on value. Consistency and directionality of fire are important, too.

A separate section covers determination of value, based on a point system devised by the author. If the point-evaluation system could somehow be correlated to a more accurate scale of prices, it would be very useful. As described in the book, however, the author's pricing system is impractical and does not seem to correspond to that found in the trade.

Dr. Downing does discuss world opal localities, but he states that in general locality does not affect price. Valuable guidelines—to evaluate doublets, triplets, synthetics, simulants, intarsia, mosaics, and rough—are also proposed. The book concludes with an extensive bibliography and thorough glossary.

This book represents extensive knowledge accumulated on opals, and reflects the obvious enthusiasm and sincerity of the author.

JO ELLEN COLE
Richard T. Liddicoat Library
and Information Center
Gemological Institute of America
Santa Monica, California

** This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, California. Telephone (800) 421-7250, ext. 282.*

GEMOLOGICAL ABSTRACTS

C. W. FRYER, EDITOR

COLORED STONES AND ORGANIC MATERIALS

Forme, structure et couleurs des perles de Polynésie, suite II (Shape, structure, and color of Polynesian pearls, part II). J.-P. Cuif, Y. Dauphin, C. Stoppa, and S. Beeck, *Revue de Gemmologie a.f.g.*, Vol. 115, 1993, pp. 9–11.

This article describes a statistical study of the color of Polynesian black pearls that was conducted to help optimize production. The pigmentation of these pearls is associated with the mixture of probably three pigments of relatively low mass. The visible-range transmittance spectra of solutions containing pigments from various black pearls reveal significant variation in the importance of the transmission windows at 490 and 700 nm. Fiber optics were used to measure the reflectance of a pearl's surface without touching that surface (and thus risking damage to the pearl). The differences in reflectance spectra between a white, a black, and several gray pearls are illustrated. Statistical correlation of the various features of the spectra with culturing conditions may help explain which factors of the culturing process influence the final color of the pearl. Similar studies can be conducted in the near-infrared region of the spectrum, and might prove useful in separating Polynesian cultured pearls from other similar-appearing products, possibly treated or even imitation pearls. *EF*

Gemmology Study Club lab reports. G. Brown and S. M. B. Kelly, *Australian Gemmologist*, Vol. 18, No. 5, 1993, pp. 169–173.

Several materials are described in this series of brief reports. The first is calcareous bamboo coral that had been turned dark brown through silver nitrate treatment. Although the enhancement masked the longitudinal striations along the length of the branches, the material was easily separated from natural black coral by differences in heft and reaction to dilute hydrochloric acid. Other organic gem materials covered are carved buffalo and cow horn as well as grayish cultured pearls; the color of the latter may be natural, or it may be enhanced by dyeing or irradiation.

Also described are a modern Eskimo "spirit" carving in greenish gray soapstone; diamond crystals from Macquarie River gravels near Wellington, N.S.W., Australia; opaque, massive pink petalite; and trapiche emeralds. The authors

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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 editor and his reviewers, 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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The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names. Opinions expressed in an abstract belong to the abstracter and in no way reflect the position of Gems & Gemology *or GIA.*

ask for help from readers in identifying unusual ball-like masses of radially oriented fibrous crystalline inclusions in a colorless quartz crystal, and fine white powder in a bottle (labeled "Diamantine No. 2"). *RCK*

Gemstone business benefits from diamond stability. D. Hadany, *Mazal U'Bracha,* No. 52, 1993, pp. 101–103.

In a presentation to the Tel Aviv Congress of the International Colored Gemstone Association in Tel Aviv, Dan Hadany, managing director of the Israel Diamond Exchange, pointed out that the managed equilibrium between diamond production and sales greatly stabilizes the $100 billion jewelry market, balancing the nonregulated colored stone sector, which tends to fluctuate unpredictably between shortages and oversupply. The colored gem industry is also riding the coattails of the diamond engagement ring, wedding ring, and anniversary jewelry, cultural fixtures that are becoming increasingly popular as diamond-gemstone "mixed jewelry." The author believes that the diamond and gemstone industries can compliment, rather than compete with, each other if designers and manufacturers work together to develop emerging markets and create new jewelry pieces that combine diamonds and colored stones. *Andrew Christie*

An historical note on the colour phenomenon in precious opal. D. B. Hoover, *Australian Gemmologist,* Vol. 18, No. 5, 1993, pp. 145–148.

Although it was not until 1964 that a three-dimensional array of silica spheres was shown to be responsible for the play-of-color in opal, the optical principals behind the effect have been known for over 100 years. The author of this brief report substantiates this claim by referring to *Physical Optics,* by Robert W. Wood, first published in 1905. Mr. Wood referenced the even earlier work of G.G. Stokes (1819–1903), who equated the phenomenal colors in opal with a similar effect in polysynthetically twinned potassium chlorate crystals. Wood also quoted Lord Rayleigh, who claimed in 1888 that the effect resulted from a number of multiple reflecting surfaces, approximately equally spaced.

The author also describes how to make two types of imitation opals. The first involves growing small, twinned potassium-chlorate crystals—a potentially dangerous process. These are then embedded in Canada balsam and cemented to the back (painted black) of a meniscus lens. The spectral colors observed result from the presence of a great number of poorly reflecting, equally spaced surfaces.

The other imitation uses a method known as Lippman photography, which employs a very fine-grained black-and-white film backed with a first-surface mirror. The developed film has many equally spaced planes of silver particles that interact with light in a manner analogous to the twin planes in the previously described potassium chlorate crystals.

The author states that although Bragg diffraction is needed to explain play-of-color in natural opal, play-of-color in Lippman-photography or potassium-chlorate crystals can be explained by simple multiple reflection with wave interference. The observable color phenomenon, however, is the same. *RCK*

Possible prehistoric glasses in the gem trade in Sri Lanka. H. Harder, *Journal of Gemmology,* Vol. 23, No. 5, 1993, pp. 267–273.

Glass found in the gem gravels of Sri Lanka is sold locally as being of natural origin. However, the actual origin of this material has never been confirmed. The glass occurs in a wide variety of colors—including green, blue, and red—and the multicolored appearance of some of this material is unusual for tektite or other meteoritic glasses. An alternate theory is that this glass may be the remnants of ancient manufactured glass that found its way into the gem gravels. Chemical analysis of several samples of the Sri Lankan glass revealed compositions significantly different from those of known tektites, which tends to confirm the theory that the former are not natural in origin. The author concludes that this material is artificial and prehistoric, possibly of local manufacture or imported along ancient trade routes from India or Egypt. He closes the article with the comments that further research is needed and that, should this glass prove to be of prehistoric manufacture, its value as a collectible could be enhanced. Color photographs, a map, and tables of chemical data accompany the article. *CMS*

Unusual inclusion in an aquamarine. A. de Goutiére, *Journal of Gemmology,* Vol. 23, No. 5, 1993, pp. 286–287.

This very brief note describes a three-phase thin-film inclusion in an aquamarine. Four color photomicrographs illustrate the change that takes place in the inclusion as the stone is slowly heated. The reaction is unusual because of the slow rate at which the change occurs. *CMS*

DIAMONDS

Arkansas, Canadian pipes show promise in surveys. R. Shor, *Diamant,* Vol. 35, No. 361, 1993, pp. 15–16.

Two North American diamond sources are being studied: the Crater of Diamonds State Park in Murfreesboro, Arkansas, and the Lac de Gras area of northern Canada.

A ring, created by Henry Dunay and worn by Hillary Rodham Clinton to her husband's inauguration, gave a major public relations boost to the Crater of Diamonds State Park. The ring contains a 4.23-ct rough yellow diamond found in the park. A geologic survey revealed that the pipe is a hybrid of kimberlite and lamproite and contains at least 78 million tons of diamond-bearing ore. The similarity of the rock composition to that of the Argyle mine in

Western Australia explains the high percentage of colored diamonds at the Arkansas site. The economic viability of commercial mining has yet to be determined, as the average quality and quantity of diamonds found there is unknown. Environmentalists and park friends are pursuing court actions to prevent mining companies from doing further tests.

In Canada, mining giant RTZ Corp. has committed to spending up to $30 million on diamond-exploration options at Lac de Gras. Analysts consider this a signal that the area is economically viable because of RTZ's conservative nature. Kimberlite pipes sampled to date have yielded mixed results.

Nanette Colomb

The core-mantle boundary. R. Jeanloz and T. Lay, *Scientific American,* Vol. 268, No. 5, May 1993, pp. 48–55.

In what may be one of the most unusual applications for faceted diamonds yet, scientists are using them to help duplicate the high pressure and temperature of the mantle-core boundary, some 2,900 km below Earth's surface. In a device called a diamond-anvil high-pressure cell, geophysicists compress—between the enlarged culets of two round brilliant diamonds—minuscule samples of minerals believed to exist in the boundary region.

Diamond was chosen for its hardness *and* transparency. A high-powered laser beam can be focused through it to heat the compressed sample to thousands of degrees Celsius. The sample can also be viewed through the diamond during the experiment.

Discovering the composition of what might be Earth's most geologically active zone could lead to better understanding of the earth's magnetic poles and tectonic plate movement. *Andrew Christie*

Crater of diamonds. R. R. Reneau, *Rock & Gem,* Vol. 23, No. 6, June 1993, pp. 14–16.

This article offers some interesting information about the unique Crater of Diamonds State Park. Located near Murfreesboro, Arkansas, Crater of Diamonds is actually an eroded volcanic pipe of kimberlite and lamproite. Originally discovered by Dr. John Banner nearly 100 years ago, much of the land that is now the state park was purchased by farmer John Huddleston, who found the first diamonds in the area. After the land was sold by Mr. Huddleston, a number of unsuccessful attempts were made to mine diamonds commercially. The area was finally purchased by the state of Arkansas in 1972, and Crater of Diamonds State Park was created.

For a nominal fee, visitors may enter the park to search for diamonds as long as they do so without mechanized equipment. They are allowed to keep any that they find. According to Mr. Reneau, two mining methods are usually used. The first involves slowly searching as much ground as possible. The trick is to look for a diamond sparkling in the sunlight. The second method involves actual digging. Visitors stake out a small area and sift dirt through a screen that may be rented at the park headquarters. Thousands of diamonds have been found here, including the notable 40.23-ct Uncle Sam. The article also provides useful information on area accommodations and dining for those wishing to visit this unusual attraction. *JEM*

A notable red-brown diamond. J. E. Shigley and E. Fritsch, *Journal of Gemmology,* Vol. 23, No. 5, 1993, pp.259–266.

Drs. Shigley and Fritsch describe a 5.03-ct red-brown diamond of unknown provenance that was recently donated to the Smithsonian Institution. Microscopy revealed the presence of moderately strong red-brown graining along octahedral planes, as well as strong anomalous birefringence that correlates with the graining pattern. The stone luminesced weak yellow to both long- and short-wave ultraviolet radiation, and it exhibited moderately strong green luminescence to intense transmitted visible light. Spectroscopic data were difficult to obtain because the stone is so dark, but results revealed a feature centered about 550 nm that is typical of pink and purple diamonds; type-Ia infrared features; and an unusual infrared feature known as the "amber center," with its principal band at about 4150 cm^{-1}. Comparison of the spectrum of this stone to the spectra of other reddish diamonds indicates that the 550-nm feature is responsible for the red overtone. The source of this feature is thought to be plastic deformation of the diamond crystal structure. Color photographs and graphs of spectral data accompany the article. *CMS*

Notes from the Laboratory—17. E. C. Emms, *Journal of Gemmology,* Vol. 23, No. 5, 1993, pp. 274–277.

The Gemmological Association of Great Britain Gem Testing Laboratory reports on "three unusual diamonds" that were recently examined. The first was submitted to the laboratory because its cutter observed bright orange-yellow luminescence and phosphorescence while polishing the stone. The 0.49-ct finished stone was a greenish yellow color of "fancy" intensity, with an intense yellow fluorescence to long-wave U.V. and a yellow phosphorescence that persisted for more than five minutes. Storage overnight in the dark resulted in an intense yellow coloration that faded to a stable greenish yellow within a few minutes of exposure to light. Heating of the stone regenerated the intense yellow color and confirmed that this stone was a chameleon type. Spectral features were consistent with those observed in other chameleon diamonds.

The second unusual diamond was a 0.04-ct particolor, part pink and part colorless. The pink portion exhibited typical zoning, with no evidence of artificial coloration. The third unusual diamond was a 0.24-ct nonconductive "blue" diamond. Properties were consistent with those described for similar stones by E. Fritsch and K. Scarratt

(*Gems & Gemology*, Spring 1992, pp. 35–42). Color photographs of the three stones and their infrared spectra illustrate this feature. *CMS*

Opening JV Intertrade polishing factory in Moscow. *Diamant*, Vol. 35, No. 362, 1993, pp. 17–20.

A diamond-polishing factory, owned by the Russian-Belgian joint venture Intertrade, opened March 10 in Moscow. Belgian partners Kaszirer Diamonds NV and Oltuski Diamonds NV each own 20%; the Moscow City Council owns 33%; and a department of the Russian Ministry of Finance, Komdragmet, owns 27%. The percentages are based on contributions made by each partner. The technology and most of the machinery came from Belgium.

The Intertrade factory is modest in size compared to at least one other in Russia, which employs 2,000, but capacity is expected to increase. Intertrade will preferably process stones averaging 1.5 ct, achieving an initial capacity of up to 150 carats per polisher per month, or between 200,000 and 215,000 carats per year.

Kaszirer has been trading with the former Soviet Union for 23 years and wants Antwerp to remain the foremost world diamond trade center in Russia's eyes. They feel that more Russian polished goods will be exported in the future at reasonable cost, due to the low labor costs.

Nanette Colomb

Terrestrial carbon and nitrogen isotopic ratios from Cretaceous-Tertiary boundary nanodiamonds. I. Gilmour, S. S. Russell, J. W. Arden, M. R. Lee, I. A. Franchi, and C. T. Pillinger, *Science*, Vol. 258, No. 5088, December 4, 1992, pp. 1624–1626.

This article describes the methodology used to conclude that the tiny (10^{-3} micron) diamonds found at the Cretaceous-Tertiary (K-T) geologic boundary were formed during impact by a large asteroid that supposedly led to the extinction of dinosaurs, 65 million years ago. Diamonds from three boundary sites in North America and Europe were shown to have a cubic morphology, to occur in clumps, and to be typically 6 nm. Carbon and nitrogen isotope ratios and the carbon and nitrogen release ratios, obtained during heating experiments, suggested strongly that the diamonds were not from kimberlite or lamproite or of a type found in meteorites. They were, however, roughly similar to diamonds generated by explosive detonation of TNT. Hence, the article concludes that diamonds found at the K-T boundary were formed by a large asteroid (thought to have struck the Earth in the Caribbean north of the Yucatan Peninsula in Mexico). These diamonds might have been produced either by shock alteration of carbon, in the asteroid or the Earth, or by a quick chemical-vapor-deposition (CVD) type of mechanism, with meteoritic diamonds possibly acting as seed crystals.

Charles E. Ashbaugh III

GEM LOCALITIES

Australia's treasures from the deep. G. Van Zuylen, *Jewellery International*, No. 13, 1993, pp. 65–72.

Australia has become a leader in the production of South Sea cultured pearls, producing almost half the total market, most of this in fine white pearls. Other countries (such as Tahiti, Burma, and the Philippines) produce mostly non-white pearls. Australia's pearls are the product of many years of pearling experience in and around the port town of Broome.

Production starts with the collection—controlled by a quota system—of indigenous *Pinctada maxima* oysters from natural oyster beds. (Australian production uses mostly "wild" oysters, although pearl oysters may be bred in the future.) After these oysters are "seeded" (implanted with a mother-of-pearl nucleus and mantle tissue to initiate pearl growth), they are transported to farming bases. Once the oysters have been set at these farms, they are diligently cared for. Pearls form in 20 to 24 months.

Pearling in Australia is very advanced. Wild oyster beds are located by satellite and computer technology, and implantation of the nucleus is done by teams of highly skilled technicians. One area that needs to be developed is marketing. Previously, pearls were usually just sent to Japan to be sold. Now, pearl dealer Rosario Autore, former managing director of Devino Pty. Ltd., oversees much of the marketing of Australian pearls. Besides Japan, Mr. Autore has developed markets in the U.S., Italy, Germany, Hong Kong, and Thailand. Seven photos illustrate the article.

JEM

Faceted dark-green uvarovite from Outokumpu, Finland. U. Henn and H. Bank, *Australian Gemmologist*, Vol. 18, No. 5, 1993, pp. 142–143.

After an overview of the garnet group, the authors focus on uvarovite. This green $Ca_3Cr_2(SiO4)_3$ garnet is probably the least known to gemologists because it is rare and generally does not occur as transparent crystals in sizes large enough to facet. One source is Outokumpu, Finland, a site about 350 km northeast of Helsinki and 100 km from the Russian border.

The authors describe their examination of a 0.95-ct faceted uvarovite that was fashioned from an Outokumpu crystal. The stone gave a typical singly refractive reaction in the polariscope, had a refractive index over the limits of the standard gemological refractometer, and produced a specific gravity of 3.76. Chemical composition, determined by microprobe analysis, revealed a uvarovite-rich mixed specimen: 59.80% uvarovite, 38.24% grossular, and 1.96% andradite end-members. The absorption spectrum, as determined by a spectrophotometer, showed a broad, intense absorption band at 700 to 550 nm in the red, orange, and yellow and another from 480 nm in the blue, violet, and U.V. wavelengths. *RCK* wt.%) as follows: Ce^{3+} 27.93, La^{3+} 13.84, Nd^{3+} 7.32, Pr^{3+} 4.34, Ca^{2+} 7.62, C^{4+} 5.70, F^- 10.47, O^{2-} 22.78 [=100.00].

R. A. Howie

"Smaragdminen der Cleopatra": Zabara, Sikait und Umm Kabo in Ägypten ("Emerald Mines of Cleopatra": Zabara, Sikait and Umm Kabo in Egypt). G. Grundmann and G. Morteani, *Lapis,* Vol. 18, No. 7/8, 1993, pp. 27–39 and 90; **"Tsavorit," der grüne Grossular aus Kenya ("Tsavorite," the green grossularite from Kenya).** W. Schäfer, *Lapis,* Vol. 18, No. 7/8, pp. 57–66 and 90.

This issue of *Lapis* is entirely dedicated to gems. Besides a number of smaller articles (e.g., on color-change hackmanite from Canada and tourmaline from Saxony), it contains an updated German version of "Status of Ruby and Sapphire Mining in the Mogok Stone Tract," by R. E. Kane and R. C. Kammerling (see *Gems & Gemology,* Vol. 28, No. 3, 1992, pp. 152–174). The article by Grundmann and Morteani is a welcome addition to the scarce literature on Egyptian emeralds and provides information gathered during a visit to the mines in February 1992. Along with a historical overview, the authors give a geologic description of the locality and show that the emeralds occur in schists along a system of thrusts. Schäfer's article offers information on the tsavorite occurrences: geologic setting and conditions of formation, the mines and mining methods, and some production figures and criteria for quality assessment. All articles are written in German and are illustrated with color photographs. *Rolf Tatje*

INSTRUMENTS AND TECHNIQUES

The Raman microprobe in gemology [in French]. *Revue de Gemmologie a.f.g.,* special issue, 1992.

This special issue is devoted to the use of Raman spectroscopy in gemology. Raman spectroscopy is a nondestructive technique that detects characteristic molecular vibrations in a material.

The first of the two articles, by H.-J. Schubnel, is an overview of the usefulness of Raman spectroscopy for gemologists, accompanied by several detailed examples. Mr. Schubnel's paper largely uses material from his pioneering 1977 article. He states the absolute necessity of a catalog of Raman spectra to compare spectra of unknown materials with those of well-characterized minerals and organic materials.

The second article, the main part of this special issue, contains such a catalog. Authors M. Pinet, D. C. Smith, and B. Lasnier provide structural and spectroscopic details for about 80 gem materials. They focus on the use of a Raman microprobe (with the help of a microscope) to obtain spectra from very small areas. First, they present the elementary physical processes responsible for the Raman effect. Then they explain the acquisition of a spectrum and how the Raman microprobe works, before pointing out advantages of this technique (nondestructive, fast, microscopic; works on solid, liquid, and gaseous materials, even if included in a transparent solid). The Raman spectrum of a gem, or an inclusion in a gem, represents a "fingerprint" of its structure, much like an X-ray diffraction pattern. Even if all individual peaks cannot be attributed to specific molecular vibrations, overall it is a useful identification tool. The various factors that can affect the quality or usefulness of a spectrum are also listed.

This issue is illustrated with 28 color and 17 black-and-white photographs of equipment or inclusions. Although the articles are written in a language other than English, the numerous spectra alone make this special issue an extremely valuable reference for those interested in this spectroscopic technique. *EF*

Test report on the Hanneman Mini-cube II. P. G. Read, *Journal of Gemmology,* Vol. 33, No. 6, 1993, pp. 360–361.

The increased production of diffusion-treated sapphires has made immersion inspection a particularly valuable gemological test. The author describes a simple immersion cell (manufactured by Hanneman Gemological Instruments) designed for use with a "pocket torch" (a "penlight" to American gemologists). The Mini-cube is a useful portable tool for identification. Different sizes are available. *CMS*

JEWELRY HISTORY

Out of Africa: The superb artwork of ancient Nubia. D. Roberts, *Smithsonian,* Vol. 24, No. 3, June 1993, pp. 90–100.

This article is a study of, and tribute to, an enigmatic people whose cultural remnants still exist in the modern world, although their civilization does not. In addition to a number of permanent displays that recently opened, an exhibition that includes Nubian jewelry and other jeweled personal objects is now traveling to various museums around the U.S. Many of these items have helped archeologists and anthropologists uncover some of the secrets of this lost civilization. Confounded by wars and cultural assimilation between the Nubians and their northern Egyptian counterparts, items once thought to be of Egyptian origin are now attributed to the Nubian culture. There is lively debate as to this question of origin, and Egyptologists are enjoying renewed interest in their field because of the questions now posed by these artifacts. The article includes photos of some of the more important artifacts, as well as a map for geographic orientation. *JEC*

Steven Kretchmer: Today's alchemist designer. R. Weldon, *Jewelers' Circular-Keystone,* Vol. 164, No. 1, January 1993, pp. 70–71.

This informative article showcases the work of one of America's most popular designer/goldsmiths—Steven Kretchmer—Jewelers of America's New Designer of the Year Award winner for 1992. A graduate of Rhode Island School of Design, he began his career with the renowned jewelry firm Faraone in Italy. After returning to the U.S., he earned a Master of Fine Arts degree from the University of Michigan. Subsequently, he worked for Harry Winston, Inc., researching exotic golds, specifically to find ways to produce blue gold. He currently has a design studio in Los Angeles. Illustrated with breathtakingly beautiful photographs, the article details his accomplishments in tension setting, mokume-gane, and blue gold. *KBS*

The stolen gold of Troy. R. Covington, *Art & Antiques,* Vol 9, No. 8, October 1992, pp. 74–79 (part 1); **Twisted fate of the Trojan gold,** Vol. 9, No. 9, November 1992, pp. 75–79 (part 2).

This fascinating two-part series traces the history of the treasure of Troy, a 4,000-year-old trove found in Hisarlik, Turkey. Part one describes its discovery by archeologist Heinrich Schliemann in 1873. In 1881, Schliemann donated the collection to the German government. It remained in Berlin until 1945, when invading Russian soldiers removed it from Germany. Since then, rumors have circulated about this treasure and other confiscated artworks.

In part two, Mr. Covington details the events that led to the treasure falling into Russian hands. Political conditions now permit greater access to historical records, and investigators have located information on these missing art collections. Some 36 miles (58 km) north of Moscow, in a 16th-century monastery at Zagorsk (renamed Sergiev Posad), the Pushkin Museum stores about 16,500 works of confiscated art. Among these are reportedly more than 4,600 extraordinary pieces—gold diadems, necklaces, earrings, cups, silver vases, and jars—that make up the treasure of Troy. Part two includes a photograph of Schliemann's wife, Sophie, wearing part of the "Jewels of Helen"—a headdress with 16,000 tiny gold leaves and a necklace with 8,700 small gold components.

At the time the articles went to press, the Russian government still had not acknowledged possession of the collection. *Alicia G. Powers*

JEWELRY RETAILING

Season closes on antique high. V. Becker, *Retail Jeweller,* Vol. 30, No. 801, July 15, 1993, p. 14.

Healthy buying activity by trade and private buyers from Europe, the United States, and the Middle East was reported at Sotheby's July 1 auction in London. A continental buyer purchased two unmounted diamonds (5.7 ct and 5.96 ct) for £54,300 and £52,100, respectively. A 1930 diamond plaque brooch was sold to a European dealer for £26,450, and a private buyer purchased a 1950 diamond bracelet for £23,000. A European dealer paid £12,650 for a cabochon sapphire ring.

Egyptian-style jewelry is always desirable, and jewels made at the time of the opening of the Suez Canal are rare and in demand. The cover lot included an 1870 gold-and-enamel fringed necklace, made in the Egyptian revival style, which brought in £7,500. A diamond-and-pearl bracelet from about 1900 sold for £5,000. *Maha DeMaggio*

Selling to the senses. M. Ondovcsik, *Accent,* Vol. 18, No. 5, May 1993, pp. 44–46.

This short article focuses on how to influence buyers through the use of touch, smell, sight, and sound in retail design and display. It offers several helpful tips regarding the jewelry industry, and comments on many subtle, but important, effects. For example, Ruth Mellergaard, director of the International Design Group in New York, recommends placing display cases at an angle or curve, because they are more intriguing to the customer, who is induced to take more time going through the aisles. J'Amy Owens, president of Retail Planning Associates in Seattle, recommends placing more popular items toward the back of the store, so that customers will pick up impulse items on the way. Scent can have dramatic effects on a person's attitude; women will spend more time at a counter when a floral scent is present, and men will be more attracted by spicy smells like cinnamon. Colors can set a person's mood; burgundy, purple, and blue entice people to buy big-ticket items. This useful article offers several clever ways to help your business become more profitable.

Elizabeth A. Keller

PRECIOUS METALS

990 Gold: An unsung alloy. F. Keller-Bauer, *JQ Magazine,* Vol. 47, 1993, pp. 94–96 (reprinted from *Gold Technology,* May 1992).

The 990 gold alloy, which includes less than one weight percent of titanium, is now available to the jewelry industry. Christian Bauer GmbH played a leading role in developing this 23.75k alloy, which wears much like 18k. In addition, titanium is known to be a nonallergenic metal.

Along with the Precious Metals Research Institute in Schwäbisch Gmünd, Germany, Christian Bauer developed a method of alloying gold with titanium in a vacuum atmosphere utilizing argon, followed by a specialized homogenization process. This technique produces a hard alloy ideal for cold working. When an additional hardening process is carried out, the alloy is ready for lathe turning.

Unfortunately, the jewelry industry and consumers have not been very receptive to the new alloy, possibly due to the belief that all high-karat alloys are too soft for everyday wear. Education about this alloy is needed. This interesting report is accompanied by several photographs of wedding rings made by Christian Bauer from 990 gold.

JEM

Gem-quality scapolite from Sinjiang Region, West China. Z. Peili, *Australian Gemmologist,* Vol. 18, No. 4, 1992, pp. 115–117.

Gem-quality chatoyant scapolite—in colorless and pinkish purple to purple hues and light to dark tones—was discovered in the Kashi area, Sinjiang Uighur Autonomous Region, China, in 1989. The material, found in strata whose wall rock is composed of biotite-plagioclase-schist and tremolite-dolomite, occurs in three contexts: scapolite-titanite-diopside skarn, scapolite-titanite breccia, and scapolite-titanite eluvial slope layers. The crystals found in skarns and breccia, 3%–5% of which are considered gem quality, are relatively dark in tone; those from the eluvial-alluvial deposits, roughly 1%–3% of which are gem quality, are typically lighter in color.

The euhedral crystals, usually tetragonal prisms with longitudinal striations on prism faces, range from 0.5 to 1.5 cm in diameter and from 1 to 3 cm in length. Some are transparent and relatively free of inclusions, while others are translucent due to fine, densely packed tubular inclusions. Gemological properties determined are: R.I. 1.540–1.535, with 0.005 birefringence; dispersion 0.017; uniaxial negative optic character; pleochroism, dark purple parallel to the c-axis and light to very light pinkish purple perpendicular to it; dark orange U.V. fluorescence (long- and short-wave); S.G. 2.51–2.59; Mohs hardness of 6.27 [sic] to 6.4. Magnification revealed dense filiform and tubular inclusions, light purple columnar crystals, negative crystals, and columnar zircon crystals.

The author also describes the gemological properties of titanite (sphene) found in association with the scapolite, and indicates that recent prospecting has revealed additional occurrences of the latter in the Kashi area.

RCK

The mineral industry of California. J. Burnett, *California Geology,* Vol. 46, No. 3, 1993, pp. 74–75.

California produced US$22,070,000 worth of gemstones from 1990 to 1992, but gemstones only rate one line in an accompanying chart. Gemstone quantity is "not available," and types are not listed. To be fair, portland cement, the state's big money-maker at approximately $1.67 billion for the three years, doesn't fare much better—one line in the chart and eight words in the text. (Although one wonders when portland cement became a mineral.) For reasons not given, gemstone production jumped almost sevenfold from US$1.501 million in 1990 to 10.450 million in 1991; the total for 1992 was 10.119 million. *Irv Dierdorff*

Orissa's production to increase. V. Kuriyan, *Jewellery News Asia,* No. 106, June 1993, pp. 66–74.

Orissa, a state on the east coast of India, could become an important source of gemstones. Corundum, garnet, aquamarine, chrysoberyl, and iolite are among the gems being mined there. It is believed that inventory already held by local traders is substantial. This, coupled with the fact that much of the material is not sold as originating from Orissa, could explain why the jewelry industry is not more aware of Orissa as a gem source. Although Orissa Mining Corporation (OMC), a government-owned company, is in charge of mining operations in the area, independent miners (not licensed by the government) are responsible for most of the gem production. Historically, OMC's activity has been in industrial ores and granite, not gems. This inexperience has produced some set-backs. As a result, to encourage organized mining and the development of a cutting industry in Orissa, the government is looking for private companies that can mine and process gemstones profitably. The article includes a number of photos of the mining operations and a map of the area. *JEM*

Petrographic and microthermometrical studies of emeralds in the 'Garimpo' of Capoeirana, Nova Era, Minas Gerais state, Brazil. J. L. Souza, J. C. Mendes, R. M. S. Bello, D. P. Svisero, and J. V. Valarelli, *Mineralium Deposita,* Vol. 27, No. 2, 1992, pp. 161–168.

Studies of this locale have revealed two main lithostructural units. The first consists of gneissic rocks of granitic composition that belong to the basement complex. The second is a highly weathered metasedimentary-metavolcanic sequence composed of metapelitic schists, amphibolites, schists derived from ultramafic rocks, and quartzites. Quartz and pegmatoid veins occur near the contacts between the gneissic rocks and the metasedimentary-metavolcanic sequence. The emerald mineralization is mainly concentrated within the intercalations of meta-ultramafic schists near the contact with the pegmatitic veins.

Microthermometric studies of the fluid inclusions in the emerald grains indicate that crystallization occurred in the pressure and temperature ranges of 2000–2750 bar and 450°–650°C. The data suggest that the mineralizing solutions had a late hydrothermal-pneumatolytic origin characterized by low pressures, indicating the paragenesis talc + tremolite + carbonate + biotite/phlogopite + chlorite in the emerald wall rocks. *R. A. Howie*

Physical and chemical properties of gem parisite from Muzo, Colombia. U. Henn, H. von Platen, W. Hofmeister, and H. Bank, *Neues Jahrbuch für Mineralogie Monatshefte,* No. 6, 1992, pp. 258–264.

The authors present the properties of parisite, a pegmatite mineral found in Muzo, Colombia, and often as inclusions in emeralds from this locality. Faceted, transparent yellow-brown gem-quality parisite, a fluorine carbonate, reveals refractive indices of n_o=1.671, n_e=1.772; density 4.33–4.34 g/cm^3; and lattice constants of $\underline{a}$=7.1102, $\underline{c}$=83.834 Å. The optical spectrum shows a line group typical of Nd^{3+}. Microprobe analysis yielded a chemical composition (in

U.S. attracts the most 1992 nonferrous exploration spending. *California Mining Journal,* Vol. 62, No. 4, 1992, p. 5.

This article explains a few conclusions drawn from Metals Economics Group's recent study—"Corporate Exploration Strategies: A Worldwide Analysis." The study indicates that of the 161 companies surveyed worldwide, US$1.7 billion was spent in 1992 toward exploration for precious, base, and other nonferrous hard-rock metals, as well as any industrial minerals sought by the mining companies. Among the 10 largest spenders on exploration were De Beers and Argyle Anglo American Corp. The United States led the world with $363 million, or 21.4% of the budgeted expenditures for those same companies. Australia was second with $324 million, or 19.1%. Canada fell to third place from $430 million in 1991, to $302 million (or 17.8%) in 1992. Latin America followed at $256 million, or 15.1%. The rest of the world (Africa, Europe, and the western Pacific region) showed a 13% decrease from 1991 ($522 million) to 1992 ($453 million). The complete study is available for $6,750 from the Metals Economics Group, Halifax, Nova Scotia, Canada. *Lawrence E. Marmorstein*

TREATMENTS

Radiation-induced colour change in natural and synthetic emerald. K. Schmetzer, *Journal of Gemmology,* Vol. 23, No. 5, 1993, pp. 288–293.

Early, unsystematic experimentation with radiation treatment of emeralds indicated that radiation turns synthetic emeralds black or violet, but leaves natural emeralds essentially unchanged. The observed changes have been attributed to a yellow color center, presumably related to the oxidation of iron, and a violet color center, possibly associated with an electron-hole occurrence. This differential response to irradiation has been proposed as a means to distinguish natural from synthetic emeralds.

The present study entailed a more systematic exploration of these phenomena. Initially, slices of six natural and six synthetic (three each flux and hydrothermal) emeralds were subjected to cobalt-60 gamma-cell, linear-accelerator, and nuclear-reactor radiation treatment. In the second phase, 228 natural, 31 hydrothermally grown, and 41 flux-grown emeralds were exposed to X-rays. None of the irradiation methods produced the violet color center in any of the samples. At least two types of yellow color centers, which generate a strong absorption band in the ultraviolet, were produced. These are responsible for the observed changes in color, that is, from green to yellowish green or greenish yellow in the natural stones, and from green to greenish black or "smoky" black in the synthetic emeralds. The resulting color depends on the intensity of the U.V. band, such that its tail extending into the visible range more or less radically affects the color of the emerald subject. Type-A yellow color centers were produced by all types of radiation tested and were bleached by daylight, U.V. radiation, or low heat. Type-B yellow color centers appeared to be confined to iron, are not produced by X-rays, and were relatively stable.

Exposure to gamma rays, electrons, or neutrons should not be used in gem testing for several reasons. Neutron-irradiated samples cannot be returned to a client for a considerable time because of residual radioactivity. Electron irradiation often induces cracks. Gamma irradiation can result in an appreciable change in the color of natural emeralds; although the change can be reversed by heating, the annealing process can also produce cracking. X-rays, however, may offer a viable test if other methods fail or are unavailable. Some natural Colombian emeralds, and all Biron synthetic emeralds, respond to X-rays by generating a low concentration of yellow color centers that do not produce a visually observable effect on color. Otherwise, the spectral and visible responses to X-rays are distinct for natural and synthetic emeralds. The change in color experienced by synthetic samples is usually reversed by exposure to daylight, although a few samples will require heat treatment to restore their original color. Dr. Schmetzer concludes with the warning that this test should be used only with the client's permission and knowledge of the risk involved. *CMS*

LETTERS

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Kashmir, and Montana)—often do not achieve good results with basaltic sapphires. Thus, studies into the response of the Fe^{2+}/Fe^{3+} IVCT absorption to different methods of heat treatment promise to be of great importance to the jewelry industry.

EMMANUEL FRITSCH, Ph.D.
MEREDITH MERCER
Research Department
Gemological Institute of America
Santa Monica, California

REFERENCES

Ferguson J., Fielding P.E. (1971) The origins of the colours of yellow, green, and blue sapphires. *Chemical Physics Letters,* Vol. 10, No. 3, pp. 262–265.

Fritsch E., Rossman G.R. (1988) An update on color in gems. Part 2: Colors involving multiple atoms and color centers. *Gems & Gemology,* Vol. 24, No. 1, pp. 3–15.

Poirot J.-P. (1992) Spectrométrie et fluorescence X, des aides pour la détermination de types de gisement de saphirs. *Revue de Gemmologie a.f.g.,* Vol. 110, pp. 4–9.

Schmetzer K., Bank H. (1981) The colour of natural corundum. *Neues Jahrbuch für Mineralogie Monatshefte,* No. 2, pp. 59–68.

Schmetzer K., Kiefert L. (1990) Spectroscopic evidence for heat treatment of blue sapphires from Sri Lanka—additional data. *Journal of Gemmology,* Vol. 22, No. 2, pp. 80–82.