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DIAMONDS

Diamonds from Kelsey Lake, Colorado. More than 1,000 carats of diamonds from the mine at Kelsey Lake, Colorado, were examined by Thomas Hunn of Thomas Hunn Co., Grand Junction, Colorado, during his October 1996 visit to this newly active locality (see, e.g., figure 1). Mr. Hunn provided the following report based largely on his examination of these diamonds and on conversations with Howard Coopersmith, manager, North America, for Redaurum Ltd. of Toronto, Ontario, Canada, which owns the mine.

When the Kelsey Lake mine officially opened on June 1, 1996, it became the only active commercial diamond mine in the United States. (Although Crater of Diamonds State Park in Arkansas is well known as a primary diamond occurrence in this country, we know of no significant commercial production from that source in recent years.) Mr. Coopersmith spent 20 years tracking indicator minerals and geologic clues to locate the heavily weathered kimberlite pipes at Kelsey Lake. With approximately 16.9 million tons of ore reserve (that is,

not proven but potential ore), and a monthly production of 2,000 to 4,000 carats, the mine has an estimated life of at least seven years.

The mix of "mine-run" (i.e., not specially selected) stones that Mr. Hunn examined contained both gem-quality and industrial crystals. Of the more than 1,000 carats of rough diamonds that Mr. Hunn examined, 20%–25% were one carat and over, 50%–75% were 0.25 to 1 ct, and 10%–20% were smaller than 0.25 ct. Some crystals weighed more than 9.5 ct, and a 28.3 ct diamond from Kelsey Lake was sold recently (*Rapaport Report*, October 11, 1996, p. 5). Most of the crystals were dodecahedra or octahedra, with a few macles; well-shaped transparent octahedra ("glassies"), twinned crystals (interpenetrant and multiple twins), and modified dodecahedra were also present.

Figure 1. These diamonds (3.28 ct total weight) are from Kelsey Lake, Colorado. Photo © 1996 Thomas Hunn Co.



Figure 2. This 0.27 ct round brilliant (about 4.08 mm diameter × 2.60 mm deep) was cut from one of the "copper" brown diamond crystals found at Kelsey Lake, Colorado. Photo © 1996 Thomas Hunn Co.



The crystals varied from near-colorless to very dark brown. Most were faint to light brown, but about 10%–20% were in the near-colorless range. Only a very few crystals were yellow. Mr. Hunn noted a subtle “copper” tint in some of the brown crystals (figure 2).

With regard to clarity, about half the crystals were cuttable quality; this was true for stones of all sizes, shapes, and colors. “Feathers” (fractures or cleavages) and some inclusions were common throughout the rough; a garnet crystal was identified in one stone. Most crystals displayed fine growth striations on the surface.

Some of the Kelsey Lake diamonds already have been sold (again, see the previously mentioned *Rapaport Report*). Redaurum Ltd. is currently discussing (with various firms) the possibility of bringing the mine’s entire production onto the U.S. market.

Update on synthetic diamonds in jewelry. In the Summer 1996 Gem News section (pp. 128–129), we presented information on the marketing of synthetic diamonds in jewelry. At that time, we believed that these synthetic diamonds were being produced by the joint-venture company Taurus. Recently, Dr. Vitaly Efremov, deputy director of the United Institute of Geology, Geophysics and Mineralogy, Siberian Branch of the Russian Academy of Science, Novosibirsk, Russia, clarified this information. (Dr. Efremov also provided the technical information presented in the Summer 1996 issue.) Although Taurus was involved in the early marketing of these synthetics, they actually were grown at the United Institute in Novosibirsk. They are currently being marketed—through Superings, Los Angeles—as “Superdimonds.”

COLORED STONES AND ORGANIC MATERIALS

Natural “carvings.” For several years now, we have witnessed the creation of increasingly attractive and detailed carvings in various gem materials, including beryl, tourmaline, and quartz. The gem artisans who carve these works of art are usually highly skilled, having labored many years to perfect their craft. Kevin Lane Smith of Tucson, Arizona, has shown a special ability to create pieces that blend nature with artistic vision.

His latest endeavors involve transparent gem crystals with picturesque natural etch or growth patterns that are works of art in themselves. When he locates such a crystal, Mr. Smith works the natural pattern into a fashioned gem, using cabochon or faceting methods, so that light hitting the stone casts shadows that enhance the effect of the pattern. One such natural scene in rock crystal quartz (figure 3) looks like the rugged crags of a mountain range. Most who saw this “carving” thought that the “mountain scene” had been artificially produced. Perhaps the only immediate clue that it is natural is the myriad of tiny red iron oxide diskettes that paint the concave surfaces of the “mountain range” a subtle red.



Figure 3. The detailed mountain scene in this 48.7-mm-long fashioned rock crystal quartz by Kevin Lane Smith is the result of natural “carving.” Photo by Maha DeMaggio.

A number of other artists are incorporating the surface texture of natural crystal faces into the pavilions of their faceted stones. The distinctive optical effects that result make every stone unique. This past year, the editors have seen the unusual works of some talented Idar-Oberstein artisans, including the designers of the Philipp Becker Company, who work primarily in beryls (aquamarine, morganite, and heliodor; figure 4), and Klaus Schäfer.

Figure 4. To produce the unusual optics in these two faceted beryls, a 50.66 ct heliodor and a 67.51 ct aquamarine, artists of the Philipp Becker Company incorporated natural faces of the original crystals into the pavilions. Courtesy of James Alger Co., Manchester, New Hampshire; photo © Harold & Erica Van Pelt.

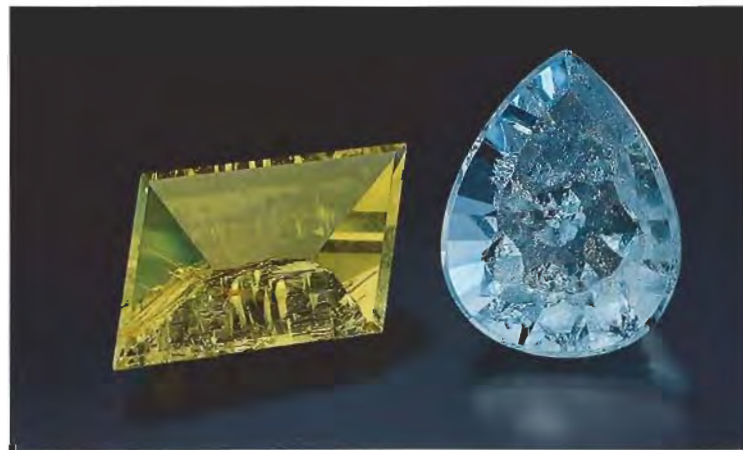




Figure 5. A new deposit in Nevada is the source for this 26.59 ct blue chalcidony cabochon, the polished nugget, and the piece of rough. Photo by Maha DeMaggio.

A new chalcidony locality. A new source for gem-quality blue-to-purple chalcidony was discovered in summer 1994 by geologist Chris Rose, of High Desert Gems and Minerals, Walker Lake, Nevada. The new deposit is located on Mount Airy, near the town of Austin in central Nevada.

Mining, which started in 1996, is currently done by hand. Initial exploration indicated that the site is a typical geode ("thunder egg") deposit; in some areas, the chalcidony nodules are only four inches (10 cm) apart. Eight full claims have been staked out along a mile-long (1.6 km) zone that shows continuous mineralization. The thunder eggs removed so far are typically a few centimeters in diameter, but some nodules over a meter (as large as four feet) across have been found. To date, Mr. Rose has recovered approximately 150–200 kg (330–440 pounds) of nodules, approximately 20% of which contained gem-quality chalcidony. Minerals commonly associated with the chalcidony are calcite and the rock crystal and amethyst varieties of quartz.

Mr. Rose supplied some of the newly discovered material to lapidary Kevin Lane Smith, who provided the Gem News editors with three samples for examination: a large piece of rough, a 474 ct polished "nugget" and a 26.59 ct polished oval cabochon (figure 5).

The Mount Airy chalcidony ranges from a slightly grayish blue (the most common color) to a more purple hue, according to Mr. Rose. The finest specimens are translucent. Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy of the cabochon in figure 5, performed by Sam Muhlmeister in GIA's Research Department, provided no clue as to a possible coloring agent; only silicon and a very small trace of iron were detected. Even at 200× magnification, with pinpoint

fiber-optic illumination, we could not resolve any inclusions in the cabochon. We saw only the fine fibrous texture typical of chalcidony.

On the basis of his exploration activities to date, Mr. Rose believes that there are significant reserves of chalcidony in this area.

Cat's-eye emerald from Colombia . . . Chatoyant emerald has been found at the historic Coscuez mine, in the Muzo region of Colombia. Ron Ringsrud, of the Constellation Colombian Emerald Company, Saratoga, California, supplied us with two pieces from this new source: a 22.21 ct oval double cabochon and a 6.75 ct piece of rough (figure 6). In the past, we have seen both cat's-eye and star emeralds from Santa Terezinha de Goiás, Brazil (Gem News, Spring 1992, p. 60; Spring 1995, pp. 60–61; Fall 1995, p. 206); this is the first report of cat's-eye emerald from Coscuez.

The cabochon measured 18.97 × 15.80 × 11.20 mm. Its properties were consistent with those of natural emerald: spot R.I. of 1.58, doubly refractive optic character, typical emerald absorption spectrum when viewed with a desk-model spectroscope, and inert to both long- and short-wave UV radiation. The inclusions that caused the chatoyancy occurred as hazy linear "clouds." Irregular and conical black inclusions were seen at either end of the cabochon.

To date, according to Mr. Ringsrud, chatoyant emerald has been found in only one vein in the Coscuez mine,

Figure 6. Reportedly from Colombia's Coscuez mine, this cat's-eye emerald weighs 22.21 ct. The inset shows part of the chatoyant emerald rough; note the dark carbonaceous shale matrix on the upper and lower faces. Cabochon photo by Shane F. McClure; inset photo by Maha DeMaggio.



embedded in carbonaceous shale (figure 6, inset) rather than calcite. Discovered in 1996, this vein was depleted within a month. Most of the rough crystals were suitable for fashioning into flattened elongated cat's-eyes; the 22.21 ct stone shown here is the largest that was cut.

... And an update on emerald mining at the Muzo mine.

On August 16, 1996, *Gems & Gemology* editor Alice Keller and William Rohtert, manager of gemstones for the Kennecott Exploration Company, visited the historic Muzo emerald mine in the state of Boyacá, Colombia. They provided the following account of current activities there.

The Tecminas lease to mine at Muzo was renewed for 25 years in 1995. The three principals are Juan Beetar, Victor Carranza, and Miller Molina. Mr. Rohtert and Ms. Keller were accompanied on their trip to the mine, 100 km north of Bogotá (about a half-hour ride by helicopter from a private airport on the outskirts of the capital), by Tecminas general manager Germán Bernal and geologist Adolpho Pacheco. They spoke with Mr. Beetar and Mr. Carranza at the mining complex in Muzo, and Mr. Carranza conducted the tour of the tunneling operation. At the mining complex, Mr. Carranza brought out a large group of fine emerald crystals—approximately 3,000 carats of rough—that represented the production from a particularly good day (figure 7).

The large mining complex has formal accommodations for dozens of technical staff and has both television and cellular phone capabilities, with power supplied by on-site diesel generators. There is also a small mining village and trading area a few hundred meters down the valley.

Currently, 350 people are working the main Muzo mine, with all organized mining underground, although Tecminas has helped approximately 1,000 local residents form cooperatives for small-scale surface mining and the re-processing of dump material throughout the Muzo area. Most of the tens of thousands of *guaqueros* (independent miners) who once worked the hills and streams at Muzo have moved on to Coscuez, about 10 km to the north, which is responsible for about 85% of Colombia's current emerald production. Tecminas has two concessions (85 ha and 115 ha) at Muzo and a 73 ha concession at Coscuez.

There are two major shafts at the main mine at Muzo—125 m deep and 95 m deep at the time of the August visit—approximately 1.5 km apart. The visitors descended through the 125 m shaft, which measures 5 m in diameter, in a dual-compartment skip (a small open elevator). This shaft is connected to the other, smaller shaft by an intricate network of reinforced tunnels, with a total length of about 2,000–2,500 m. Every 3 m down is a new horizontal level. The mineralized (strike) zone in the district is 1 km wide by 15 km long, and trends north-south. The actual ore zone developed at the Muzo mine measures about 100 m wide by 3 km long. It is discontinuous, so exploration is difficult. The miners look



Figure 7. William Rohtert, Juan Beetar, and Victor Carranza (from left to right) examine approximately 3,000 carats of emeralds recently recovered from the historic Muzo mine, in Boyacá, Colombia. Photo by Alice S. Keller.

for calcite veins and breccias, usually than 1 m thick, with evidence of green beryl and pyrite in the highly carbonaceous black shale. When dolomite bodies are encountered, this signals the end of the emerald mineralization zone.

Blasting is used to move the waste rock. An average of 30 tons of ore a day is shoveled into half-ton ore cars, which are pushed by hand through the tunnels and then taken to the surface in skips for processing in a trommel operation set up a few meters from one of the shafts. When a calcite vein is encountered while tunneling, the miners remove it with handheld pneumatic chisels in a careful and meticulous search for emeralds. About half the emeralds produced are collected by hand from underground, with the remainder recovered from the trommel at the surface. At the time of the visit, a large calcite vein was encountered toward the ceiling of one of the tunnels; four or five miners worked the heavy chisel in rapid succession.

To date, the best stones have come from a small area on the surface called *La Tequendama*. According to Victor Carranza, efforts are now under way to tunnel under the Tequendama area. If the results are not satisfactory, they will return to open-pit mining in this region. Mr. Carranza believes that this is the richest "fringe" of the emerald area. Although the Muzo district has been mined for emeralds for more than a thousand years, Mr. Carranza believes that the reserves are excellent, and his company has identified a number of new mining prospects.

A second Sri Lankan locality for color-change garnet. Garnets that exhibit different colors in incandescent and

daylight-equivalent fluorescent light are known from at least three localities: Umba and Tunduru, Tanzania (Spring 1996 Gem News, pp. 58–59), and Embilipitiya, Sri Lanka. Similar garnets—with a color change strongly reminiscent of alexandrite chrysoberyl—have now been found at a second locality in Sri Lanka, according to Gordon Bleck of Radiance International, San Diego, California. This new locality, Athiliwewa, consists of about 25 acres (10.1 ha) of alluvium, approximately 1.5 miles (2.4 km) east of the Kirindi Oya (stream), near Telulla, in the Monaragala district of southern Sri Lanka. The gem-producing area lies about 4 km east of highway A2 (between the 298 km and 302 km signs), which runs between Tissamaharama and Wellawaya, the nearest large town. Because Athiliwewa is on government land, all mining there is illegal and so is usually done at night.

The garnets are found in alluvial gravels, usually less than a meter below the surface, although one productive hole was reported by Mr. Bleck to be about 3 m deep. The alluvial material, or *illum*, differs from most Sri Lankan *illum* in that it has less clay. The garnets were supposedly discovered by a vegetable farmer in the course of planting. Production as of May 1995 was estimated at 1 kg of garnet rough. Mr. Bleck was told that the largest piece of rough weighed 173 ct, but he did not actually see it. He did see a 40 ct piece of rough (that was later fashioned into a 9.75 ct color-change garnet with a six-rayed star) and a particularly gemmy 32.9 ct piece. As with other color-change garnets that have similar colors (see Spring 1996 Gem News, p. 53), some buyers have mistaken this material for alexandrite.

Gemological properties were acquired for two oval stones, a 1.92 ct modified brilliant (figure 8) and a 0.82 ct mixed cut. In both, the color was evenly distributed and changed from gray-green (in daylight-equivalent fluorescent light; grayish yellowish green in the 0.82 ct stone) to purple (in incandescent light; see again, figure 8). Both also had strong anomalous double refraction when viewed between crossed polarizers, and both were inert to long- and short-wave UV. The large stone had an R.I. of 1.760 and a specific gravity of 3.89; the smaller one had values of 1.768 and 3.91, respectively. Both showed similar absorp-

tion spectra with the desk-model spectroscope—435 nm cutoff; 460, 480, 504, and 520 nm lines; and a wide band at 573 nm—typical for color-change pyrope-spessartines. Visible with magnification were iridescent needle-like inclusions (roughly parallel in the larger stone), “fingerprints” (with a two-phase inclusion in the smaller stone), and fractures with iron-oxide stains. EDXRF analysis of these two garnets revealed Al, Si, Mg, Mn, and Fe, as well as lesser amounts of Ca, V, Y, Zr, and Ti.

It is interesting that the color change in these stones was much more obvious when viewed with transmitted light (an effect described by C. M. Stockton in “Two Notable Color-Change Garnets,” Summer 1982 *Gems & Gemology*, pp. 100–101; see also “Pyrope-Spessartine Garnets with Unusual Color Behavior,” D. V. Manson and C. M. Stockton, Winter 1984 *Gems & Gemology*, pp. 200–207).

SYNTHETICS AND SIMULANTS

Composite tablets, imitation “anyolite.” While in Thailand for the International Gemmological Conference in November 1995, the late Robert Kammerling acquired two inexpensive plaques, each representing a seated religious figure (in pink) against a green background (figure 9). Mr. Kammerling suggested that the materials used in these plaques were meant to imitate so-called anyolite—ruby in a green-and-black zoisite matrix. Each plaque was tablet shaped; one measured 35.8 × 24.5 × 9.1 mm, and the other measured 35.3 × 24.3 × 9.5 mm. With magnification, we resolved individual grains of various colors (pink and near-colorless grains in the pink regions; near-colorless, yellow, blue, and green grains in the green regions) set in a pale yellow polymer. Bulk properties included an R.I. of 1.55 (for both tablets; a poor spot R.I. off the polymer filler material) and S.G.’s of 2.54 and 2.51, respectively. The pink regions fluoresced a weak, uneven red to long-wave UV radiation and a faint, uneven red to short-wave UV; the green regions were either inert or fluoresced a very faint bluish white to both short- and long-wave UV.

Both the pleochroism of the grains and the spectrum seen with the handheld spectroscope suggested that most



Figure 8. The color change in this 1.92 ct garnet from Athiliwewa, Sri Lanka, is apparent in different lighting conditions (left, daylight-equivalent fluorescent light; right, incandescent light). Photos by Maha DeMaggio.

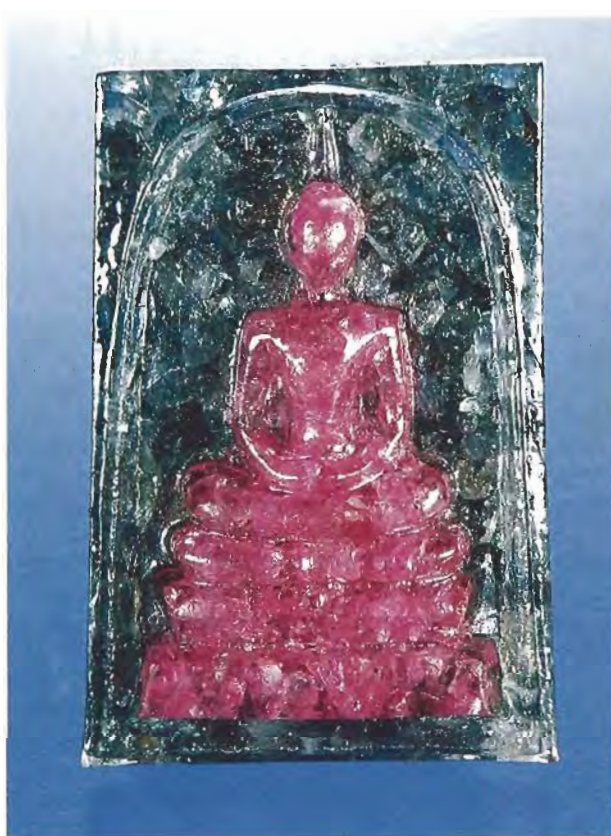


Figure 9. This molded tablet resembles a ruby-in-zoisite ("anyolite") carving. Photo by Maha DeMaggio.

of the grains, in areas of both colors, were corundum. For example, the spectrum of the green area showed readily discernible bands at 450, 460, and 470 nm. The polymer-like material in which the grains were set had many spherical gas bubbles (figure 10). In some of the ruby/pink sapphire chips, we saw clouds of gas bubbles, which indicate synthetic origin. In fact, we could not identify any of the grains in the pink region as natural corundum. Some grains in the green region showed evidence of heat treatment. Some yellow and near-colorless grains appeared to be of a different material, but we could not identify them by standard gemological testing.

UV-visible spectroscopy for the pink region of one plaque revealed a typical ruby spectrum, with an additional absorption edge at about 400 nm, possibly caused by the polymer-like binder. The UV-visible spectrum of the green region showed a band at about 450 nm (resolvable into the 450, 460, and 470 nm peaks seen with the hand spectroscope by looking at the sharp edges) and broad bands centered at about 560 and 820 nm; the latter are related to Fe-Ti and Fe-Fe charge-transfer phenomena. Infrared spectra (between 6000 and 440 cm^{-1}) resolved for both the pink and green regions of one tablet were virtually identical to each other. They were consistent (in the range between 4000 and 1000 cm^{-1}) with the polymer being a mixture of polymethyl methacrylate and alkyd resin (by comparison with the Hummel polymer library).

Bahamian beauties. One tourist now knows that the old adage "let the buyer beware" is more than an idle warn-

ing. Susan Hendrickson of Seattle, Washington, an expert and dealer in conch "pearls," was recently shown two beads that had been sold to a friend as conch "pearls." They were purchased during a visit to the Bahama Islands, off Florida's southeast coast.

As is typical with conch "pearls," the two beads were not perfectly spherical (figure 11). Their colors were also somewhat convincing: One (18.49 ct) was an intense slightly brownish red, and the other (18.89 ct) was somewhat more orange. However, the presence of eye-visible swirls in the beads—rather than the flame structure characteristic of conch "pearls"—was immediate cause for suspicion.

Subsequent gemological testing revealed that each bead had a spot refractive index of 1.49 and a specific gravity of 2.52. When the beads were examined with 10 $\times$ magnification, small spherical gas bubbles were easily seen beneath the surface of each. All of these properties

Figure 10. With magnification, gas bubbles can be seen in the polymer matrix. The grains in the pink region appear to be synthetic ruby and synthetic pink sapphire; in the green region, some of the corundum grains show evidence of heat treatment. Photomicrograph by John I. Koivula, magnified 5 $\times$.



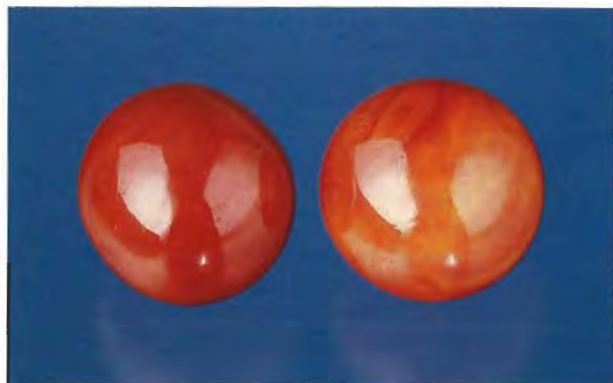


Figure 11. These 14.2 mm (red) and 14.3 mm (orange) glass beads were sold in the Bahamas as conch "pearls." Photo by Maha DeMaggio.

proved that the two beads were actually glass.

On further investigation, Ms. Hendrickson learned that such glass imitations were being sold as conch "pearls" by local Bahamian fishermen. Apparently, at least some of the fishermen were convinced that these glass beads actually were conch "pearls." Ms. Hendrickson was not able to find out who was manufacturing and distributing the glass beads.

An ancient Tibetan pendant, represented as a meteorite.

Nickel-iron meteorites have long been a source of iron metal, especially in times and regions that lacked easily processed or acquired iron. The Ahnigito meteorite, for example, now at the American Museum of Natural History in New York City, was used as a source of metal

by early Greenlanders. So it seemed plausible that a gray metal pendant in the form of a dog (figure 12) could be meteoritic iron that was fashioned in 15th century Tibet (as was represented to its newest owner).

Close examination of the piece, however, revealed various features that made such a composition improbable. Specifically, the piece looked brown in reflected light, not steel gray. In addition, it appeared to be developing a green patina (figure 13), whereas nickel-iron meteorites alter to brown rust in most climates. On the other hand, the green patina could be residual polishing compound, and perhaps the metal surface was brown because it was only slightly rusty. Magnification (again, see figure 13) revealed no evidence of exsolution into a lattice of lath-like metal grains [Widmanstätten structures—Summer 1992 Gem News, p. 133], but only certain nickel-iron meteorites—those with the appropriate composition and cooling history—show these patterns. Etching with a caustic compound is usually needed to expose the pattern when it is present. Ultimately, EDXRF spectroscopy provided the definitive evidence: It revealed copper, tin, zinc, lead, only a trace of iron, and no nickel. Consequently, the material was a bronze (copper-tin) or brass (copper-zinc) alloy, but not a nickel-iron alloy.

University geology departments often are called on by members of the public to determine whether particular samples are meteorites; most of these unknown materials turn out to be "meteor-wrongs." Although this pendant is not a meteorite, it is an unusual and attractive piece. (For more on meteorites and jewelry, see Spring 1995 Gem News, pp. 62–63.) Its age, and whether it came from Tibet, are beyond the scope of our normal identification process.

Figure 12. The gray metal dog-shaped pendant, or tokcha, around which this pin was built was represented to the owner as manufactured in 15th-century Tibet from meteoritic iron. The brooch (40.7 × 30.9 mm) is courtesy of David Humphrey, Pacific Palisades, California; photo by Maha DeMaggio.



Figure 13. With magnification, the metallic brooch in figure 12 appeared brown, with a greenish patina in some regions. Chemical analysis confirmed that the material was not a nickel-iron meteorite but rather a copper alloy. Photomicrograph by John I. Koivula; magnified 10×.



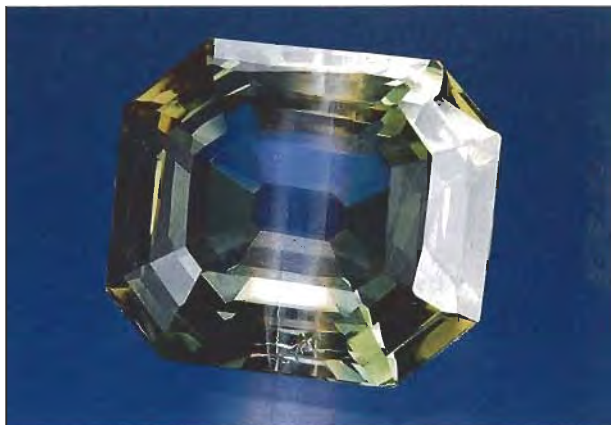


Figure 14. This 45.45 ct synthetic quartz was fashioned to emphasize the near-colorless seed plane. Stone courtesy of Paddie Harris, Santa Monica, California; photo by Maha DeMaggio.

An unusual fashioned "tricolor" synthetic quartz. Last summer, *Gems & Gemology* editor-in-chief Richard T. Liddicoat examined a particularly interesting example of a color-zoned synthetic quartz (figure 14). Most of the synthetic materials that we see have been fashioned in ways that disguise their manufactured origin, but this 45.45 ct emerald cut flaunted its synthetic nature: The near-colorless seed plane formed an obvious stripe through the center of the table. Thin bands of synthetic yellow citrine flanked both sides of the stripe, and the balance of the sample was grayish green. The piece was acquired, already fashioned, in an inexpensive bag of mixed, predominantly rough material purchased at an auction. (For gemological information on a more typically fashioned color-zoned—green and yellow—synthetic quartz, see Winter 1995 Lab Notes, pp. 268–269.)

Figure 15. The 4.01 ct modified brilliant pear shape and 3.84 ct triangular modified brilliant shown here are synthetic spinel triplets, imitating tanzanite. Photo by Maha DeMaggio.



Another tanzanite imitation: Synthetic spinel triplets. So far, we have seen no examples of synthetic tanzanite, although rumors of its existence have circulated since the early 1990s. However, several tanzanite imitations were available at Tucson in February 1996, including synthetic sapphire, a compound of yttrium, aluminum, and europium; and glass (see the article by L. Kiefert and S. Th. Schmidt in this issue, pp. 270–276). Another imitation, marketed as "Tanzation," consisted of synthetic spinel triplets (figure 15). Max Schuster of Los Angeles gave two samples of this material to contributing editor Dino DeGhionno for examination.

We recorded the following gemological properties for these triplets: color—violet; color distribution—even (face up), but all color was contained in the middle "glue" layer; diaphaneity—transparent; optic character—weak anomalous double refraction, manifested as cross-hatching; color-filter reaction—red; refractive indices—1.727 (top and bottom of larger sample), 1.729 (top and bottom of smaller sample); and specific gravity—3.73 (probably unimportant, as the imitation is likely to be successful only when mounted). Each triplet was inert to long-wave UV radiation, but the top and bottom layers fluoresced a strong chalky even greenish yellow to short-wave UV. The "glue" layer was inert to short-wave UV, but was a weak red transmitter to visible light ("transmission luminescence"). When viewed with a desk-model spectroscope, each sample showed three diffuse absorption bands, the strongest at 570–590 nm and the other two at 520–540 nm and 630–650 nm.

With magnification, the "glue" layer in each piece was seen to extend from midway down the girdle into the upper pavilion (figure 16). This layer showed gas bubbles, flow structure, and mottled color distribution, with the color occurring in "thready spots." EDXRF spectroscopy revealed major Mg and Al in the top and bottom layers—consistent with synthetic spinel; the middle layer also contained Si, Pb, Nd, and Co. Therefore, we believe that the "glue" in the middle is, in fact, a silicate

Figure 16. In profile, the bottom of the "glue" layer of the pear-shaped triplet in figure 15 can be seen as a faint line near the top of the pavilion. Photo by Maha DeMaggio.





Figure 17. The bright red stones in this historic cross from Basel Cathedral were identified as dyed red quartz by means of Raman spectroscopy. Photo by P. Portner, Museum for History, Basel, Switzerland.

glass that owes its color to cobalt and neodymium chromophores. The glass is fused to the synthetic spinel crown and pavilion layers.

INSTRUMENTATION

International conference on Raman spectroscopy and geology. Prof. Emmanuel Fritsch of the Institut des Matériaux, University of Nantes, France, provided the following report on the Georaman 96 conference held in Nantes last June. The conference focused on applications of Raman spectroscopy to geologic objects. One session concentrated on applications to gemology, with many of the talks related to the identification of inclusions.

Prof. Paul Dhamelincourt and his colleagues from Villeneuve d'Ascq, France, have identified—using Raman spectroscopy—the following inclusions in Vietnamese

rubies: rutile, apatite, muscovite, margarite, phengite, zircon, dolomite, calcite, labradorite, goethite, pyrite, chalcopryrite, and quartz. It is unusual to get good Raman spectra from sulfides (pyrite, chalcopryrite), and quartz was unexpected as an inclusion in ruby, as it should react with corundum to form aluminosilicates. Prof. Dhamelincourt et al. also identified carbon dioxide as an inclusion in an African ruby, and kaolinite and hydrocarbons in fractures in a Burmese (Myanmar) ruby. Finally, they studied in extreme detail an inclusion in a diamond from Liaoning Province, China: The core of the inclusion was a pure forsterite (olivine) crystal that itself contained a microscopic diamond. The forsterite crystal was surrounded by silicate glass and black dendritic plates of graphite and majorite garnet; calcite and a possible sulfate mineral were also found in the inclusion.

Dr. Lore Kiefert, from the SSEF Swiss Gemmological Institute in Basel, reported that organic fracture fillings in filled emeralds can be recognized easily using Raman spectroscopy, as their Raman spectra are distinctive. In another study, grains of albite were detected as a minor rock component in a cabochon of deep violet jadeite jade.

Professors B. Lasnier, Fritsch, and Serge Lefrant from the University of Nantes identified—using Raman spectroscopy and scanning electron microscope data—a spectacular “golf ball” inclusion in a heat-treated sapphire as the product of incongruent melting of zircon.

Another topic was the ability of Raman spectroscopy to characterize samples in geometrically obstructed environments. For instance, Prof. Lasnier demonstrated Raman spectroscopy's ability to document many small stones set in a large ring. Dr. Kiefert reported on identifying diamonds set in a watch face, testing through the transparent synthetic corundum watch “glass.”

Raman spectroscopy is now routinely used for the nondestructive identification of archaeological or museum objects, the subject of another session. Using this technique, Prof. Lasnier characterized a neolithic bead from Western Brittany as a sericitic mica; Dr. Kiefert identified red dyed quartz set in a crucifix from Basel Cathedral (figure 17); and Prof. David Smith, from the Paris Museum of Natural History, identified the component minerals of eclogite, gabbro, and jade rocks in pre-Columbian Mexican artifacts. Prof. H. G. M. Edwards and co-workers at the University of Bradford (United Kingdom) identified cinnabar and lazurite pigments in wall paintings and frescoes.

Raman spectroscopy provides information about the vibrations of groups of atoms in a mineral or compound; because of this, it can be used to provide fundamental information on gem- and gem-related-minerals. Dr. Giancarlo Parodi and Prof. Smith used Raman spectroscopy to describe the structures of the Fe^{3+} analog of beryl—the new mineral stoppaniite—and a kimzeyite (titanium-zirconium-rich garnet), both from Latium, Italy. Prof. Smith also has interpreted systematics among the

Raman spectra of over 100 garnets from the pyrope-almandine-spessartine and grossular-andradite-uvarovite subgroups. Dr. Shiv Sharma, of the University of Hawaii, Honolulu, Hawaii, obtained structural details of natural amphibole crystals. By using a special technique called resonance Raman spectroscopy, Dr. Mikhail Ostrooumov, from the St. Petersburg School of Mines, found that $(\text{SO}_4)^{2-}$ ionic groups may play an important role in the coloration of lazurite, the main component of lapis lazuli.

Instrument improvements were discussed as well. The use of the confocal technique has proved invaluable for obtaining the spectrum of an inclusion separate from that of the surrounding host. Near-infrared lasers and Fourier-transform spectrometers do not excite visible luminescence (sometimes called "transmission luminescence") and so are ideal for running highly fluorescent materials. Also, Dr. Sharma and associates developed an oblique-illumination confocal microscope for the study of weakly (Raman) scattering materials, such as glasses.

The notion of a standard catalog of reliable Raman spectra is still being pursued, although at the time of the meeting too few individuals had subscribed to a proposed standard database that was unavoidably expensive. One additional difficulty is that Raman peak intensities—though not positions—may vary with crystallographic orientation, which could lead to misidentifications by uninformed users of such a catalog. Abstracts of the Georaman 96 conference are available as *Terra Abstracts*, Volume 8, supplement number 2 of *Terra Nova*, a Blackwell Science, London, journal. The next Georaman meeting is planned for 1999 in Valladolid, Spain.

MISCELLANEOUS

Synthetic sapphire assemblage with a gold "fractal" design. In triplets, the material of greatest interest is often that in the interlayer. In opal triplets, for example, a fragile piece of opal with a desirable play-of-color is protected by a backing material and a cover plate made of a durable transparent substance, such as quartz or glass (see Fall 1996 Lab Notes, pp. 209–210). Recently, the editors became aware of a different type of patterned assemblage (figure 18), in which a microscopically detailed design is etched on the back of a single crystal of Czochralski-pulled synthetic sapphire; the pattern is then deposited with gold. The front surface of the transparent crystal protects the design. The piece is then "backed" by another material. This assemblage is by Refractal Designs, of Danvers, Massachusetts.

According to Refractal Designs president Rick Becker, a proprietary technique (patent pending) photolithographically deposits the 18k gold on a specially prepared surface. With this technique, extremely intricate designs can be created, some 10 times finer than a human hair.

A fractal is the physical representation of a very complicated mathematical pattern that is "infinitely self-iterating," according to Mr. Becker. In effect, design

elements visible in the overall view are also seen in the components of that design (figure 19), at (in theory) any magnification level. Mr. Becker reports clearly visible detail in the pattern at 1,000× with the proper instrumentation. Benoit Mandelbrot first brought these patterns to general attention over a decade ago [see, for instance, *The Fractal Geometry of Nature*, W. H. Freeman and Co., New York, 1982], but the complexity of the calculations made the representations very hard to produce until recently. Even with powerful desktop computers and special software, the generation of these images can take many hours.

The imaged crystal section is "R-plane" Czochralski-pulled synthetic sapphire from Union Carbide, according to Mr. Becker. We measured refractive indices consistent with this material (1.762–1.770). The blue background to the gold design is a metallic oxide that has also been deposited photolithographically. In the prototype sample we examined, glass was used as the backing material. Mr. Becker states that, in production runs, another piece of synthetic sapphire will be used. The

Figure 18. This 22-mm-diameter assemblage, called "Deep Sea Rising," consists of a piece of synthetic sapphire on one side of which a fractal design has been rendered in gold. The design is protected in the back by another slice of a transparent material. Courtesy of Refractal Designs; photo by Rudy DeLellis.





Figure 19. At 11× magnification, individual components of the fractal design in the assemblage shown in figure 18 can be seen to mimic the overall pattern. Photomicrograph by John I. Koivula.

company is also developing processes to deposit more than one color of metal simultaneously. The designs reportedly can be deposited on many jewelry materials.

Completely internal “carving” of glass. At two shows during the last year, one of the editors (MLJ) encountered an unusual method for carving isotropic materials. The 78.25 × 50.2 × 49.8 mm sculpture in figure 20 was made from optical-quality (manufactured) glass. The balloons, and the ground below them, are completely internal to the glass block; they are actually patterns of short dashes that have been carved by a laser.

Richard Sittinger of WonderWorks, Cambria, California, provided some information about this cutting style. The sculptures, called “Erokhin Laser Glass Crystals,” are made in Russia. For each piece, the three-dimensional design is created using computer graphics; a computer-controlled “focus laser-ray apparatus” then produces tiny energy bursts at specified points within the optical glass block. The laser ray actually passes through the glass and affects only the spot on which it is focused, according to information provided by Mr. Sittinger. Additional designs were available at both shows, including abstract geometric figures and sailboats.



Figure 20. The balloons in this glass block are completely contained by the surrounding glass; they were carved using a focused laser beam. Photo by Maha DeMaggio.

When examined with magnification and polarized light, the glass showed areas of strain in the regions of the laser-etched pattern elements (figure 21). We see no obvious reason why this technique could not be applied to other isotropic substances, such as cubic zirconia—or even diamond.

Figure 21. When examined in polarized light, the areas of laser damage in the glass are seen to be surrounded by small regions of strain. Photomicrograph by John I. Koivula; magnified 15×.

