

GEM N.E.W.S

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DIAMONDS

Diamond production starts at Canada's Ekati mine.

October 14, 1998, marked the opening of the Ekati diamond mine in Canada's Northwest Territories (NWT). About 125 guests attended the event, including ministers from both the federal and territorial governments, officials of indigenous peoples' groups and municipal governments, executives of several mining companies, and media representatives. Prof. A. A. Levinson (University of Calgary, Alberta) attended on behalf of *Gems & Gemology* and provided the following report.

Several large mining companies began exploring for diamonds in the NWT in the early 1980s, but by 1985 most had withdrawn from the area. However, the indefatigable Charles E. Fipke, who in 1983 incorporated Dia Met Minerals Ltd., continued the arduous and expensive exploration along with his partner, Stewart L. Blusson. In 1985, Fipke found the first diamond indicator minerals (most importantly, "G10" pyrope garnets) in glacial deposits in the vicinity of Lac de Gras (figure 1). He staked the first claims for diamonds in the NWT in 1989. In September 1990, Dia Met and BHP Minerals (a subsidiary of Australia-based Broken Hill Proprietary Ltd.) signed a joint-venture agreement for the NWT Diamonds Project; BHP became operator of the project.

Within a few months, the joint venture had located a likely source of the diamond indicator minerals (which now included chrome diopside) under what was subsequently named Point Lake. Following geophysical sur-



Figure 1. Five kimberlite pipes make up the Ekati diamond mine, which is located about 300 km northeast of Yellowknife in the Northwest Territories. Artwork modified from original provided by Outcrop; courtesy of BHP Diamonds Inc.

veys, in spring 1991 a core hole was drilled under Point Lake and the first diamond-bearing kimberlite pipe was confirmed (it is presently noneconomic, at a grade of 0.6 ct/tonne with diamonds valued at less than US\$40/ct). To date, the joint venture has discovered more than 100 kimberlite pipes, many of which contain diamonds, within its 1,820 km² stake on the north side of Lac de Gras. The economic potential of some of the pipes has yet to be determined. The five kimberlite pipes that now comprise the Ekati diamond mine, in order of their discovery between 1992 and 1995, are Fox, Koala, Misery, Panda, and Sable (again, see figure 1).

Most of the pipes are located under lakes that formed because the kimberlite was eroded more easily than the surrounding granite by advancing glaciers during the last Ice Age. By world standards, these kimberlite pipes are small (e.g., Panda is about 3 ha [hectares], or 7.4 acres), but they can have extremely high grades and/or high values (table 1 and figure 2). (Most kimberlite mines operating today are larger than 6 ha. For example, Mir is 6.9 ha, Venetia is 12.7 ha, and Premier is 32.2 ha.)

By late 1993, it was clear to the joint venture that a viable diamond mine could be developed in the Lac de Gras region. In 1994, BHP Minerals transferred its interest to BHP Diamonds Inc., a newly formed Canadian corporation. In December of that year, BHP Diamonds Inc. notified the Canadian government of its intent to mine the deposit. However, the mine is located in an area of continuous permafrost, with a fragile ecosystem. In July



Figure 2. All of these diamonds were recovered from the Ekati mine. (The largest rough diamond reported thus far weighed 47 ct, but we do not know if it was gem quality.) Photo courtesy of BHP Diamonds Inc.

1995, an extensive environmental impact study was submitted for government review. Following a careful evaluation, the successful conclusion of negotiations with four indigenous peoples' groups, and approval by the Federal Cabinet, all necessary licenses and permits were obtained by January 1997, allowing construction to begin. Close attention was paid to integrating the project with the local communities and the economy of the NWT (for example, about 550 permanent jobs have been created, 30% of which are held by indigenous people.)

The project was named Ekati in 1997, with the ownership distributed as follows: BHP Diamonds Inc. (51%), Dia Met Minerals Ltd. (29%), Charles E. Fipke (10%), and Stewart L. Blusson (10%). *Ekati* means "fat lake" and is the name traditionally used by indigenous people for Lac de Gras. It refers to the white quartz rock found in abundance around the lake, which resembles caribou fat.

Construction of the mine presented numerous challenges because of the remoteness of the area, the lack of permanent roads (a 475 km ice road is available from Yellowknife, the territorial capital, for only 8–10 weeks from mid-January to mid-April), the lack of other types of infrastructure (e.g., electricity), and the harsh climate (temperatures can drop to –50°C in the winter months). Yet construction of a processing plant and supporting facilities, as well as preparation of the first kimberlite for mining (Panda; see figure 3), were completed on schedule in 21 months. This is an amazing engineering and logistical feat, considering the difficulties mentioned above. So far the investment in Ekati totals about US\$700 million.

The five kimberlites at Ekati will be mined in a sequence determined by the size and location of each pipe, as well as by the projected value of (and market demand for) the diamonds they contain. This plan is designed to provide a consistent production, both by quality and value of the diamonds. Some ore will be stockpiled in case mining is interrupted by equipment

TABLE 1. Ore reserves and the timetable (anticipated production dates) for mining diamonds at the five pipes comprising the Ekati diamond mine.^a

	Panda	Misery	Koala	Sable	Fox	
Production	1998–2009	1999–2013	2002–2013	2007–2013	2008–2015	Total (T) Avg. (A)
Mining reserves (millions of tonnes) ^b	13.4	5.5	17.4	12.9	16.7	66.0 (T)
Grade of kimberlite (ct/tonne)	1.09 ^c	4.26	0.76 ^d	0.93	0.40	1.09 (A)
Average value of diamonds (US\$/ct)	130	26	122	64	125	84 (A)

^a Production schedules are subject to change. All pipes will be mined initially by open-pit methods. Underground mining will occur later at the Panda and Koala pipes. Modified from Dia Met Minerals Ltd. Annual Report 1997–1998. A particular year (e.g., 1999) refers to the fiscal year, which starts in June (e.g., June 1999–May 2000).

^b Includes both proven reserves (43.5 million tonnes total) and probable reserves (22.4 million tonnes total); 1 tonne = 1,000 kg = 2,204.6 pounds (avdp).

^c Grade includes the 0.97 ct/tonne material in the underground mining portion of 2.8 million tonnes.

^d Grade includes the 1.63 ct/tonne material in the underground mining portion of 0.8 million tonnes.



Figure 3. This aerial photograph of the Ekati diamond mine, looking south (with the camp and processing facilities in the distance), was taken in August 1998. The Panda pit (foreground) measures about 900 m in diameter; the kimberlite is the much smaller dark region in the center and lower right of the pit floor. (The area of the pit is larger than the pipe because of the requirements of open-pit mining.) Eventually, the bottom of the pit will be about 100 m wide and 300 m below the present surface, at which time underground mining will commence. Just beyond the Panda pit is Koala Lake, which marks the location of another kimberlite that is scheduled to begin mining in 2002. Photo © Jiri Hermann/BHP Diamonds Inc.

breakdown or extreme weather. Production from Ekati, initially only from the Panda pipe, is scheduled at 9,000 tonnes of kimberlite per day, yielding approximately 10,000 carats of diamonds daily (about enough to fill a large coffee can). Annually this is equivalent to 3.5–4.5 Mct (million carats) of rough gem and industrial diamonds, worth about US\$500 million. On the basis of current world production (115 Mct), this will constitute about 4% of the total annual supply by weight and 6% by value. It is planned that, after 10 years, production will be increased to 18,000 tonnes of kimberlite per day, requiring an additional investment of US\$80 million. Over the initial 17 year life of the Ekati mine, about 66 million tonnes of ore will be processed from the five kimberlite pipes (again, see table 1), yielding about 72 Mct of diamonds (based on an overall grade of 1.09 ct/tonne). In view of the numerous other kimberlites in the area, some of which almost certainly will be mined in the future, mining in this region is expected to last for at least 25 years.

The rough diamonds will be sorted and evaluated at a specially designed facility near the Yellowknife airport, beginning in early 1999. Initially, all of the rough dia-

monds will be exported to Belgium, to be marketed through BHP Diamonds' sales office in Antwerp, with the assistance of I.D.H. Diamonds NV. It is anticipated that a limited number of cutting facilities eventually will be established in various parts of Canada.

Ekati is the first of what are likely to be several new diamond mines in Canada. The Diavik project, which borders Ekati on the south, is being developed by Rio Tinto PLC and Aber Resources; it is expected to begin production in 2002 with about 6 Mct annually. When the Diavik production is combined with that of Ekati, about 10% of the world's diamonds (by both weight and value) could come from Canada; this is comparable to current production from South Africa.

Financial Times Diamond Conference. *Gems & Gemology* editor Alice Keller attended this one-day conference, which was held in Antwerp, Belgium, on October 28. Three main areas of the diamond business were addressed: supply, manufacture, and demand.

De Beers has a major stockpile of diamonds (which they valued at about \$4.6 billion as of June 1998) and can adjust supplies to assure stability for rough diamond prices. Given concerns about diamond demand (see below), the Central Selling Organisation (CSO) will continue to restrict sights, and not all sightsholders will receive diamonds at each one. The main sources for stones outside CSO marketing channels have been Russia, Angola, and Australia; Canada is now poised as a fourth source. Despite its own economic crisis, Russia is in a good position to continue diamond mining; however, production is not likely to increase in the near future, and current production is completely absorbed by the CSO and the Russian cutting industry. Mining in Angola is uncertain (and expensive) because of the civil war raging there, which shows no sign of abating. However, Angola has produced several million carats of alluvial stones in recent years, and the first kimberlite pipe to be mined there, Catoca, recovered more than 122,000 carats in one month in 1998. Although Canada's Ekati mine will produce about 3.5–4.5 Mct annually, with no plans by BHP to stockpile goods, De Beers's representatives do not believe that Canadian production will have a significant impact on supply.

Two related economic problems bedevil manufacturers: overcapacity and financial liquidity. Today, the diamond industry is in transition from being supply driven to being demand/marketing driven. India is now the world's leading diamond manufacturer, producing 9 of every 10 fashioned diamonds, with costs as low as \$0.75 to cut a small sawn stone. The huge manufacturing capacity there has led to excess inventory. Israel is suffering because so much of their business fed demand in Asia. Rough imports to New York decreased 23% for 1997 compared to 1994, yet diamond jewelry sales in the U.S. continue to rise. However, this increased demand is

primarily for less-expensive goods, rather than for the more important stones cut in New York. Like Israel and New York, the Belgian diamond industry must contend with high wages relative to India. Recent allegations that drug dealers are laundering money through the Antwerp diamond trade may lead to further scrutiny on the part of government authorities.

Diamonds have been adversely affected on the demand side, not only because of the Asian financial crisis, but also because consumers in Japan appear to be putting disposable income into goods other than diamonds. (In Japan, diamonds—especially solitaire rings with certificates—are perceived to be the least profitable part of a jeweler's inventory.) More and more diamond manufacturers look to U.S. consumers to compensate for lost Asian sales. The auction market saw a recent drop in demand: Christie's sold only 50% of the lots offered at its October 1998 sale in New York, and the company responded immediately with a reduced, more selective, December auction. One key to building demand is advertising; in addition to its own branding initiative (still being "test-marketed"), De Beers continues to invest \$200 million per annum in "generic" diamond advertising worldwide. Overall, technology is altering the "diamond landscape": improved communications (e.g., the Internet), new instruments, and ongoing research are changing the way diamonds are found, fashioned, and regarded.

COLORED STONES

Colored stone presentations at the International Mineralogical Association meeting. The Fall 1998 Gem News section reported the results of several diamond investigations described at the 17th IMA meeting in Toronto, Ontario, last August. There were also numerous presentations on colored stones, several of which are summarized below.

George Rossman (California Institute of Technology,

Pasadena) delivered a plenary lecture on the origin of color in minerals. The coloration of tourmaline, garnet, and the colored varieties of quartz are due to transition metal ions (often interacting to produce different colors) and microscopic inclusions. Color also can be induced when natural background radiation changes the oxidation state of ionic impurities. D. C. Grenadine (Slippery Rock University, Pennsylvania) attributed the formation of the color centers that produce yellow to brown in silicate minerals such as quartz, topaz, and beryl, to ionic impurities in the presence of aluminum that has substituted for silicon in tetrahedral sites. In two presentations, John Emmett and Troy Douthit (Crystal Chemistry, Brush Prairie, Washington) described the techniques used to treat some gemstones (especially sapphire), which may result in a substantial improvement in color and/or clarity (see, e.g., figure 4) and therefore value.

There were numerous presentations on gem corundum. F. L. Sutherland (Australian Museum, Sydney) presented a model for the origin of two geochemically distinct suites of corundum from alkali basalts, whereby partial melting of the lithosphere over a rising plume of the earth's mantle can lead to repeated eruptions of potentially gem-bearing lava. M. I. Garland and colleagues (University of Toronto) inferred that the alluvial sapphires from southwest Montana came from a crustal metamorphic source, on the basis of their relatively low (40–60 ppm) gallium contents. T. Häger (University of Mainz, Germany) and colleagues studied the trace-element chemistry and inclusions in rubies from two mining areas in Vietnam—Luc Yen (where the rubies are produced by metasomatic processes in marble) and Quy Chau (where pegmatites introduced into sillimanite-bearing schists are responsible for ruby formation). T. Häger also studied the cause of color in sapphire, and noted that magnesium seemed to be required (as well as Fe and Ti) to explain the coloration of heat-treated yellow sapphire. D. Tang (University of Fuzhou, Fujian, China) attributed the blue color of sapphires from Mingxi

Figure 4. Some near-colorless geuda sapphires from Sri Lanka (left) become commercially important after heat treatment improves their color (right). The stones range from 1 to 4 ct. Photos courtesy of John Emmett, Brush Prairie, Washington.

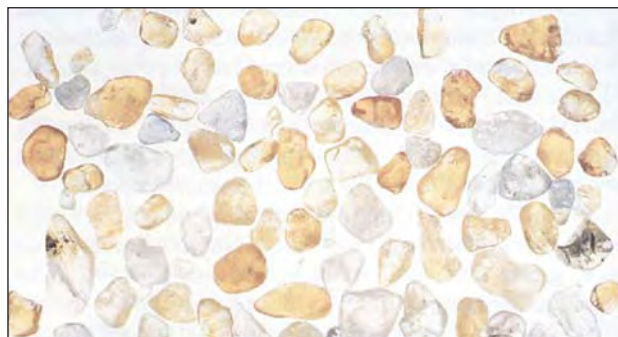




Figure 5. Granitic pegmatites in Afghanistan are renowned for producing large quantities of gem-quality spodumene in a variety of colors. This kunzite crystal is 11.8 cm long. Courtesy of Bill Larson, Fallbrook, California; photo © Jeff Scovil.

(Fujian Province) to a defect cluster containing hydrogen as well as iron and titanium. A. V. Lyutin (Moscow State University, Russia) and colleagues grew flux synthetic rubies with up to 6.38 wt.% Cr_2O_3 from $\text{PbO-V}_2\text{O}_5\text{-WO}_3$ flux. They found that samples grown in this flux, and in $\text{Li}_2\text{O-WO}_3$ flux, at $1100^\circ\text{--}1250^\circ\text{C}$, had rather equidimensional shapes.

I. I. Moroz (Hebrew University of Jerusalem, Israel) and G. Panczer (University Claude Bernard, Lyon, France) examined the Raman spectra of emeralds from several deposits, and suggested that this technique might someday be useful to differentiate emerald localities. I. Z. Eliezri (Colgem Ltd., Ramat Gan, Israel) and I. I. Moroz examined the compositions of mica and talc inclusions in emeralds from different sources, and likewise suggested that these compositions might be useful to identify emerald sources. G. Graziani (University of Rome "La Sapienza," Italy) used infrared spectroscopy to investigate several possible sources for ancient Roman emeralds.

A. M. R. Neiva (University of Coimbra, Portugal) and co-workers described the trace-element chemistry of blue, green, pink, and white beryl from Namivo, Alto Ligonha, Mozambique. Z. L. Li and colleagues (Zhongshan University and Nanjing University, China) characterized zinc spinel and other daughter crystals found in

melt inclusions in pegmatite beryl from Xinjiang, Hunan, and Yunnan Provinces, China. J. M. Evenson (University of Oklahoma, Norman) and colleagues looked at the equilibrium among beryl, aluminosilicates, chrysoberyl, and quartz in an aluminum-rich granitic melt; they found that beryl could crystallize at very low beryllium concentrations in low-temperature-solidifying melts.

T. Lu (GIA Research, Carlsbad) and colleagues described differences between natural and synthetic amethyst, citrine, and ametrine. Some synthetic amethyst can be identified by the orientation of color zones and growth bands, pleochroism, and a characteristic IR absorption peak at 3540 cm^{-1} . I. K. Bonev (Bulgarian Academy of Science, Sofia) suggested that thin microscopic calcite plates acted as seeds for well-formed crystals of "fadenquartz" (quartz crystals containing opaque white strips that might be mistaken for the seed plates in synthetic quartz), which form in Alpine-cleft-type deposits in Switzerland and elsewhere.

Advanced analytical techniques were described in many presentations. M. Gaft (Open University of Israel, Tel Aviv) and G. Panczer illustrated the use of laser-induced time-resolved luminescence spectroscopy to differentiate among luminescence centers with similar emission spectra but different decay times; previously unknown causes of luminescence (mostly involving rare-earth elements) were documented. M. Superchi and E. Gambini (CISGEM, Milan Chamber of Commerce, Italy) discussed the use of infrared spectrophotometry, energy-dispersive spectrometry, and Raman microspectrometry to identify treatments and differentiate between varieties of organic and amorphous gem materials. A. Banerjee (University of Mainz, Germany) and D. Habermann (Bochum University, Germany) used hot-cathode cathodoluminescence to differentiate between natural and cultured freshwater pearls from North America and China, respectively. P. Zecchini (University of Franche-Comté, Besançon, France) and colleagues used reflectance IR spectroscopy, electron microprobe analysis, and X-ray diffraction to determine nondestructively the species, composition, and lattice parameters of gem garnets.

Gem-bearing pegmatites were highlighted by several researchers. K. L. Webber and colleagues (University of New Orleans, Louisiana) calculated the crystallization times of some gem-bearing pegmatites in San Diego County, California; for the famous Himalaya dike at Mesa Grande, they estimated that the pegmatite cooled to 400°C in only five to 14 days. P. Keller (University of Stuttgart, Germany) defined several belts of rare-element pegmatites in Namibia's Central Damara Province; gem tourmaline has been found in some of these pegmatites. B. M. Laurs (GIA *Gems & Gemology*) surveyed the gemstone resources and the geologic setting of kunzite-elbaite-beryl pegmatites in Afghanistan (see, e.g., figure 5), and suggested possibilities for further exploration. A.

B. Rao and M. S. Adusumilli (University of Brasilia, Brazil) gave exploration guidelines for aquamarine- and elbaite-bearing pegmatites in Borborema Province, Rio Grande do Norte, Brazil. C. Kasipathi (Andhra University, India) and A. B. Rao described the source rocks (mostly pegmatites) for many gems (e.g., ruby, alexandrite, tourmaline, topaz, and garnet) in the Khammam, East Godavari, and Visakhapatnam districts of Andhra Pradesh State, India.

Chalcedony with goethite inclusions from Madagascar.

On a recent trip to Madagascar, Michel Bricaud of La Rose du Désert, Bagneux, France, acquired a large quantity of an unusual variety of chalcedony (figure 6), some of which was examined by Gem News contributing editor Emmanuel Fritsch at the University of Nantes, France. The material is currently being fashioned into cabochons.

The chalcedony contains abundant tiny, dark spherical aggregates, typically 0.1–0.2 mm in diameter. Their dark brown color contrasts sharply with the white or beige of the matrix, and their small size creates very fine detail in the inclusion patterns. With magnification, these spherules show yellow-brown internal reflections, which suggests that they are goethite.

Chemical analyses of the spherules were performed with a JEOL 5800 LV scanning electron microscope, equipped with an energy-dispersive detector that can detect most light elements, including oxygen (but not, e.g., hydrogen). The only elements detected by SEM-EDX were iron and oxygen, as well as small amounts of silicon from the chalcedony matrix. This chemistry is typical of iron oxides and hydroxides. X-ray diffraction analysis of a fragment of chalcedony particularly rich in the inclusions showed peaks corresponding to goethite, in addition to the quartz peaks. Dr. Fritsch therefore identi-

Figure 6. The tiny black inclusions forming fine patterns in these chalcedony samples from Madagascar (each about 4 cm across) were identified as goethite. Photo by A. Cossard.

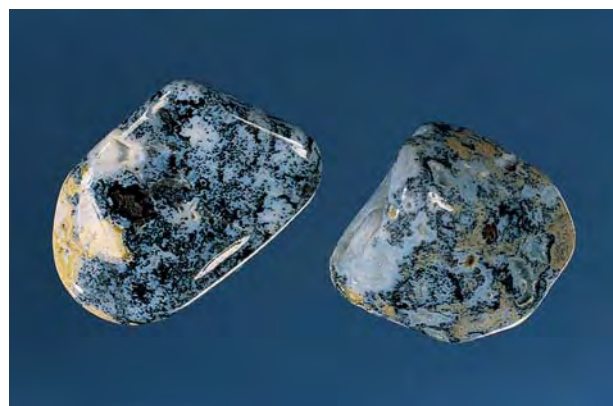


Figure 7. At first, this 1.48 ct colorless iolite was thought to be feldspar. The 18.49 ct iolite block shown on the left was used as a reference standard for Raman analysis. Photo by Maha DeMaggio.

fied the small brown spherules as goethite [α -FeO(OH)] inclusions in chalcedony.

Iolite gemologically indistinguishable from feldspar. The vast majority of gem identifications today—well over 90%—can still be made with the standard methods available to most gemologists and jewelers. However, occasionally we receive gem materials that present especially subtle challenges. The actual identities of these materials often are not even suspected unless so-called advanced testing techniques are used. One example was the faceted genthelvite described in the Fall 1995 Gem News (pp. 206–207), which could not be distinguished from (much more common) pyrope-almandine garnet using standard gem-testing methods.

Recently, we were asked to look at a colorless, transparent oval mixed cut (figure 7), which weighed 1.48 ct and measured $9.31 \times 7.09 \times 4.05$ mm. The stone was initially represented to K & K International of Falls Church, Virginia, as oligoclase feldspar from Sri Lanka. The gemological properties of this stone were typical for plagioclase feldspar in the albite-oligoclase compositional range. Its three refractive indices were $\alpha = 1.531$, $\beta = 1.534$, and $\gamma = 1.541$, yielding a birefringence of 0.010. The optic character and sign were biaxial positive. The specific gravity, as determined hydrostatically, was 2.62 (average of three measurements). The stone was inert to both long- and short-wave UV radiation. When it was viewed with a microscope in polarized light, lamellar twinning was obvious (figure 8); this feature was similar to that commonly seen in plagioclase.

To confirm the stone's identity, we analyzed it with the laser Raman microspectrometer. We were surprised when the Raman spectrum indicated that this colorless

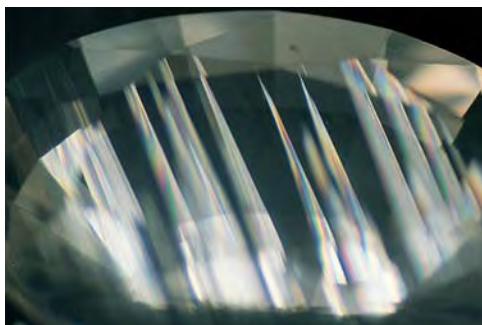


Figure 8. In polarized light, the colorless iolite showed obvious polysynthetic twinning. These two views illustrate the sample at slightly different orientations. Photomicrographs by John I. Koivula.

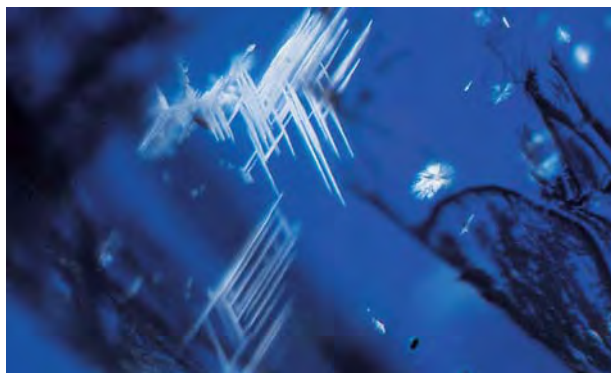
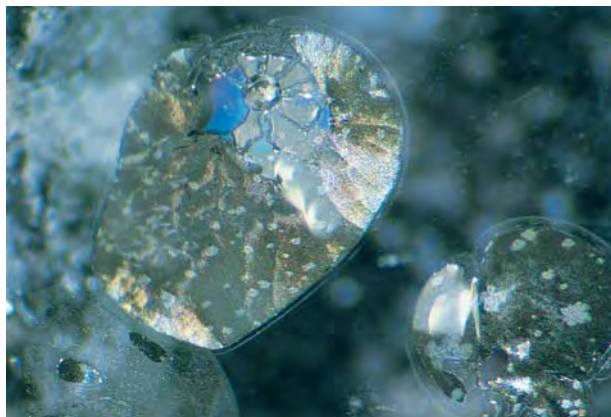


Figure 9. Areas of polysynthetic twinning were also observed in the iolite block shown in figure 7. Photomicrograph by John I. Koivula; polarized light, magnified 20x.

gem was cordierite (iolite). Three different areas of the stone were tested, all with the same result. To corroborate this identification, we performed Raman analysis on an 18.49 ct rectangular block of blue iolite (also shown in figure 7). On the basis of the results obtained, there is no question that the colorless stone is cordierite and not a feldspar, even though the gemological properties of this stone would be consistent with either gem material.

Figure 10. Rounded, metallic grains of pyrrhotite are surrounded by decrepitation halos in this sapphire from Dry Cottonwood Creek, Montana. Photomicrograph by John I. Koivula; magnified 25x.



Although lamellar or polysynthetic twinning of cordierite is not mentioned in gemological texts, mineralogy texts do list this structural property as a common feature. For example: "Cordierite may show polysynthetic twinning and birefringence resembling that of plagioclase" (W. R. Phillips and D. T. Griffen, *Optical Mineralogy, the Nonopaque Minerals*, 1981, W. H. Freeman and Co., San Francisco, p. 168). In fact, the blue iolite sample that we used as a Raman standard also showed excellent twinning in polarized light (figure 9).

Because plagioclase and cordierite have similar gemological properties, it is quite possible that these gems could be misidentified, especially samples from a locality that hosts both gem minerals (e.g., Sri Lanka, India, and Madagascar).

New features of Montana sapphires: Gold is where you find it. Since 1992, Marc Bielenberg of Hamilton, Montana, has been involved in an extensive sapphire sampling project on the main drainage and both forks of Montana's Dry Cottonwood Gulch. Those gem-quality, water-worn crystals that were deemed suitable for heat treatment were visually separated from the "rejects,"

Figure 11. This crystal of clinozoisite in sapphire from Dry Cottonwood Creek displays perfect cleavage; it also hosts a smaller unidentified rod-shaped inclusion. Photomicrograph by John I. Koivula; magnified 35x.



which were mostly smaller stones of apparent lower quality. These reject stones were stored for several years without any further examination.

During the 1997–1998 winter season, when mining activity had ceased, Mr. Bielenberg decided to examine the reject sapphires more closely. While searching for interesting or unusual inclusions, he discovered what later were proved to be (by Raman analysis and X-ray powder diffraction) mineral inclusions of pyrrhotite (figure 10) and clinozoisite (figure 11), which were not previously known as inclusions in Montana sapphires.

A real surprise, however, was the discovery of microscopic grains of gold in the crevices, pits, and cracks of some of these sapphires. The gold had the form of tiny water-worn nuggets (figure 12) rather than flakes. In no instance was gold observed as an actual inclusion in any of these sapphires. Mr. Bielenberg observed gold on the surfaces of 135 of the 600–700 stones he examined. Most of these stones had only one microscopic nugget; the most gold particles found on any one stone was four. Higher magnification shows that, at least in some instances, the gold appears to have been smeared by friction across the surface and into cracks and crevices (inset, figure 12). To confirm the identification, energy-dispersive X-ray fluorescence analysis by Sam Muhlmeister of GIA Research resolved a gold peak from each of two different sapphires.

Because the gold can be removed from the surface of the sapphires with a small probe, it is evident that the grains are not strongly bonded to the sapphires. Apparently, the gold was naturally wedged in place as the stone was moving through its alluvial environment. This discovery suggests that the Dry Cottonwood Creek area might also have potential for gold recovery.

Highly translucent green serpentine from Afghanistan.

Franck Notari of GemTechLab in Geneva, Switzerland, provided contributing editor Emmanuel Fritsch and the gemology laboratory at the University of Nantes with several highly translucent yellowish green beads (figure 13). These poorly polished beads came from necklaces that were reportedly purchased in Afghanistan. One bead was sawn in two and polished for gemological testing. Refractive index measurements varied between 1.563 and 1.567, and the specific gravity (determined hydrostatically) was 2.55 ± 0.05 . These data are typical for serpentine. Further testing was required to identify the particular species in the serpentine “subgroup” of the kaolinite-serpentine mineral group. Energy-dispersive spectroscopy, with the University of Nantes SEM-EDX system, showed the presence of oxygen, magnesium, and silicon, with lesser amounts of aluminum and iron. (Although oxygen can be detected with this system, hydrogen cannot.) The X-ray diffraction pattern was an excellent match for a monoclinic polytype of antigorite, antigorite-6M, which is a serpentine mineral. The chemical formula usually quoted for antigorite is



Figure 12. A cluster of gold micronuggets is visible in a surface depression on this sapphire from Dry Cottonwood Creek. Photomicrograph by John I. Koivula; magnified 15 $\times$. The inset shows a small particle of gold that appears to have been smeared into the surface of the sapphire. Photomicrograph by John I. Koivula; magnified 40 $\times$.

$(\text{Mg}, \text{Fe}^{2+})_3\text{Si}_2\text{O}_5(\text{OH})_4$; the yellowish green color is probably caused by the iron present.

Etch-decorated topaz. Two interesting samples of colorless topaz were recently sent to the Gem News editors for photodocumentation and gemological investigation of their inclusions (figure 14). Bill Larson, of Pala International, Fallbrook, California, reported that both samples were from the Mogok region of Myanmar.

The cabochon was thought to contain inclusions of the mineral goethite (an iron oxyhydroxide), as suggested by the brown color and acicular habit. When these inclusions were viewed with magnification, however, their

Figure 13. These unusually translucent yellowish green beads, reportedly from Afghanistan, are antigorite, a serpentine mineral. Photo by A. Cossard.





Figure 14. The $26.31 \times 20.08 \times 13.24$ mm (62.68 ct) cabochon of colorless topaz contains etch channels filled with yellowish brown limonite. The crystal (73 mm long) also contains numerous etch channels, but these do not show any evidence of staining. Courtesy of Bill Larson; photo by Maha DeMaggio.



Figure 15. These tourmaline crystals come from a new find in Nigeria. Red, pink, colorless, and green zones are typical, but grayish blue zones were also seen. The largest crystal, on the left, measures 49 mm long and 13.5 mm across. Courtesy of Karl Egon Wild Co.; photo by M. Glas.

appearance was identical to the so-called “rutilated” topaz that was described and documented in the Summer 1987 issue of *Gems & Gemology* (J. Koivula, “The rutilated topaz misnomer,” pp. 100–103). Although the inclusions in the topaz crystal were identical in shape to those in the cabochon, they were colorless. All the inclusions in both samples appeared to reach the surface of their host topaz.

In the earlier *Gems & Gemology* article, Brazilian “rutilated topaz” was actually shown to contain ribbon-shaped (to somewhat more prismatic) etch channels that were stained by limonite. The channels probably formed as surface-reaching fissures during growth of the topaz and were significantly enlarged through later etching by corrosive hydrothermal fluids. The “earthy” yellowish brown limonite was later deposited in the channels by iron-rich groundwaters. Therefore, although the inclusion channels co-existed with the growth of the topaz, the filled inclusions developed after the crystal had formed; these were not solid mineral inclusions that grew at the same time as the topaz. (The channels would be colorless if they were not stained or filled with epigenetic material.) The colorless channels present near the termination of the topaz crystal in figure 14 indicate that this particular crystal may not have been exposed to the same epigenetic solutions that entered the stone from which the cabochon was cut; or perhaps the iron-rich stains were removed during cleaning of the specimen.

Red, pink, and bicolored tourmaline from Nigeria.

Tourmaline from Nigeria has been known in the gem trade since at least the middle 1980s (see, e.g., *Gem News*: Spring 1988, p. 59; Spring 1989, p. 47; Spring 1992, p. 62). These stones originated from tin-bearing pegmatites in Kaduna State, as well as from a pegmatite belt southeast of Kaffi in central Nigeria (J. Kanis and R. R. Harding, “Gemstone prospects in central Nigeria,” *Journal of Gemmology*, Vol. 22, No. 4, 1990, pp. 195–202). Gem-quality green, red, pink, and bicolored tourmalines have been recovered. Recently, contributing editor Karl Schmetzer provided information on a new tourmaline find in Nigeria.

In summer 1998, Nigerian traders at Idar-Oberstein offered large parcels of gem tourmaline from a locality west of the town of Ogbomosho, near the border with the country of Benin. More than 100 rough crystals and 10 faceted stones were loaned to Dr. Schmetzer by Karl

Egon Wild Co. (Kirschweiler) and Julius Petsch Jr. Co. (Idar-Oberstein). Dr. Schmetzer described the crystals as prismatic in habit (figure 15), with trigonal prism faces m $\{01\bar{1}0\}$ and hexagonal prism faces a $\{11\bar{2}0\}$; the dominant trigonal pyramid faces were o $\{02\bar{2}1\}$, sometimes in combination with ditrigonal pyramid x $\{12\bar{3}2\}$ faces. The relative size of the terminal face, or pedion, c $\{0001\}$ varied from small to large (figure 16).

Most of the crystals were color zoned purplish red to pink to nearly colorless. In some samples, the growth zones adjacent to the pedion (parallel to the pyramid faces) were medium to intense yellowish green or green; rarely, this end of a crystal was bluish gray (again, see figure 15). The pleochroism for the red and pink zones was colorless to medium pink parallel to the c -axis, and intense pink to red perpendicular to the c -axis. For green zones, it was light yellowish green parallel to the c -axis, and intense yellowish green or green perpendicular to this axis. For the bluish gray zones, pleochroism was light grayish blue parallel to the c -axis, and intense grayish blue perpendicular to this axis.

The faceted stones were evenly colored red or pink (figure 17), bicolored green and pink (and, rarely, blue and pink), or color zoned in various shades of red and pink. The refractive indices and specific gravities varied within relatively small ranges: $n_o = 1.640$ and $n_e = 1.620$ (both ± 0.002); specific gravity = 3.05 ± 0.02 . On the basis of visible absorption spectroscopy, Dr. Schmetzer determined that Mn^{3+} was the dominant chromophore in the red and pink samples.

TREATMENTS

On the burning of polymer-impregnated synthetic and natural opals. In polymer-impregnated gem materials (e.g., opal, turquoise, and jade), the question sometimes arises as to how much polymer is present. This is especially a cause for concern with opal, since the refractive index and specific gravity values of the polymer compound(s) commonly used are so similar to those of the opal itself. Furthermore, the two materials are not easily distinguished by visual examination, even with the microscope. Consequently, the amount of polymer present is generally unknown, and might constitute a significant portion of the weight of a sample.

In addition, the Materials Safety Data Sheets provided with polymers state that many are flammable. To study this possible durability concern, as well as to investigate the amount of polymer present in some natural and synthetic opals, Gem News editor Mary Johnson and GIA Gem Trade Laboratory staff gemologist Maha DeMaggio destructively tested seven samples by burning them. Since heat drives off both water and volatile organic materials (such as some of the breakdown products of heated polymers), the approximate amount of these substances present can be measured by weighing the sample before and after heating. Although this test would not be

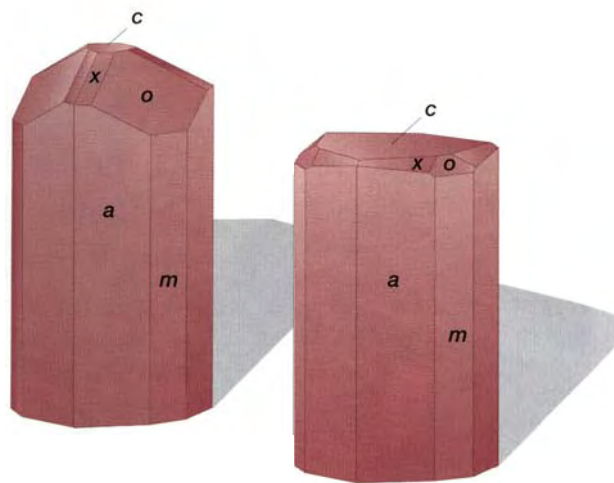
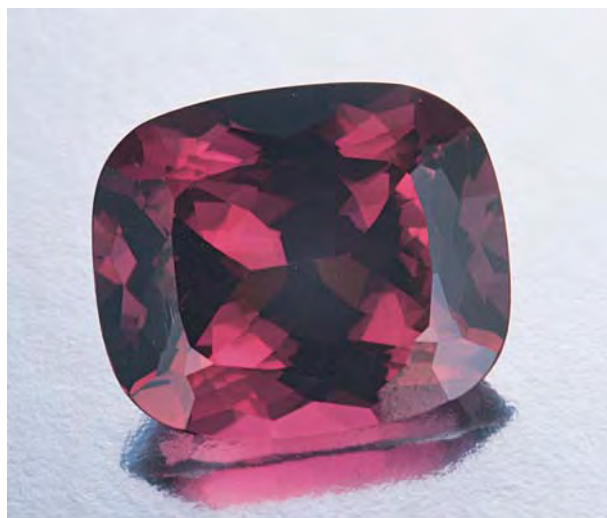


Figure 16. These schematic drawings illustrate the crystal faces seen on the tourmaline crystals recently found in Nigeria. Variations in the size of the pedion c $\{0001\}$ face primarily account for the differences in morphology between the two crystals. After drawings by Karl Schmetzer.

applied in the course of routine gem testing, it does provide some idea of the potential weight component of the polymer in such treated synthetic opal (which, based on earlier research, appears to be largely anhydrous).

The samples used were: one (untreated) "white" Gilson synthetic opal (2.43 ct), one (untreated) "black crystal" Gilson synthetic opal (1.13 ct) [Gilson synthetic opals are not polymer-treated, in our experience], four polymer-impregnated synthetic opals (0.21, 0.65, 1.39, and 8.14 ct), and one polymer-impregnated natural opal

Figure 17. Attractive faceted stones are being cut from the new find of Nigerian tourmaline, such as this 21.10 ct rectangular cushion. Courtesy of Bill Larson; photo by Maha DeMaggio.



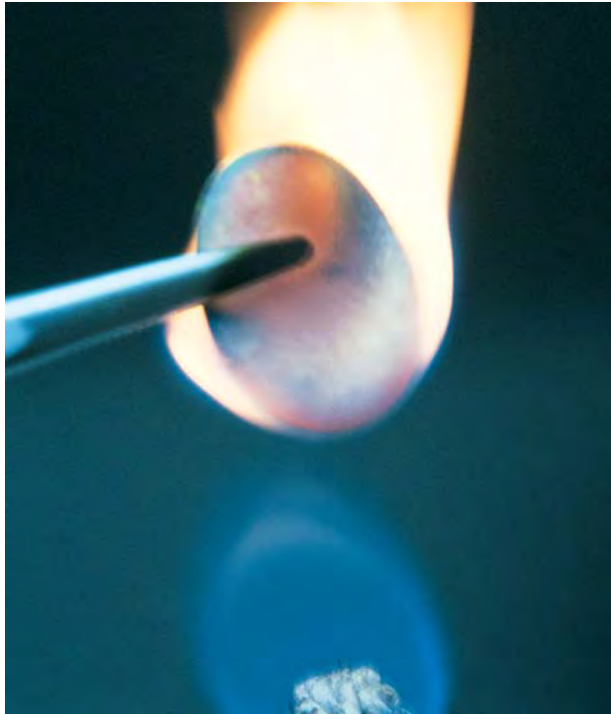


Figure 18. This 8.14 ct polymer-impregnated synthetic opal burned readily in the flame of an alcohol burner. Photo by Maha DeMaggio.

from Brazil (1.14 ct). We attempted to ignite each sample using a match or an alcohol burner; this was done in a fume hood, to avoid exposure to (possibly toxic) combustion gases.

All the polymer-impregnated samples caught fire readily (figure 18), and they continued to burn when removed from the flame. The four polymer-impregnated synthetic opals lost 16%–27% of their weight by burning, with an average weight loss of 21%. Because the resulting residue broke apart easily, we did not attempt

Figure 19. After burning, droplets of charred polymer residue can be seen on the surface of this impregnated synthetic opal; a network of cracks is also visible. Photomicrograph by John I. Koivula; magnified 20×.



to burn the samples all the way through, so these values represent the minimum weight of the polymer in these samples. Subsequent microscopic examination showed deep cracks throughout, as well as charred droplets of exsolved polymer (figure 19). The impregnated natural opal also burned, although somewhat less readily. Because this stone broke apart during examination, weight loss from the burning alone could not be determined. The two Gilson synthetic opals (which had not been polymer-impregnated) reacted the least: The “black crystal” synthetic opal appeared unchanged, while the “white” opal became more transparent. Neither lost weight or caught fire.

In a previous examination of polymer-impregnated synthetic opals (“Kyocera plastic-impregnated synthetic opals,” Summer 1995 Gem News, pp. 137–139), we reported the results of heating experiments performed by Jeffery Bergman in Bangkok, who found weight losses of about 20% at 600°C. The results of the simple pyrolysis test reported here are consistent with this finding.

In the 1995 study, scanning electron microscopy revealed that Kyocera polymer-impregnated synthetic opal contains organized aggregates of small silica spheres, as does natural opal. The polymer may stabilize the silica lattice and improve both the durability (under normal wear conditions) and clarity of the synthetic opal. However, the flammability hazard that is now introduced may be a consideration for the wearer of such a piece, as well as for the jeweler (although we would not expect a jeweler to use direct flame in the vicinity of an opal).

Irradiated inclusions in topaz. At the 17th IMA meeting in Toronto, Ontario (reported above), I. L. Komov (State Science Centre of Environmental Radiogeochimistry, Kiev, Ukraine) reported that colorless halite (NaCl), sylvite (KCl), and villiaumite (NaF) crystals in fluid inclusions became yellow, “lilac-colored,” and brown, respectively, when exposed to gamma radiation (the host mineral was not specified). Over a decade ago, in 1987, the late Charles Ashbaugh, then at UCLA and collaborating with GIA in Santa Monica, examined one such example. The core of a colorless sylvite in a fluid inclusion in a Nigerian topaz became purple after exposure to ionizing radiation from a linear accelerator (“linac” treatment; figure 20). (The sylvite identification was confirmed by Chuck Fryer of GIA GTL, using X-ray powder diffraction analysis.) The topaz itself turned blue. At the time, Mr. Ashbaugh and John Koivula speculated that the presence of such purple crystal inclusions might prove that a topaz had been irradiated, as sylvite crystals in natural-color near-colorless and brown topaz are near-colorless. Unfortunately, this project was never pursued. However, Dr. Komov’s IMA presentation supports these earlier findings. For more on irradiated gems, see C. E. Ashbaugh III, “Gemstone irradiation and radioactivity,” *Gems & Gemology*, Winter 1988, pp. 196–213.

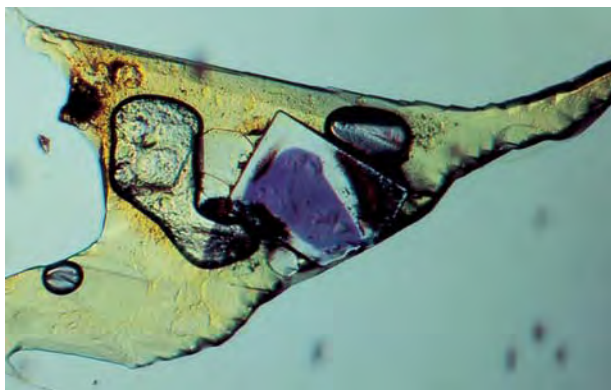


Figure 20. In this linear-accelerator-treated piece of blue topaz, a fluid inclusion contains several phases. The core of the colorless sylvite crystal turned purple from the irradiation. Photomicrograph by J. I. Koivula; magnified 80 $\times$.

SYNTHETICS AND SIMULANTS

Obsidian imitation. On a visit to Idar-Oberstein, Germany, one of the editors (JIK) found an attractive glass sphere in one of the many gem and jewelry shops that make this area famous. Represented as "obsidian from Russia," this well-polished sphere was relatively large (approximately 9 cm in diameter) and opaque. The sphere was predominantly a mottled brownish green, with a diffused stripe of lighter green to grayish green through the center. Perhaps the most distinctive feature, however, was the presence of numerous spherical inclusions with a silvery metallic luster that appeared as circles scattered over the entire surface. These inclusions ranged from well under a millimeter to just over 3 mm in diameter. If in fact this object was a natural glass, then it was certainly unusual. The sphere's cost however, made its acquisition for scientific examination impractical.

This "problem" was solved shortly thereafter with the discovery by this editor of a partially polished piece of the distinctive glass in a box of cutting scraps and crystal fragments at the shop. This piece weighed about 213 grams and measured 8.3 cm on its largest dimension (figure 21). It had one large, flat, polished surface, while the opposite side was "rough." The botryoidal appearance, flow structure, and bubble pits on the unpolished surfaces made it obvious that this was not obsidian or any other form of natural glass. It was apparent that this large mass, and the sphere that had been fashioned from the same material, were a form of slag (manufactured) glass.

The refractive index of this glass was 1.606. It showed no fluorescence to UV radiation. No absorption spectrum was visible with incident illumination. The specific gravity was determined hydrostatically to be 2.99, although it was undoubtedly influenced by the numerous metallic-appearing inclusions present.

Chemical analysis showed that this glass contained several elements in addition to the expected silicon. EDXRF chemical analysis (by Sam Muhlmeister of GIA

Research) showed the presence of barium, calcium, copper, iron, manganese, potassium, rubidium, strontium, and titanium. A few small fragments were broken off the sample so that the spherical metallic inclusions could be extracted, cleaned, and analyzed separately by EDXRF. These proved to contain primarily manganese, possibly as an oxide.

Diffusion-treated synthetic sapphire. Contributing editor Karl Schmetzer has sent word that greater quantities of diffusion-treated *synthetic* sapphires are showing up on the market in Bangkok, Thailand. Diffusion-treated natural sapphires have been known in the trade since the late 1970s (see, e.g., R. E. Kane et al., "The identification of blue diffusion-treated sapphires," *Gems & Gemology*, Summer 1990, pp. 115–133), but large quantities again became available in recent months. One diffusion-treated synthetic blue sapphire was mentioned as early as 1982 (Summer 1982 "Lab Notes," p. 107), but the treater of that sample might not have known that it was synthetic. The first notice that larger parcels of synthetic sapphires were being treated in this fashion was issued in 1992 (R. C. Kammerling et al., *ICA Laboratory Alert No. 55*, June 2, 1992). Recently, similar large parcels were offered in the Bangkok market, and the appearance of this material at other trading sites is only a matter of time.

Five faceted samples, submitted by gem dealer M. Steinbach, were made available to Dr. Schmetzer for examination. They were comparable in color to good-quality natural sapphire of Sri Lankan origin. Absorption spectroscopy showed that the color of the samples was due to $\text{Fe}^{2+}/\text{Ti}^{4+}$ charge transfer, which is also common for natural blue sapphire.

No inclusions or growth patterns that are typical of natural stones were observed in any of these samples

Figure 21. Represented as obsidian from Russia, this decorative glass proved to be manufactured. Photo by Maha DeMaggio.





Figure 22. The uneven color distribution between facets and the color concentrations along facet junctions—both typical of diffusion-treated sapphire—are best seen with the samples immersed in methylene iodide. The dark spots on four of the samples are cavities that were found to be filled with synthetic sapphire. Photo by M. Glas.

when viewed with the microscope. Two of the samples revealed a number of tiny gas bubbles, indicating that they were Verneuil-grown synthetic sapphires. However, Dr. Schmetzer did not observe any of the curved color banding that is also typical of Verneuil-grown synthetics, and would have been expected if the color were inherent in the material (instead of being due to diffusion treatment).

As described in the references cited above, the diffusion treatment of either natural or synthetic sapphires can be identified (often macroscopically) when the sample is immersed in methylene iodide (or observed using diffuse transmitted white light). This was the case for the present samples, all of which showed an uneven coloration from one facet to the next (figure 22). This pattern is caused by variation in the thickness of the diffusion layer on different facets that results from the repolishing that is always necessary after diffusion treatment. In most of the samples, a greater color concentration was also observed along facet junctions (also visible in figure 22). Four of the samples had cavities on the surface that were filled with a dark-blue-appearing solid material (figures 22 and 23). In two of these samples, some of the cavities were only partially filled. With SEM-EDX analysis, Dr. Schmetzer found that the material in each cavity was actually a tiny synthetic sapphire crystal.

ANNOUNCEMENTS

Indonesian South Sea Pearl auction. Philmore USA and PT Philmoremas have organized a group of Indonesian South Seas pearl producers, whose harvests will be sold at ISSPA 1999. This is the first such auction to be held, and will occur on February 8–9, 1999, at the Hong Kong Convention and Exhibition Centre. For further information, contact Philmore USA representative Stephen

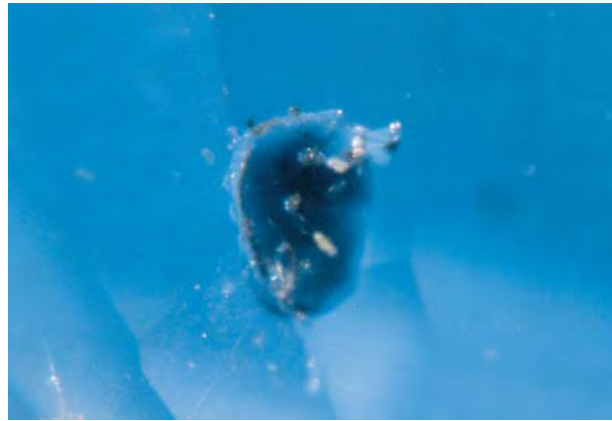


Figure 23. A dark-blue-appearing synthetic sapphire crystal is seen within a cavity on the surface of this diffusion-treated synthetic sapphire. Photomicrograph by Karl Schmetzer; magnified 50 $\times$.

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Congratulations to *Gems & Gemology* authors Kurt Nassau, James E. Shigley, and Shane McClure. Their Winter 1997 article "Synthetic moissanite: A new diamond substitute" won a Certificate of Achievement from the American Society of Association Executives 1998 Gold Circle competition. This is the 10th award that *Gems & Gemology* has won in this competition since 1992.

Note. The entry "'Wild Life' assembled natural gemstone cabochons" in the Fall 1998 Gem News section was contributed by Emmanuel Fritsch.

ERRATA:

1. The photograph of Dr. George Rossman and Richard T. Liddicoat in the Fall 1998 Gem News (p. 230, figure 23) was taken by Judy Colbert.
2. In the Fall 1998 Gem News entry "Color-change pyrope-spessartine garnet, also from Madagascar" (pp. 222–223), the positions of the UV-visible absorption bands were listed incorrectly. The correct wavelengths for the Mn²⁺ bands are 408, 413, 422, and 483 nm, and the Fe²⁺ bands are at 459 and 503 nm.
3. On p. 164 of the Hemphill et al. article "Modeling the Appearance of the Round Brilliant Cut Diamond: An Analysis of Brilliance" (Fall 1998), the source for the information given in table 3 on the European Gemological Laboratory (EGL) should have been listed as Federman, 1997.