

VOLUME XXXIX

# GEMS & GEMOLOGY

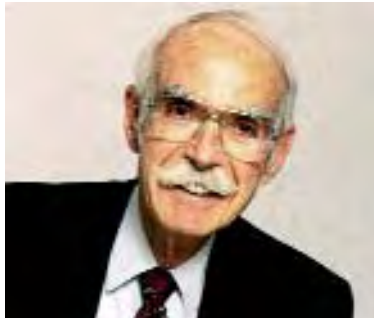
FALL 2003



Featuring:

Legendary Gemologist  
G. Robert Crowningshield  
Black Diamonds  
Diamond Cut Copyright

THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA



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G. Robert Crowningshield:

# A Giant among Gemologists

One of my first introductions to gemological greatness came in the late 1970s at an American Gem Society Conclave. I was relatively new to GIA and gemology, but eager to learn as much as I could. Phil Minsky, a longtime officer of AGS, described Richard Liddicoat, Bob Crowningshield, and Bert Krashes to me as “giants in the industry.” They were the ones I should look to for guidance, the footsteps I should follow. I never forgot his words as I worked with all three men over the years. All were, indeed, giants in the gem and jewelry industry, each in his own unique way. And it was the tall, thin, unassuming yet always polished gentleman, Bob Crowningshield, who dominated gemological research at the Institute.



The article on G. Robert Crowningshield in this issue highlights a remarkable gemological career that has spanned some 55 years. The contributions described in this article illustrate what Minsky was referring to when he used the word *giants*. Minsky knew GIA almost from its infancy, and he understood the contributions that this humble man had already made to our field.

Having just published a book on the history of GIA, authored by JCK senior editor Bill Shuster, I can attest to the singular greatness that Robert Crowningshield embodies. Bob’s role in the development of the science of gemology is legendary, but equally important is his contribution to the emergence of gemology as a respected profession. Bob was one of the many men who came to GIA and gemology right after World War II and ultimately propelled the Institute and gemological science to greater heights than ever before. He helped take gemology from a peripheral curiosity to an integral part of a jeweler’s business.

Like many of the Institute’s early gemologists—Robert M. Shipley, Robert Shipley Jr., Liddicoat, Lester Benson, and

Krashes—Bob Crowningshield was as comfortable in front of a classroom as behind a microscope (or spectroscope). But his interest in sharing what he knew went well beyond teaching GIA students or lecturing at AGS Conclaves. Bob has produced an incredible body of published work over the decades—much of it in *Gems & Gemology*—including landmark articles on his discoveries and more than 1,000 entries in our popular Lab Notes section alone.

Arguably, with his entire laboratory career in the center of the New York trade, he has seen and identified more gems of

beauty and uniqueness than anyone before him, and likely anyone after him. For Bob Crowningshield has been a practicing gemologist throughout his career, never tiring of the challenge of identifying gem materials, never losing his interest in scientific inquiry and discovery, and never ceasing to share what he has learned with other gemologists, jewelers, and students alike.

As the authors declare in their article, it is impossible to overstate the contributions that Bob Crowningshield has made to GIA and to the industry. For Bob, though, from the beginning, it was only about establishing gemology as a positive force for the professional jeweler—never about making a name for himself or becoming a legend in his own right. Perhaps this is the greatest lesson we can learn from Bob Crowningshield: Doing a job well, with integrity and virtue, is the mark of true greatness. A giant among gemologists, Bob Crowningshield has left an indelible mark on GIA and on gemology.

A handwritten signature in black ink that reads "William E. Boyajian". The signature is written in a cursive, flowing style.

William E. Boyajian, President  
Gemological Institute of America

# LETTERS

## **Gabrielle Trademark Not Abandoned**

I wish to thank you for your recent article listing existing diamond brands (T. W. Overton, Winter 2002, pp. 310–325). Such a condensed reference manual will serve many in our industry in navigating the maze of branded diamonds in existence today.

However, I must point out some mischaracterizations in this article. While it is true that Suberi Brothers Inc. has abandoned its application for U.S. trademark registration for the name *Gabrielle*, the article failed to state that it continues to use the mark in connection with its diamonds and has done so since 1997, which gives it uninterrupted rights of ownership. The term *abandoned* in trademark law is a term of art having a meaning distinct from conventional meaning, and does not mean that a mark is no longer in use or is no longer protected. It merely means that a company chose not to act on a pending application for registration with the U.S. Patent and Trademark Office. Thus, use of the word *abandoned* without further explanation can be misleading and lead to damage to those to whom the mark is attributed.

In addition, Gabrielle diamonds are available in all eight traditional shapes, not simply rounds. Suberi Brothers is also the owner of the trademarks *Empress Cut*, *Baroness Cut*, and *The Royal Cuts*.

Marvin Markman  
Suberi Brothers Inc.  
New York

**Reply:** We thank Mr. Markman for his thoughts and the additional information. He is correct that the term *abandoned* refers only to the trademark registration process and not to ownership or use of the trademark. As stated in the article, ownership of a mark depends on its use in commerce, not registration with the USPTO. It was not our intention to imply that Suberi Brothers has abandoned use of the Gabrielle mark. *Gems & Gemology* regrets any misunderstandings that may have occurred.

Thomas W. Overton  
Managing Editor, *Gems & Gemology*

## **Black Freshwater Pearls Must Be Treated Color**

Your journal does a great service for the industry in providing so much in-depth information on a variety of subjects. We are not all experts in every aspect of the field of gemology, and the knowledge I have gained from your publication has helped me expand my horizons in many ways.

However, I noticed something in the Spring 2003 *Gem News International* item “Cultured pearls with diamond insets” (p. 56) that should be brought to your attention. Nowhere in the figure caption does it mention that these pearls have been dyed or treated in another fashion to make them black, or that black is not their natural color. To the best of my knowledge, there are no natural-color black freshwater cultured pearls. In the text, the freshwater pearl is discussed alongside Tahitian pearls, and this may mislead readers into thinking that “black freshwater pearls” are in the same category as Tahitians and natural in color.

Also, black pearls are being produced in areas other than Tahiti, such as the Cook Islands, so it is important not to refer to the pearls by an assumed locality. Rather than use the term *Tahitian*, it is preferable to refer to them as black South Sea cultured pearls.

Avi Raz  
A@Z Pearls  
Los Angeles

**Reply:** Mr. Raz is correct that the earrings pictured are not natural color. Although *Gems & Gemology* typically does not indicate every instance where a material illustrated is treated unless it is germane to the accompanying text, we can understand his concern in this instance and thank him for giving us the opportunity to remind our readers that, to the best of our knowledge as well, freshwater cultured pearls do not occur naturally in black.

Alice S. Keller  
Editor-in-Chief, *Gems & Gemology*

# G. ROBERT CROWNINGSHIELD: A LEGENDARY GEMOLOGIST

Thomas M. Moses and James E. Shigley

During his more than 50 years of involvement with the GIA Gem Laboratory, G. Robert (Bob) Crowningshield has made many significant contributions to the study of gems and the science of gemology. These include fundamental advances in the understanding and identification of treated and synthetic diamonds; of colored stones such as tanzanite, amethyst, “padparadscha” sapphire, and heat-treated corundum; and of natural and cultured pearls. In the early 1950s, Crowningshield demonstrated the value of new equipment in gem testing, in particular the spectroscope. He also helped develop and teach the GIA diamond grading system, now the standard worldwide. Along the way, he shared his wealth of practical experience in hundreds of articles, lectures, and industry presentations. All of these achievements helped lay the foundation of modern gemological research.

Much of gemology as we know it today can be traced to the work of just a few individuals, mainly in Europe and the United States, who pioneered the modern study of gem materials in the 1930s, '40s, and '50s. This group includes G. F. Herbert Smith, Robert Shipley, Robert Shipley Jr., Basil Anderson, Dr. Edward Gübelin, Prof. Karl Schlossmacher, Richard Liddicoat, Robert Webster, Lester Benson, Prof. Hermann Bank, and Alan Jobbins. Their work involved not only the examination and classification of natural gems, but also the expanding study of treated, synthetic, and imitation gem materials, and the development of new methods and equipment for gem identification and quality grading. Prominent in this small group is G. Robert Crowningshield (figure 1), who joined GIA in 1947 and subsequently became one of the original staff members of the GIA Gem Trade Laboratory, which was formally established in 1949.

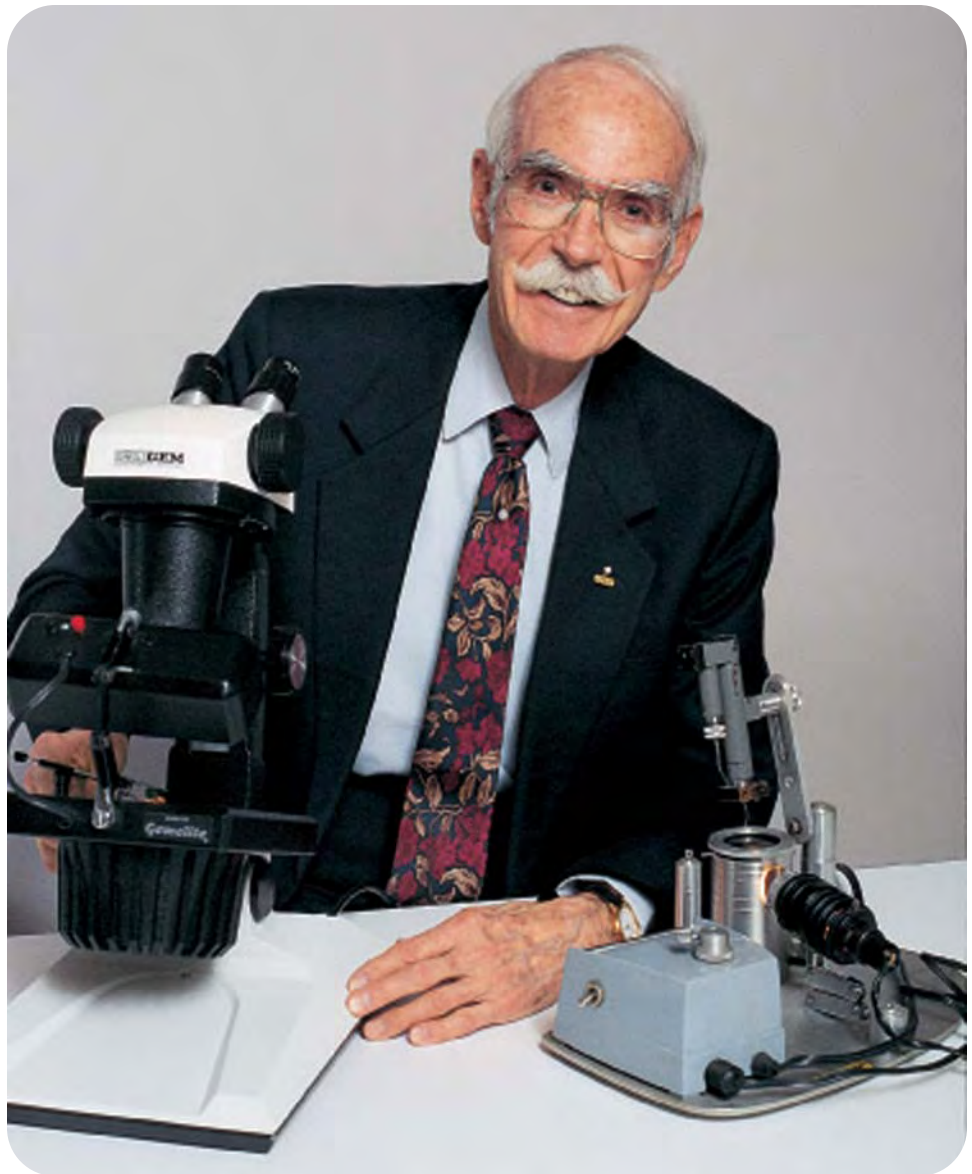
October 29, 2002, marked Crowningshield's 55th anniversary with the Institute. In the course of his laboratory career, he arguably tested more colored stones and pearls and analyzed more diamonds than anyone else during that period.

Throughout his tenure in the laboratory, he has brought keen observational and analytical skills, as well as a phenomenal memory, to the identification of a broad variety of gem materials. He has shared the results of his work with thousands of GIA students and members of the trade through his presentations and published articles. Since 1958, he has co-authored (and served as contributing editor for) the popular “Lab Notes” section of *Gems & Gemology*, where in more than 1,000 entries he reported on interesting items encountered in the GIA laboratory. As a tribute by colleagues who have been fortunate to work alongside him, the present article highlights some of Crowningshield's many contributions to gemology, and provides a bibliography of his published articles, to which readers are directed for information on the many discoveries and developments discussed below.

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See end of article for About the Authors and Acknowledgments.  
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*Figure 1. For more than 50 years, G. Robert Crowningshield has devoted his life to the study of gems and sharing this information with members of the jewelry industry. During this time, he has made important contributions to gem identification and grading, instrument development, and gemological education. Photo by Howard Wechsler, © GIA.*



## BACKGROUND

George Robert (Bob) Crowningshield was born on June 16, 1919, in Colorado Springs, Colorado. In 1927, his parents moved Bob and his three siblings to San Diego, California, where an early interest in gemstones was further sparked by visits to the famous gem pegmatites in San Diego County. He attended high school in Spring Valley, California, and in 1942 received a Bachelor of Arts degree in natural science from San Diego State College (now San Diego State University). There, he also developed an interest in drawing as a “way to train myself to pay close attention to things.” He would later put this skill to great use in his gemological career.

During World War II, from 1942 to 1945, Crowningshield served with the U.S. Navy. As a way to

pass long hours at sea, he read books on gemstones. He began purchasing gems during port visits to Australia, India, and Ceylon (now Sri Lanka), and even designed gold settings for the gems that he and others had bought. Toward the end of the war, a chance encounter during one of these port visits led him to the Gemological Institute of America.

Crowningshield’s budding interest had made him the ship’s unofficial authority on gems, an adviser to shipmates who went shopping for stones when in port. One of these was the ship’s captain, who needed a gift to take home to his wife (figure 2). Crowningshield, the ship’s navigator, suggested an unscheduled stop in Ceylon to purchase some star sapphires. When the ship pulled into the port of Colombo—“the captain told [the Navy] we were



*Figure 2. Crowningshield first learned about GIA's gemology program while serving in the U.S. Navy during World War II. Here, the young navigator (left) is shown with the captain (center) whose desire to purchase star sapphires for his wife took the ship to Colombo and led to Crowningshield's chance meeting with GIA student Sardha Ratnavira.*

low on provisions," Crowningshield recalled—the two of them went shopping along the docks. At one of the stores, they encountered a young man named Sardha Ratnavira, who had attended GIA before the war. Impressed with Crowningshield's interest in

*Figure 3. In this 1949 photo, Bob Crowningshield (right) and Richard Liddicoat (center) join another colleague in testing gemstones at the original GIA facility in New York.*



gems, Ratnavira recommended that he look into studying at the Institute. Ratnavira's suggestion "planted the seed in my mind that I should go there," said Crowningshield years later. "Gradually, it dawned on me that there was a career in the knowledge of gemstones" (Shuster, 2003).

Following his discharge from the Navy as a lieutenant, and with financial aid from the GI Bill, Crowningshield enrolled in the GIA education program and soon earned his diploma. While still a student, his gemological talents came to the attention of Robert Shipley and Richard Liddicoat, and Shipley personally recruited him as an instructor. As Liddicoat later recalled, "Bob already stood out as one of the top students in his class—a natural at gemology." Crowningshield joined the GIA staff on August 29, 1947, and later that year completed the course requirements for his Diploma in Gemmology (FGA—Fellow of the Gemmological Association), with distinction, from the Gemmological Association of Great Britain.

In August of 1948, Shipley sent Crowningshield with Dr. Mark Bandy to organize a GIA office in New York City and conduct Institute training there. When Dr. Bandy unexpectedly resigned at the end of the year to run the Paris office of the U.S. Atomic Energy Commission, Shipley sent Liddicoat to lead GIA's new East Coast operation, with Crowningshield remaining as his assistant. At the time, they performed only limited gem identification activities—primarily colored stone identification and pearl testing—and the GIA laboratory was barely noticed by the jewelry industry.

That began to change in 1949, when GIA purchased Gem Trade Laboratories Inc., a facility established in 1940 by New York gem and pearl dealers. When the head and founder, Dr. A. E. Alexander, left to become a buyer for Tiffany & Co., sponsors of this predominantly pearl-testing laboratory approached GIA to take it over. On October 13, 1949, GIA formally acquired Gem Trade Laboratories Inc., and the merged facility was renamed the Gem Trade Laboratory of the Gemological Institute of America. At the time, the facility was no more than one large room with a small staff (figure 3). When Liddicoat returned to Los Angeles the following year, Crowningshield became director of the GIA Gem Trade Laboratory in New York, a position he would hold until 1977, when he was named its vice president.

More than 50 years of working in the laboratory gave Crowningshield an unparalleled opportunity to

examine tens of thousands of gemstones of all kinds. In fact, only a little more than 10 years after the East Coast laboratory was formed, its staff members were examining over 100,000 diamonds, colored stones, and pearls annually (see “The new Eastern headquarters. . .,” 1960). Passionate about the mysteries that surrounded natural, treated, and synthetic gem materials, Crowningshield embraced gemological research as an important component of laboratory work, and in the process made a number of important contributions to gemology.

### MASTER OF THE SPECTROSCOPE

Although Crowningshield was as astute in the use of the gemological microscope as any of the world’s most renowned gemologists (figure 4), perhaps the most significant advance associated with him is the use of the spectroscope in gem identification (again, see figure 1). Although not the first to see its potential in gemology, he was arguably the most successful in applying it to this new science, sharing the information it provided with the gemological community.

One day in 1950, Crowningshield and his colleague Bert Krashes were trying, unsuccessfully, to master a recently acquired Beck diffraction-grating spectroscope when Hans Myhre—a Norwegian gemologist and wholesale jeweler—stopped by. Recognizing their dilemma, Myhre placed a garnet in front of the instrument and calmly showed them how to view the spectrum. Crowningshield was fascinated, and within a short time he became one of the masters of the spectroscope for gem identification. Just as important, he made it his mission to *record* the spectrum of every gem variety that came through the lab—using a stencil, charcoal dust, cotton swabs, erasers, a cotton rag, and pencils to mimic the subtle spectral features he saw in the instrument. Through months of painstaking work, often on weekends when the building housing the laboratory was unheated, he created a collection of realistic, hand-drawn spectra of a wide variety of gemstones. He recorded them in a notebook along with other properties of the gem, so he could make correlations. This ability to make correlations and, as a result, new discoveries, was one of Crowningshield’s greatest assets as a gemologist.

His collection of drawings, one of the earliest databases of the visible spectra of gem materials, was first published as 114 black-and-white plates in the sixth edition (1962) of Richard T. Liddicoat’s *Handbook of Gem Identification* (see, e.g., figure 5). Crowningshield documented nearly every transpar-



Figure 4. During his several decades in the laboratory, Bob Crowningshield used the microscope for many of his discoveries. This photograph, taken in the 1950s, shows him using an early-version Diamondscope, a binocular gemological microscope with lightfield and darkfield illumination that had been developed by GIA in the 1930s and '40s.

ent colored stone he had studied in the laboratory. These illustrations in Liddicoat’s widely used textbook, combined with an earlier description that Crowningshield wrote in a 1957 *Gems & Gemology* article (in which he also included examples of his spectra), made the spectroscope a more practical gem identification tool for trained gemologists. In less than 10 years, largely as a result of his efforts, the spectroscope went from a rarely used specialist’s instrument to one of the practicing gemologist’s most important gem identification tools. And it would prove essential to the development that cemented both Crowningshield’s reputation and that of the Gem Trade Laboratory.

### A WIZARD IN GEM IDENTIFICATION

#### The Clue to Color Origin in Yellow Diamonds.

Beginning in the early 1950s, commercial amounts of irradiated colored diamonds began to appear in the



U.S. market. It became critically important to develop new methods to detect these treated diamonds, which had been irradiated by nuclear bombardment from radioactive materials (mainly radium bromide) or by exposure to radiation in a cyclotron or a nuclear reactor (figure 6). Gemologists had already learned that the so-called radium-treated diamonds could be detected by their autoexposure of photographic film due to residual radioactivity ("Radium-treated diamonds," 1938), whereas most cyclotron-treated diamonds exhibited facet-related color zoning that was visible with magnification (Pough and Schulke, 1951). However, diamonds irradiated in a reactor (and then possibly heat treated to produce additional changes in color) did not leave any signature on photographic film, and displayed even coloration when examined with a loupe or microscope: This treatment appeared to be undetectable. Concerned jewelers and diamond dealers pressured GIA to find a means of identification, but the laboratory staff had little success until a watershed event in January 1956.

That month, the laboratory was asked to determine the origin of color of a 19 ct yellow diamond. "It was the biggest one we had ever seen," Crowningshield said later, "and it offered the best opportunity to see if there was something about this diamond's color that was due to treatment" (Shuster, 2003).

Figure 5. Shown here are two of the spectra Crowningshield provided for the sixth edition of Liddicoat's Handbook of Gem Identification, published in 1962. The top spectrum is of an irradiated and annealed yellow diamond (with a 5920 Å [592 nm] line); the bottom one is of an untreated yellow diamond (with a Cape spectrum, lines at 4150, 4530, and 4780 Å).

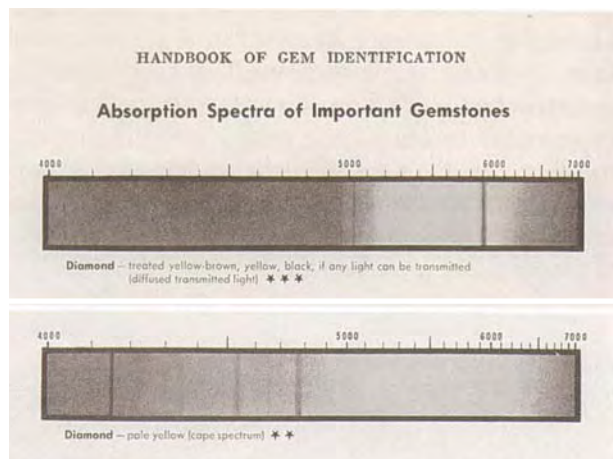


Figure 6. The detection of treatment in irradiated yellow diamonds such as these was a major challenge in the early 1950s.

Crowningshield had already used the spectroscope to examine a number of yellow diamonds that were known to be reactor irradiated and annealed, and he had observed no differences in their absorption. He even brought in an old projector and used its strong light beam to read the spectra more easily, but still saw no differences. He continued to believe, though, that if such a treatment could alter the color in the diamond, it might also alter its absorption spectrum. Because of the greater absorption of visible light in a larger stone, there was a greater chance that any possible discrepancy in the spectrum would be evident. When he examined the 19 ct diamond with the spectroscope, Crowningshield was both surprised and excited to see a faint line just below 600 nm (again, see figure 5). He had never seen this feature in a yellow diamond; nor had it been reported to occur in the absorption spectrum of any diamond, regardless of color.

He wanted to show the feature to Bert Krashes, but Krashes had just gone to lunch. By the time he returned only a short while later, the line was gone. Crowningshield stood there, puzzled, until the answer suddenly came to him: The diamond had been heated by the light from the viewing projector, and the heat had caused the line to disappear. He knew he had to cool the stone, but there were few options in the early 1950s. "Suddenly, I had an idea," Crowningshield recounted to journalist Bill Shuster years later (Shuster, 2003). "I ran downstairs to a local candy shop on the corner which sold ice cream and bought a piece of dry ice." He quickly climbed the five flights of stairs to the laboratory, put the diamond on the ice to cool, and then looked at it in the spectroscope: The line again was visible. And Crowningshield had his solution. Years later, he often mentioned that he drew strange looks from people on the street when they saw "smoke" emanating from the dry ice in his briefcase.

The principle of cooling diamonds to extremely low temperatures to get the best resolution of their

spectra is still used by gemologists today, albeit with more sophisticated techniques.

Crowningshield knew, however, that nothing could be proved by a single observation in a single stone, so he returned the diamond to the client with a statement to the effect that the origin of the color was “undetermined”—and immediately embarked on a landmark study of the absorption spectra in natural and irradiated yellow diamonds. “Before we announced anything,” he said later, “we had to be sure that what we had was foolproof” (Shuster, 2003).

Over a period of about 10 months, Crowningshield and his colleagues set out to obtain as many known natural- and treated-color yellow diamonds as possible. It was the most intensive test of a theory ever attempted in gemology to this point, and it helped to institute the rigorous analysis common in contemporary gemological research (Shuster, 2003). To this end, New York diamond dealer Theodore Moed loaned his entire stock of known treated and untreated diamonds for examination. Additional diamonds that were unequivocally natural color were found in the collections of the American Museum of Natural History and Tiffany & Co., among others. Also tested were hundreds of pieces of non-gem yellow rough that was so inappropriate for the jewelry industry that treatment was extremely unlikely.

Ultimately, Crowningshield and his colleagues examined the spectra of more than 10,000 yellow diamonds. His studies, which were published in the Winter 1957–1958 issue of *Gems & Gemology*, confirmed that the absorption line at 5920 Å (592 nm, later redesignated to occur at 595 nm when the spectra were recorded with a spectrophotometer) was indeed a diagnostic feature of laboratory-irradiated and annealed yellow diamonds. The trade was ecstatic, and soon it became essential for any yellow diamond of significance to have a laboratory report. More importantly, perhaps, wrote *Modern Jeweler's* David Federman almost 40 years later (1995, p. 26), this discovery “elevate[d] gemology from an academic pursuit to a key means of strategic defense in the jewelry industry. Seen in this way, 592 didn't just mark a point on the spectrum. It marked a turning point in the history of gemology.”

**Early Work in Colored Stones and Pearls.** Crowningshield also pioneered other methods of gem examination and identification. Using a procedure initially developed by fellow staff member Lester Benson (1948), he refined a method for measuring the R.I. of cabochon-cut gems that he described in a 1949 *G&G*



Figure 7. Crowningshield provided one of the earliest reports on the “sweating” of wax-treated turquoise when exposed to a hot point in a 1959 “Highlights at the Gem Trade Lab in New York,” a precursor to today’s Lab Notes section. Photomicrograph by Shane F. McClure; magnified 23×.

article. In 1951, decades before it became more popularized by Alan Hodgkinson (1995), Crowningshield pioneered the development of simple visual techniques to determine important optical properties by holding the gem close to the eye and looking through the table facet. As we can attest, it is amazing to actually resolve an optic figure of a gemstone using your eye as the condensing lens.

Between 1958 and 1960, Crowningshield investigated a wide variety of treated and synthetic gem materials. His discoveries and observations (e.g., as published in the “Lab Notes” listed in table 1 and his bibliography) included: the “sweating” reaction of wax-treated turquoise to a hot point (figure 7), the recognition of sugar-acid treatment of porous opal, spectroscopic studies of diamonds and their origin of color, the identification of synthetic rutile (a diamond simulant), and a study of flux-grown synthetic emerald.

The laboratory that GIA acquired in the fall of 1949 had been set up in 1940 primarily for testing pearls, and Bob Crowningshield continued its tradition of pearl research throughout his long career. As early as 1951, he participated in the development and installation of a new X-ray system, which was optimized for taking radiographs of the internal structure of natural and cultured pearls (figure 8; see Benson, 1951–1952). In 1961, Crowningshield reported on natural-color black pearls, to confirm by visual and spectroscopic methods that they had not been treated (also see Benson, 1960). A little over a decade later, in the mid-1970s, cultured black pearls were beginning to be produced in Tahiti (figure 9), but there was widespread doubt in the trade that their color was natural. Pearl dealer Salvador Assael supplied Crowningshield with hundreds of the new cultured

**TABLE 1.** Selected entries from the "Lab Notes" column by G. R. Crowningshield.<sup>1</sup>

Entry	Comments	Vol.	No.	Issue <sup>2</sup>	Page(s)
Treated turquoise	Dyed, oiled, surface treatments too often seen in the trade	9	8	W 1958–1959	229
Treated yellow, red, green diamonds	Increasing numbers submitted for identification	9	9	Sp 1959	268
Imitations for jade	Increasing variety of examples seen in the trade	9	9	Sp 1959	269
Natural-color blue diamonds	Electrical conductivity tester designed and built	9	10	Su 1959	291
Cream-rosé baroque pearls	Freshwater cultured pearls from Lake Biwa, Japan	9	10	Su 1959	292
Coated diamond	Coating substance detected on pavilion surface only	9	10	Su 1959	292–293
Brownish yellow diamond	Green in daylight, reverts to brownish yellow in dark	9	10	Su 1959	293
Treated yellow sapphires	Unstable yellow color in sunlight; stability testing needed	9	10	Su 1959	294
Black treated opal	Surface color due to carbon treatment lost during repolishing	9	11	F 1959	343
Pink diamond	Turns brown to X-rays; reverts to pink with gentle heating	9	12	W 1959–1960	360
Cultured pearls with pink dye	Pink dye stains visible in drill hole and on silk thread	9	12	W 1959–1960	361
Treated blue diamonds	Originally light brown and off-color based on spectra	9	12	W 1959–1960	361, 377
Hope diamond	Testing at Smithsonian with new conductivity tester	10	1	Sp 1960	10
Synthetic emerald	First time seen with visible platinum inclusions	10	2	Su 1960	61
Radium-treated green diamond	Blotchy green surface color, slightly radioactive	10	3	F 1960	69–70
Dyed cultured rosé pearls	Evidence of dye to produce overtone effect	10	4	W 1960–1961	114
Intense natural-color yellow diamond	Cape spectrum with yellow fluorescence	10	6	Su 1961	184–185
Cultured blister (mabe) pearls	Description of characteristics	10	7	F 1961	216–219
Pearl alteration experiments	Testing of damage by vinegar and spray cologne	10	7	F 1961	222–223
Radium-treated diamonds	Green color; autoradiograph produced on X-ray film	10	8	W 1961–1962	242
Diamond doublets in jewelry	Diamonds mounted with synthetic sapphire or spinel backs	10	10	Su 1962	305–306
Turquoise imitations	Reconstituted by compression of components	10	11	F 1962	336
Gray type IIb diamond	Electrically conductive, blue UV phosphorescence	10	11	F 1962	341
Cyclotron-irradiated diamond	Unusual pale green with a facet-related color zone	11	1	Sp 1963	26
Lavender-dyed jadeite	With pink UV fluorescence and a dye spectrum	11	3	F 1963	82
Surface-treated amber	Painted surface areas lacked expected UV fluorescence	11	3	F 1963	87
Rare cat's-eyes	Pink scapolite and green chrome diopside	11	4	W 1963–1964	104
Treated jadeite bead necklace	Dyed and plastic coated with incorrect measured R.I. value	11	6	Su 1964	182
Emeralds from Brazil	Not colored by chromium; name based on color appearance	11	8	W 1964–1965	244
Famous diamond	43.38 ct Nassak diamond submitted for examination	11	8	W 1964–1965	245
Pink conch pearl	Description of appearance	11	9	Sp 1965	270
Color-change sapphire	Similar to alexandrite in terms of color appearance change	11	10	Su 1965	310
Surface-treated diamonds	With painted surfaces	11	10	Su 1965	310–311
Button-shaped abalone pearls	With red and green colors	11	11	F 1965	333
Natural-color dark green diamond	Green bodycolor with brown radiation stains	11	12	W 1965–1966	362
Colored diamond ring	With blue, red and green natural-color diamonds	11	12	W 1965–1966	362
Famous ruby	138.7 ct Rosser Reves ruby loaned for examination	11	12	W 1965–1966	366
Freshwater cultured pearls	Round, well selected, from Lake Biwa, Japan	12	1	Sp 1966	20
Hydrothermal synthetic rubies	Description of inclusions and other properties	12	3	F 1966	68–70
Cyclotron-irradiated green diamond	Umbrella effect color zoning as evidence of treatment	12	3	F 1966	72
Blue zoisite crystals (tanzanite)	First gemological description	12	7	F 1967	201–204
Tanzanian garnets	Variety of orange-brown almandine-pyrope garnets	13	1	Sp 1969	15–16
Treated turquoise	Plastic impregnated and dyed to improve appearance	13	4	W 1969–1970	118
Laser drilling of diamonds	First description of tapering channel to bleach dark inclusion	13	7	F 1970	224–226
Treated pink diamonds	Description of distinctive properties	13	12	W 1971–1972	380
Maxixe blue beryl	Report on the material and its absorption spectrum	14	4	W 1972–1973	111–112
Gilson synthetic opal	Description of material	14	6	Su 1973	175–177
Yellow conch pearl	Examination of a rare-color conch pearl	14	8	W 1973–1974	235
Taaffeite	Large grayish violet cut stone	14	10	Su 1974	298–299
Cubic zirconia	Characterization of a new diamond imitation	15	5	Sp 1976	154–155
Cultured black pearls	Description of natural-color cultured black pearls from Tahiti	15	12	W 1977–1978	365
Diffusion-treated blue sapphires	Report on surface-related color treatment	18	3	F 1982	173
Dyed black cultured pearls	Description of distinctive properties	26	4	W 1990	286–297
Diffusion-treated blue star sapphire	Description of color and asterism produced by diffusion	27	1	Sp 1991	44–45
Fancy-color diamonds	Note on characteristic inclusions	30	1	Sp 1994	41–42

<sup>1</sup>This column began as an article titled "New and unusual gem materials encountered in the Institute's Gem Trade Laboratories" in the Summer 1957 issue of *Gems & Gemology* (Vol. 9, No. 2). It then appeared under the title "Highlights at the Gem Trade Lab in New York" beginning in the Winter 1958–1959 issue (Vol. 9, No. 8). The name was changed to "Developments and Highlights at the Gem Trade Lab in New York" (and/or Los Angeles) in the Summer 1960 issue (Vol. 10, No. 2). It was changed again to "Developments and Highlights in GIA's Lab in New York" (and/or Los Angeles) in the Fall 1969 issue (Vol. 13, No. 3). With the Spring 1981 issue (Vol. 17, No. 1), it became "Gem Trade Lab Notes," and has been "Lab Notes" since the Spring 2003 issue.

<sup>2</sup>Issue abbreviations: Sp=Spring, Su=Summer, F=Fall, W=Winter

black pearls for examination, and provided him with information on the culturing techniques. Following intensive study and consultation with GIA officials, the Gem Trade Laboratory decided to issue identification reports stating that the gems were natural-color cultured pearls. Assael recently said (pers. comm., 2003), "Thanks to this report . . . the top jewelers of the world accepted this pearl as being a natural color. I owe Bob Crowningshield a great deal."

Crowningshield began investigating tissue-nucleated freshwater cultured pearls in 1962, and showed that they, too, could be identified through X-radiography (also see Benson, 1951–1952). He examined both green and lavender dyed jadeite the following year, and proved that the presence of dye concentrations in surface-reaching fractures was a definitive criterion for recognizing many stones treated in this manner (figure 10).

In the late 1960s, a sensational new gem variety of zoisite came onto the jewelry market. Tiffany & Co. named it *tanzanite* after its country of origin (figure 11). Crowningshield and Richard Liddicoat published one of the first descriptive reports on this new gem material in a 1968 issue of *Lapidary Journal*. In 1970, Crowningshield wrote one of the first descriptions of a color-change garnet from East Africa.

At about that time, he began developing a rela-

*Figure 8. From its beginning, pearl testing has been a major function of the GIA laboratory. Crowningshield is shown here with the lab's "new" X-ray equipment (installed in late 1951), arranging a group of pearls on the photographic film cassette before exposing them to the X-ray beam to produce the radiograph that will determine if they are natural or cultured.*



*Figure 9. Largely because of Crowningshield's groundbreaking work on natural- and treated-color black pearls, jewelers were able to trade confidently in the natural-color Tahitian black cultured pearls that first entered the market in the mid-1970s. This strand of black cultured pearls (12–16 mm) is courtesy of Buccellati. Photo by Robert Weldon, © GIA.*

tionship with Dr. Kurt Nassau, a well-known scientist at Bell Laboratories in Murray Hill, New Jersey, who had an interest in gem materials. Late in 1972, the laboratory staff was shown some dark blue beryl that Crowningshield and Nassau were able to confirm as having the same properties as the so-called Maxixe beryl, a material first found in 1917 in Brazil that faded on exposure to sunlight (also see Nassau and Wood, 1973). Nassau later recalled that Crowningshield drew the spectrum of this material so precisely that the many fine lines

*Figure 10. As Crowningshield reported more than 40 years ago, color concentrations in the surface-reaching cracks of jadeite jade are proof that the piece has been dyed. Photomicrograph by John I. Koivula; magnified 5×.*





Figure 11. In 1968, Bob Crowningshield and Richard Liddicoat published one of the earliest descriptions of tanzanite, the new purplish blue zoisite. Photo © Harold and Erica Van Pelt.

and his assessment of their location corresponded very closely with the results obtained from the same samples on the sophisticated recording spectrophotometer at Bell Labs.

**Laser Drilling of Diamonds and the First Jewelry-Quality Synthetic Diamonds.** Crowningshield also remained on the cutting edge of diamond research.

Figure 12. Crowningshield reported on the laser drilling of diamonds as early as 1970. The laser drill holes serve as a conduit from a diamond's surface to dark mineral inclusions, which are then lightened or removed by acid treatment. Photomicrograph by John I. Koivula; magnified 10 $\times$ .

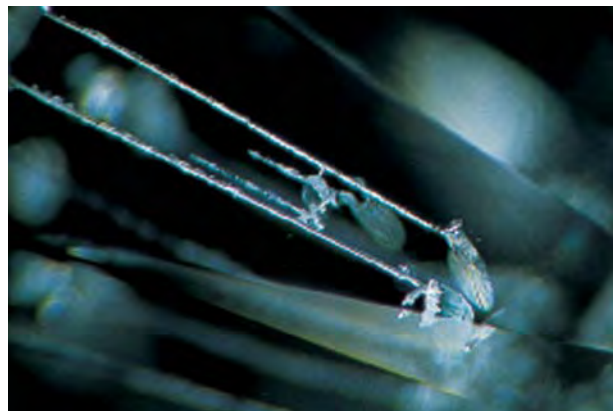


Figure 13. The synthetic diamonds shown here (0.29–0.78 ct) are among those GE produced experimentally in the 1970s. Photo by Robert Weldon, © GIA.

In the 1960s, a secretive process was developed by which a laser was used to burn a tiny hole into a diamond down to a dark inclusion (figure 12). Acids were then introduced through this open channel to dissolve or bleach the inclusion. The first reports on this new “laser drilling” process were presented by Crowningshield as Lab Notes in the Fall 1970 and Winter 1971–1972 issues of *Gems & Gemology*. In fact, while attending a gemological conference in Europe, Bob was asked to divert his return trip to London and share his observations on the new laser treatment with De Beers.

Meanwhile, in 1970 General Electric announced their production of the first synthetic diamond crystals suitable for faceting (see, e.g., figure 13). GE scientists, who had worked with Crowningshield and Richard Liddicoat in the mid-1950s following the company's announcement of the first industrial synthetic diamonds, flew Crowningshield to their headquarters in Schenectady to examine the new gem synthetics they had grown. They loaned several samples to GIA for study, and Crowningshield's 1971 article in *Gems & Gemology* provided the first gemological description of this new material (figure 14). Many of the identification criteria for synthetic diamonds discussed in that article, such as color zoning, metallic inclusions, and uneven patterns of UV fluorescence, are still in use today to distinguish synthetic diamonds produced by a variety of manufacturers.

**Later Research on Colored Stones.** Crowningshield's important work in colored stones continued well into the next decade. In the early 1980s, corundum treated by heating and diffusion techniques became more prevalent in the marketplace, thus necessitating a means of detection. In response, Crowningshield wrote two articles with Kurt Nassau on the detection of heat and diffusion treat-

ment in natural and synthetic sapphires.

Of continuing importance, however, was the characterization of natural stones. In a comprehensive Spring 1983 *Gems & Gemology* article, he described the color appearance of—and proper nomenclature for—orange pink to pinkish orange “padparadscha” sapphires (figure 15). This article is still considered by many to be the best explanation of the color of this rare natural corundum.

Crowningshield also spearheaded a 1986 article, with Dr. Cornelius Hurlbut and C. W. (Chuck) Fryer, that discussed the separation of natural from synthetic amethyst on the basis of the presence of Brazil-law twinning in the former (figure 16). While this criterion has been subverted by the availability of twinned synthetic amethyst, at the time it offered a practical means for gemologists to identify this important colored stone. Crowningshield was very concerned about the impact on the trade of natural and synthetic stones being mixed together in a single parcel without a clear-cut method to separate them.

Figure 14. In a Summer 1971 *Gems & Gemology* article, Crowningshield provided the first gemological description of the new GE jewelry-quality synthetic diamonds.



Figure 15. Crowningshield was passionate about the rare “padparadscha” sapphire, such as this 3.13 ct stone from Montana, and his 1983 article is a classic on the origin of this trade name and the definition of the color. Courtesy of M. Bielenberg; photo © GIA and Tino Hammid.

On occasion, Crowningshield was called on to examine gem materials of particular historic interest. In 1989, he described the quality grading of the 45.52 ct Hope diamond by members of the GIA laboratory staff, who were given a special opportunity to examine this famous gemstone at the Smithsonian Institution in Washington, DC. In the early 1990s, gem dealer Benjamin Zucker proposed to William Voelkle, the head of the Morgan Library in New York, that someone conduct a gemological examination of its early medieval Weingarten and Lindau Gospels, which were “illuminated” (hand-illustrated) manuscripts with gem-encrusted covers (figure 17). Although the manuscripts themselves had been stud-

Figure 16. This image from a 1986 report by Crowningshield, Hurlbut, and Fryer clearly shows the difference between the twinned natural (oval) and untwinned synthetic (emerald cut) amethyst then available in the trade. Photo by David Hargett.

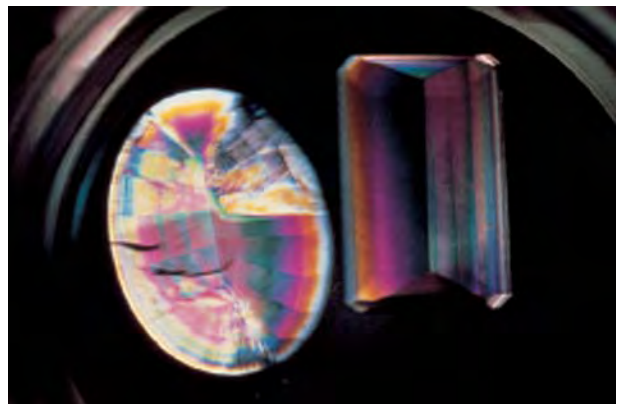




Figure 17. Crowningshield was one of three gemologists asked to identify the gemstones on the covers of the medieval Weingarten (left) and Lindau Gospels. Courtesy of the Pierpont Morgan Library/Art Resource NY.

ied extensively, the gems on the covers had never been identified or authenticated. Voelke immediately invited GIA to conduct the examination. Over the course of five or six visits to the Morgan Library, Crowningshield, Zucker, and one of the present authors (TM) examined the book covers. The challenge was handling the rather large manuscripts and the hand-wrought gold covers, into which the stones had been set with finely made bezels. They had to take the instruments to the stones rather than vice versa. To get a refractive index, for example, they placed the refractometer upside down on the stone and used mirrors to take the readings (employing some of the methods that Crowningshield had outlined in his 1949 article). Ultimately, they were able to conclude that all of the stones—primarily rubies and sapphires, with some amethysts, citrines, chalcodonyes, and garnets—were natural. As Zucker recalled in a 2003 interview:

Here was the best of all worlds: a great religious gospel, the stones embedded in this medieval book cover, the finest example of 12th century goldsmithing, and Bob Crowningshield looking at this stone and saying: "Tom [Moses], look at this. Isn't this interesting? Look at that inclusion.

This came from Ceylon." And here are these gemstones that had come in the 12th century from Ceylon by boat or across the land route through Alexandria to Western Europe and then were set in this medieval book cover. . . . I would say millennia came together in this very room.

**Notes from the Laboratory.** Many of Crowningshield's most notable contributions arrived in the form of short reports published in what is now the Lab Notes section of *Gems & Gemology*. One of the journal's most enduring and popular features, where unusual and interesting gem materials are briefly described, was inaugurated by Crowningshield with a 1957 *G&G* article titled "New or Unusual Gem Materials Encountered in the Institute's Gem Trade Laboratories."

"One of the many joys of being associated with the Laboratories of the Gemological Institute of America," he said in his 1957 introduction, "is identifying unexpected gem materials that may heretofore not have been widely reported, if at all." Over the next four decades, he wrote more than 1,000 entries on gem materials of all kinds (again, see table 1). These entries typically included why a

particular gem material was of interest at the time, its distinctive gemological properties, and what steps were required for its identification. In reviewing these Lab Notes, one is amazed at the variety of gem identification dilemmas Crowningshield and his colleagues—such as Richard Liddicoat, Lester Benson, and Chuck Fryer—faced. It is also surprising to realize that Crowningshield was one of the first to successfully address many of these challenges—often before they became more serious problems in the trade—and that his gem-testing work frequently preceded that of others.

In addition to his many contributions to *Gems & Gemology*, Crowningshield also wrote regular columns in *The Loupe* from the late 1940s through 1958, titled variously “Overheard in Manhattan,” “Overheard in the G.I.A. Lab,” and “Through the Lens at the Gem Trade Lab in New York.”

## CO-DEVELOPER OF THE DIAMOND GRADING SYSTEM

During the early 1950s, Crowningshield was deeply involved with Richard Liddicoat, Bert Krashes, and others at GIA in the development of a quality-grading system for polished diamonds. Prior to that time, there were many systems and terminologies being used within the trade to describe the qualities of diamonds, most of which were inconsistent and unscientific. Beginning in the 1930s, experts at GIA worked to develop effective grading procedures, equipment such as the *DiamondLite* (this was initially called the *Diamolite*), the *Diamondscope*, the *Gemolite* (see, e.g., “New diamond grading equipment,” 1937; Shipley and Liddicoat, 1941; Wiss, 1946; Collison, 1947), an electronic colorimeter for measuring diamond color (Shipley, 1958), reference standards (diamond “master stones”), and a formal system of nomenclature to describe the color and clarity of diamonds that were colorless to light yellow.

Not only did Crowningshield help develop what would come to be known as the GIA Diamond Grading System, but in the spring of 1953, and through one-week traveling classes beginning in 1955, he helped teach the first GIA education courses (“Diamond Grading and Evaluation”) on this system (figure 18). As journalist and GIA historian Bill Shuster reflected half a century later (pers. comm., 2003):

Just with the traveling classrooms alone, Crowningshield, Krashes, and the other GIA pio-

neers helped establish the diamond grading system with jewelers across America by taking it directly to them. This is what really helped stabilize and make the system important. Because they [the jewelers] could see right there, sitting in some little town near Atlanta, Georgia, or some hamlet up in Canada near Toronto, what the gem experts were talking about.

Although the system was initially intended simply as an evaluation procedure for use by GIA students and graduates, within a short time students and members of the trade were asking the GIA instructors to help grade their diamonds in order to provide an independent assessment of the quality. As Bert Krashes—who retired as a vice president of the laboratory in 1987—recalled:

When students returned home and graded their own diamonds, they frequently encountered challenging grading situations. As part of our service to them, we agreed to check their findings. We used diagrams of the various cuts of diamonds, on which we noted the position of inclusions as well as our grading of the stone. After word of our grading system attained some notoriety, we were asked to produce a more formal report, and that is how our diamond grading report was born.

The first formal GIA diamond grading reports were issued in 1955. Because of Crowningshield’s

Figure 18. In the 1950s, Crowningshield was one of the original instructors in GIA’s traveling classes to teach the Institute’s new diamond grading system. Crowningshield is shown here with a September 1957 class in Indianapolis, Indiana.







Figure 19. Crowningshield was an important contributor to the color grading system for colored diamonds. Reproduced here is a section of the color grid for Fancy blue diamonds (King et al., 1998).

prominence in teaching the system, he was regarded as one of its foremost practitioners (Federman, 1995). Even so, trade acceptance of the system took years of effort by Crowningshield and others, with dealers and jewelers only gradually recognizing its benefits. As Bert Krashes explained, "Little by little, jewelers both here and abroad found that our reports helped them sell diamonds. At first, Bob and I would each grade a diamond independently, then compare our findings. Eventually, this led to the establishment of the repeatable parameters we subsequently used in grading."

As the reports became more important, GIA sometimes encountered dealers who were unhappy with the grades their diamonds received—and were not shy about telling Crowningshield and Krashes what they thought. In a 2003 interview, diamond dealer William Goldberg commented, "Even way back then, I remember that Bob said 'No matter what—we're friends. You're a good guy, but [the diamond's grade] is what it is, and we're not going to change it because we play tennis together or have known each other for 30 years.' To me, that [integrity] is very crucial. If I had a certificate, and Bob Crowningshield's or Bert Krashes' names were on it, that always represented to me the essence of what GIA is all about."

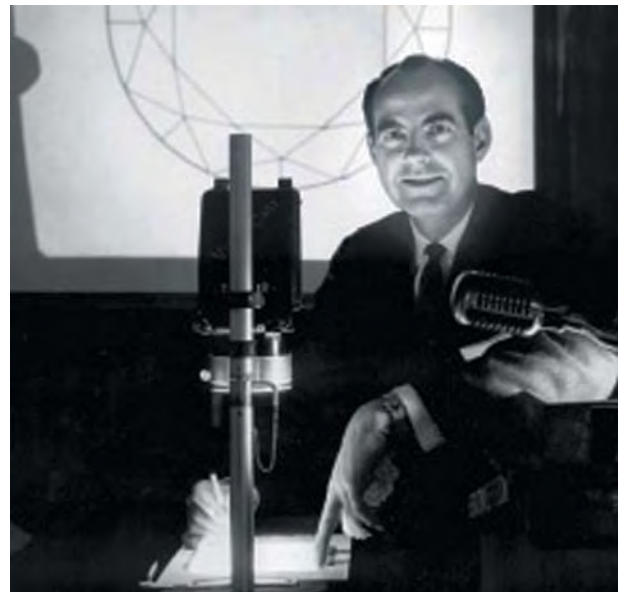
Crowningshield was also directly involved in establishing and refining the system of color terminology that Gem Trade Laboratory staff used to describe colored diamonds. The appearance of treated-color diamonds in the 1950s helped create greater interest in natural-color diamonds. In addition to

seeking origin-of-color reports, clients also brought in yellow diamonds to see if they were an unusual category referred to as "canaries." This required the development of procedures to visually assess diamond coloration, as well as references to mark color description boundaries. From the very beginning, Crowningshield was involved with establishing the boundary between the Z color grade (light yellow) and the Fancy yellow category, working with other GIA staff members as well as prominent colored diamond dealers of that era, such as Arthur Reik and Sidney DeYoung. Later refinements to this nomenclature system (see King et al., 1994, 1998, 2002) included concepts that had been developed decades earlier by Crowningshield and his colleagues (figure 19).

## ALWAYS THE EDUCATOR

Crowningshield was involved in teaching gemology to Institute students and other members of the jewelry trade from his first weeks at GIA. Over a period of 42 years starting in 1951, he was also a popular speaker at the annual educational meetings of the American Gem Society (figures 20 and 21); see the *Gems & Gemology* data depository for a list of his presentations and other contributions at these AGS Conclaves [<http://www.gia.edu/gemsandgemology>, click on "G&G Data Depository"]. Written ver-

Figure 20. For more than four decades, Bob Crowningshield was a popular speaker at the annual AGS Conclaves.



sions of the majority of these presentations can be found in the *AGS Guilds* magazine. Crowningshield also presented at several of the biannual International Gemmological Conferences as well as to other industry groups, such as GIA Alumni and trade associations.

In addition to his gemological reports, Crowningshield published many notable articles on general subjects of interest to the trade. In a two-part 1953 piece, he discussed several principles for the marketing of colored stone jewelry as accessories to current fashions. He wrote about a practical procedure, published in 1958 both in *Gems & Gemology* and the *Journal of Gemmology*, for documenting the extent of physical damage or inherent flaws in polished gemstones. This article arose from the work done by laboratory staff to ascertain damage to client gems, often in cases involving insurance claims. A 1963 article that described the care of gem materials during the manufacture, repair, display, and wearing of jewelry was also based on his examination of damaged gems that had been submitted to the lab.

An important teaching point in GIA education classes is for students to learn the correct definitions and usage of a number of gemological terms. In 1960, Crowningshield coauthored the first edition of the *GIA Diamond Dictionary*, which provided these gemological terms when no other suitable dictionary was available. Crowningshield's last published article appeared in 1995, a study on separating natural from treated pink diamonds that he wrote with several GIA colleagues for *Diamond World Review*.

Crowningshield's outreach also included the general public, with interviews about gems and jewelry on radio in the 1950s (figure 22) and television programs such as the RCA Jewelry Show in 1964.

## PROFESSIONAL RECOGNITION

During his long career, Bob Crowningshield has been the recipient of a number of professional recognitions. A Certified Gemologist of the American Gem Society since 1948, in 1983 he was awarded AGS's Robert M. Shipley Award for outstanding service to the jewelry industry. In 1991, GIA established the G. Robert Crowningshield Gemological Research Laboratory as the Institute's focal point for research work on gem identification. In 1995, he received the 12th annual Lifetime Achievement Award from *Modern Jeweler* magazine. Crowningshield is an honorary director of the Canadian Gemmological Association and a recipient of the Accredited Gemologists Association's



Figure 21. Bob Crowningshield, Eunice Miles, Glenn Nord, Richard Liddicoat, and Bert Krashes participate in a gemological panel at the 1965 AGS Conclave in Chicago. Each of these individuals played a key role in educating the industry.

Antonio C. Bonnano Award for Excellence in Gemology. Most recently, this year he was honored with the AGS Lifetime Achievement Award (figure 23) and was inducted into GIA's League of Honor.

In a 1995 article describing the Lifetime Achievement Award from *Modern Jeweler*, David Federman explained why Crowningshield was so well respected throughout the industry and the research community:

As the Sufi mystics say, "Duty is greater than God." And Crowningshield is the rare exemplar of that aphorism. No wonder he is among the most revered teachers and practitioners of gemology in the post-war era. And because of his legendary dedication to his profession, he has

Figure 22. Because of his gemological expertise, Bob Crowningshield was often asked to speak to the public about gems, as in this NBC radio interview in the 1950s.





Figure 23. In July 2003, AGS presented Crowningshield with a Lifetime Achievement Award for his “indelible and beneficial impact on the jewelry industry through outstanding scientific and educational contributions.” He is shown here with AGS President-elect Bill Sites (left) and AGS President Bill Farmer Jr. (right). Photo courtesy of AGS.

emerged as perhaps the most distinguished advocate of gemology’s daily relevance and sentinel significance to the trade at large—excelling at all the services for which the Gemological Institute of America is known: teaching, research, diamond grading, and gem identification.

## CONCLUSION

It would be impossible to overstate G. Robert Crowningshield’s contributions to GIA and the jewelry industry. In the early years of the Gem Trade

Laboratory in New York, he worked closely with two other well-recognized individuals, Bert Krashes and Eunice Miles, to build the day-to-day business of the laboratory. Most importantly, though, as stated in the published announcement for the 2003 AGS Lifetime Achievement Award, “G. Robert Crowningshield has made an indelible and beneficial impact on the jewelry industry through outstanding scientific and educational contributions toward the advancement and understanding of gemology.”

Leaders of the jewelry industry and others who have worked with him over many years would describe him as a gentleman—hard working yet caring and always courteous; debonair yet self-effacing; as ethical as he is enthusiastic; and not only intelligent, but also knowledgeable, gifted with a photographic and encyclopedic memory. He has always been committed to GIA’s mission, which—in the words of his longtime friend and colleague Bert Krashes—is to “teach the truth about gemstones, and to counsel jewelers that they do the same when they are dealing with their customers.” Although Crowningshield has received widespread recognition for his accomplishments, the most important one is the respect that his colleagues continue to hold for him as one of the greatest gemologists the world has ever known, and an individual who has dedicated his life to the study and understanding of gems.

Up until recent years, Crowningshield continued to go to the New York lab on a regular basis. Even today, in the Upper West Side Manhattan brownstone that has been his home for more than 50 years, he enjoys visits from old friends and colleagues and remains fascinated by the rapid changes in the gemological landscape. He still amazes us with occasional flashes of his vast recall of gemological information and remains an inspiration to many at GIA and throughout the international gemological community.

### ABOUT THE AUTHORS

Mr. Moses is vice president of Identification Services at the GIA Gem Laboratory in New York, and Dr. Shigley is director of GIA Research in Carlsbad, California.

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# AN INVESTIGATION INTO THE CAUSE OF COLOR IN NATURAL BLACK DIAMONDS FROM SIBERIA

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Black and dark gray diamonds from Siberia, Russia, were studied by analytical scanning and transmission electron microscopy. Their color is caused by the presence of dark inclusions. Unlike some previous reports on black diamonds in which the dark inclusions were primarily graphite, the Siberian samples with the most intense black color contained predominantly magnetite inclusions, while the dark gray diamonds most commonly contained inclusions of hematite and native iron. Moreover, the black diamonds studied exhibited anomalously high magnetic susceptibility, which may serve as one criterion for determining the natural origin of black color.

Natural diamonds occur in almost all colors (Orlov, 1977; Hofer, 1998). Most colors—including brown, pink, red, orange, yellow, green, blue, and violet—are caused by defects in the diamond's crystal structure, most commonly nitrogen and boron impurities, vacancies, and dislocations (Collins, 1982; Fritsch and Rossman, 1988). In contrast, black and gray colors in untreated natural diamonds are due to the presence of mineral inclusions rather than structural defects.

Strange as it may seem, the nature of these inclusions has not been studied in detail, although high-quality faceted black diamonds have attracted considerable interest in the marketplace (see, e.g., Gruosi, 1999; figure 1). Data on mineral inclusions in black diamonds available in the gemological literature are based mainly on examination with the optical microscope. Black inclusions clearly seen

with an optical microscope have been described previously as graphite (see, e.g., Kammerling et al., 1990). Orlov (1977) suggested that finely dispersed graphite microparticles also occur in those black diamonds in which individual inclusions could not be seen with the optical microscope.

Although very rare, facetable black diamonds are found in primary kimberlite and secondary alluvial deposits worldwide. Such diamonds are mined in Siberia, eastern Russia, mainly from the Mir kimberlite pipe. A number of companies, such as Rony Carob Ltd. (Moscow), V. N. Almaz LLC (New Jersey), and V. B. International Corp. (New York), cut black diamonds from Siberia for use in jewelry (see, e.g., figures 2 and 3).

The aim of this article is to document the identification of mineral inclusions in black and near-black diamonds from Siberian deposits using analytical scanning and transmission electron microscopy methods. In our previous work (Gorshkov et al., 2000; Titkov et al., 2001; and references therein), we used these techniques to investigate microinclusions in polycrystalline diamond aggregates (bort and carbonado) from various deposits. That data expanded our knowledge of inclusions in natural diamonds, and demonstrated their mineralogical diversity. In particular, we found that native metals—including common Fe and rare Cr, Ni, Ag, Au, Cu, Ti, and Fe-Cr, Fe-Ni,

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See end of article for About the Authors and Acknowledgments.  
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*Figure 1. Black diamonds have become increasingly popular in modern jewelry such as this brooch, which contains 992 black diamonds (total weight 54.50 ct) and 170 colorless diamonds (total weight 1.90 ct). The center diamond weighs 2.51 ct. Courtesy of Chanel Fine Jewelry, from the Collection Privée.*

Ag-Au alloys—occur widely as inclusions in natural polycrystalline diamonds. It is noteworthy that some of these metals, most often Ni and Fe, are used as fluxes in diamond synthesis, and synthetic crystals often contain them as inclusions (Muncke, 1979).

## **MATERIALS AND METHODS**

We studied four rough black diamonds (samples 1–3 and 6), and two rough nearly black or dark gray diamonds (samples 4 and 5), from which polished brilliants could be manufactured. Samples 1–5 were recovered from the kimberlites of western Yakutia and weighed 13–25 ct each; sample 6, 1.8 ct, came from the Anabar placer deposit in northern Yakutia.

All six diamonds were examined with an Olympus BX51 optical microscope, and photomicrographs were taken using a MIN-8 microscope with a Pentax-MZ5N camera.

The six diamonds were then studied with analytical electron microscopy (Wenk et al., 1995; Shindo and Oikawa, 2002), and the inclusions were identified by their chemical composition and structural parameters. Investigations were per-

formed using a JEOL JEM-100C transmission electron microscope (TEM) equipped with a goniometer and a Kevex 5100 energy-dispersive X-ray spectrometer, allowing the detection of elements from Na to U. We also used a JEOL JSM-5300 scanning electron microscope (SEM) equipped with an Oxford LINK ISIS energy-dispersive X-ray spectrometer, which permitted detection of elements from Be to U (including, most significantly, oxygen). With these two instruments, we obtained information on micromorphological features (from SEM backscattered electron images and TEM images), line and volume structural defects (from TEM images), structural parameters (from selected-area electron diffraction patterns obtained using the TEM), and chemical compositions (from energy-dispersive spectra) of inclusions as small as a fraction of a micron. Box A provides more information on analytical electron microscopy.

In preparation for analysis, each sample was crushed after being wrapped in a special thick paper to avoid contamination. In large fragments, quantitative energy-dispersive analysis of inclusions was performed by SEM on polished surfaces, and semi-quantitative analysis was performed on rough, unpolished surfaces that were quite flat and

## BOX A: ANALYTICAL ELECTRON MICROSCOPY

Analytical electron microscopy is the combination of transmission or scanning electron microscopy (TEM or SEM) with energy-dispersive X-ray spectroscopy (EDS). It is one of the most powerful tools available for characterizing the solid-state substances that occur as micron-sized inclusions in minerals.

The electron microscope uses a beam of accelerated electrons instead of visible light (as in an optical microscope). Electron microscopy provides for magnifications of more than 500,000 $\times$ , and a spatial resolution of 3 angstroms (or  $3 \times 10^{-10}$  m), because the wavelength of an electron beam is about four orders of magnitude shorter than that of visible light.

In TEM, the electron beam is focused by a magnetic lens through a specimen that is thin enough to be transparent to the beam. In image mode, it provides electron micrographs that reveal various defects (dislocations, misoriented microblocks, microtwins, etc.) in a specimen. In diffraction mode, the instrument generates selected-area electron diffraction patterns, calculation of which reveals structural characteristics. The general principle behind electron diffraction patterns is similar to that of X-ray diffraction patterns. Analysis of these patterns is very complicated, because published lattice parameters obtained with this technique are quite rare in the mineralogical literature, and absent from the gemological literature. The analysis and calculation of electron diffraction patterns are discussed in Hirsch et al. (1977).

Electron diffraction patterns may be of two types: point and ring. Point diffraction patterns are formed if the sample studied is a perfect single crystal, with each point corresponding to the reflection from a specific set of atomic planes in the lattice. Ring diffraction patterns are produced by polycrystalline aggregates, with each ring corresponding to a certain reflection from many microblocks, or grains, in various orientations (i.e., a ring consists of many points, each of which corresponds to one misoriented block). Discrete-ring diffraction patterns may arise if microblocks in the aggregate have a preferred orientation, or if the aggregate is characterized by a certain texture.

Some important limitations of the TEM technique in gemology are that the sample must be very thin (i.e., it must be crushed to a powder or chemically etched), and the area analyzed is only about 1 mm in diameter.

In a scanning electron microscope (see, e.g., figure A-1), images are recorded using secondary and

backscattered electrons reflected from a sample surface. SEM provides information on micromorphology, grain and pore sizes, sample homogeneity, the relationship between different phases, and the like.

For both TEM and SEM, the interaction of the electron beam with a sample produces characteristic X-ray radiation. Measuring the intensities of these X-rays with energy-dispersive detectors (the basis of EDS) reveals the chemical composition of the sample.

In summary, analytical electron microscopy provides unique information on micromorphological features (from SEM images and TEM images), line and volume structural defects (from TEM images), structural parameters (from electron diffraction patterns obtained using the TEM), and chemical composition (from EDS) of samples as small as a fraction of a micron. For more information on analytical electron microscopy, see Wenk et al. (1995), Shindo and Oikawa (2002), and references therein.

Facilities equipped with SEM+EDS and TEM+EDS instruments can be found at some universities or research centers, particularly those specializing in materials science, chemistry, physics, or geology. The approximate costs of these instruments are typically: SEM, \$100,000–\$300,000; TEM, \$500,000–\$1,000,000; and EDS detector, \$70,000–\$300,000.



Figure A-1. The scanning electron microscope used for this study was equipped with an energy-dispersive X-ray spectrometer, for analysis of elements ranging from Be to U. Photo by M. K. Sukhanov.

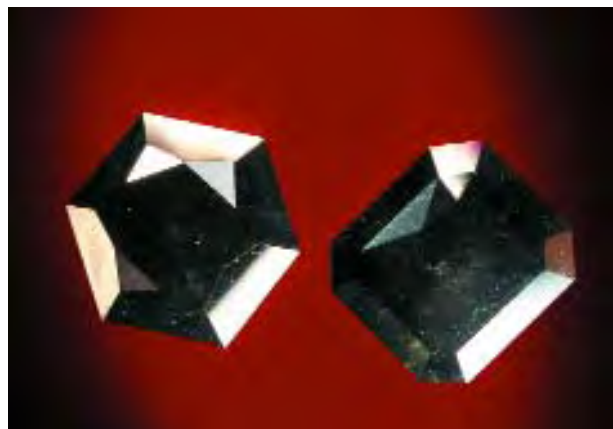


Figure 2. These two faceted diamonds are from the Siberian deposits in Russia, which were also the source of the samples examined for this study. The hexagon-shaped stone measures approximately 8.4 mm in diameter. Photo by M. A. Bogomolov.

oriented nearly perpendicular to the electron beam. These samples were carbon coated to disperse electrostatic charge in the SEM. For TEM analysis, the crushed diamond powder was placed into a test tube with distilled water, and treated ultrasonically to obtain micron-size particles. Drops of this suspension were placed onto a copper grid with an electron-transparent film and dried under a lamp. In each suspension sample, about 100–200 particles were analyzed, and for each particle, a TEM image, an electron diffraction pattern, and an energy-dispersive spectrum were obtained. The relative abundance of various types of inclusions was estimated based on the frequency of their presence in the suspension sample.

The magnetic susceptibility of the largest fragments of the six samples was analyzed with a Kappabridge KLY-2 magnetometer. Box B provides information on magnetic susceptibility.



Figure 3. The dark gray and black diamonds in these brooches came from Siberia. The length of the brooch on the right is 6.8 cm. Courtesy of Rony Carob Ltd.; photo by M. A. Bogomolov.

## RESULTS

Samples 1–5 were irregular rounded diamonds (see, e.g., figure 4). Examination with an optical microscope showed that they consisted of polycrystalline aggregates of intergrown grains from 0.5 to 5.0 mm in size, with parallel striations. Some of their surfaces showed characteristic post-growth dissolution features (e.g., block sculpture, ditrigonal striations, etc.; see Orlov, 1977). Sample 6 was a rounded, distorted crystal with octahedral habit that also displayed dissolution features (block- and drop-like hillocks; see Orlov, 1977). All six diamonds were

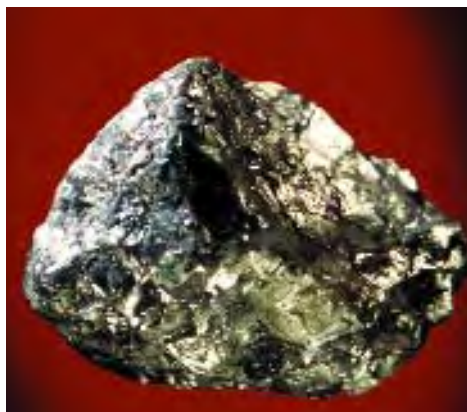
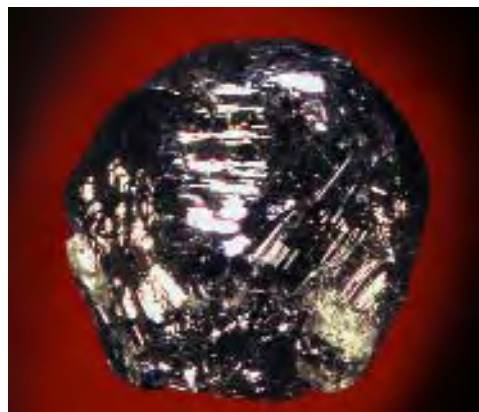


Figure 4. These two rough polycrystalline diamonds were among the six studied to determine their cause of color. Shown are sample 2 (left, 25.26 ct) and sample 5 (right, 22.36 ct). Photos by M. A. Bogomolov.



## BOX B: MAGNETIC SUSCEPTIBILITY OF MINERALS

All substances, including minerals, possess magnetic properties to some degree. These properties may be characterized by magnetic susceptibility, as well as by magnetization, magnetic permeability, magnetic structure, and the like. *Magnetic susceptibility* ( $\chi$ ) is a physical value that characterizes the relationship between the induced magnetization of a substance and a magnetic field applied. *Volume magnetic susceptibility* is defined by the ratio of the magnetization per unit volume of a substance to the strength of the magnetic field applied. For most practical purposes, *specific magnetic susceptibility* is expressed—that is, the volume of magnetic susceptibility calculated per kilogram of the material (in units of  $\text{m}^3/\text{kg}$ ). For ferromagnetic (e.g., native Fe and Ni), ferrimagnetic (e.g., magnetite, chromite), and paramagnetic (e.g., garnet, mica, tourmaline) minerals, magnetic susceptibility is positive. Its value reaches the order of  $10^6$  for the first

two groups, but is only about  $10^{-6}$ – $10^{-9}$  for the last. For diamagnetic minerals (e.g., diamond, quartz, feldspar), magnetic susceptibility is negative, being on the order of  $10^{-8}$ – $10^{-9}$ .

Magnetic susceptibility may be measured with a special magnetometer, called a  $\chi$ -meter (or kappa meter). In this device, a tube containing the material under examination is suspended from the arm of a balance between the poles of an electromagnet. When the magnetic field is activated, it will produce a certain amount of downward magnetic force, which is measured by the weight necessary to compensate for it. From the value of the downward magnetic force and the strength of the magnetic field applied, the magnetic susceptibility of the mineral can be calculated.

For more information on magnetic susceptibility, see O'Reilly (1984).

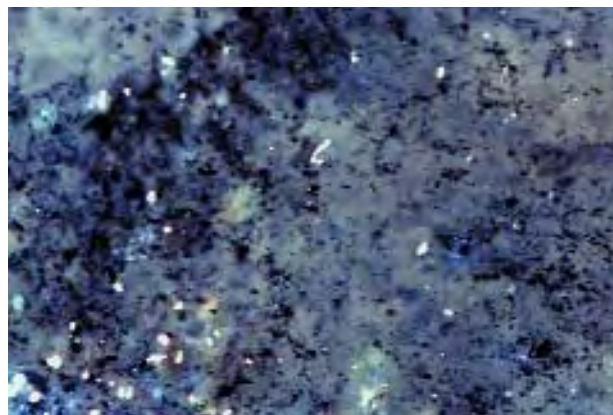
almost opaque, due to a combination of numerous inclusions and microfractures.

**Inclusions.** Examination of the six samples using an optical microscope revealed large numbers of very small dark inclusions (figure 5), the apparent cause of the black or dark gray color. To the unaided eye, these inclusions generally appeared to be evenly distributed throughout the sample. However, examination with the optical microscope revealed that they typically formed clusters or linear boundaries between individual diamond grains, where a great

number of microfractures also occurred.

Both SEM and TEM images revealed that the inclusions were diverse in size, ranging from 0.1 to 100  $\mu\text{m}$ . Most consisted of magnetite, hematite, and native iron, which were identified by their chemical composition as obtained with energy-dispersive spectroscopy and by their structural parameters as calculated from TEM electron diffraction patterns.

Figure 5. Examination with an optical microscope revealed numerous black inclusions in the sample diamonds. Photomicrograph by M. A. Bogomolov, oblique illumination; the field of view is 2 mm.



*Magnetite.* Magnetite ( $\text{Fe}^{2+}\text{Fe}^{3+}_2\text{O}_4$ ) was identified in five of the six diamonds (samples 1–3, 5, and 6), and was predominant in the two samples that showed the darkest black color (1 and 2). SEM backscattered electron images (see, e.g., figure 6, left) revealed that magnetite inclusions occurred as both individual irregular grains (1–4  $\mu\text{m}$ ) and clusters of these grains, in the diamonds themselves and along microfractures. Energy-dispersive spectra of these inclusions usually indicated the presence of only Fe and O (figure 6, right), as would be expected for magnetite. Some grains from sample 6 contained Mn impurities (about 8 wt.%).

In TEM images obtained from suspension samples, the magnetite appeared as irregular particles with varying degrees of perfection (i.e., single crystal vs. polycrystalline aggregates; see figure 7, left). The electron diffraction patterns of most of the magnetite particles showed a series of discrete ring reflections (figure 7, right), which is characteristic of a polycrystalline aggregate with preferred orientation of grains, in sizes smaller than 1  $\mu\text{m}$ . For some of the magnetite particles, the diffraction patterns exhibit-

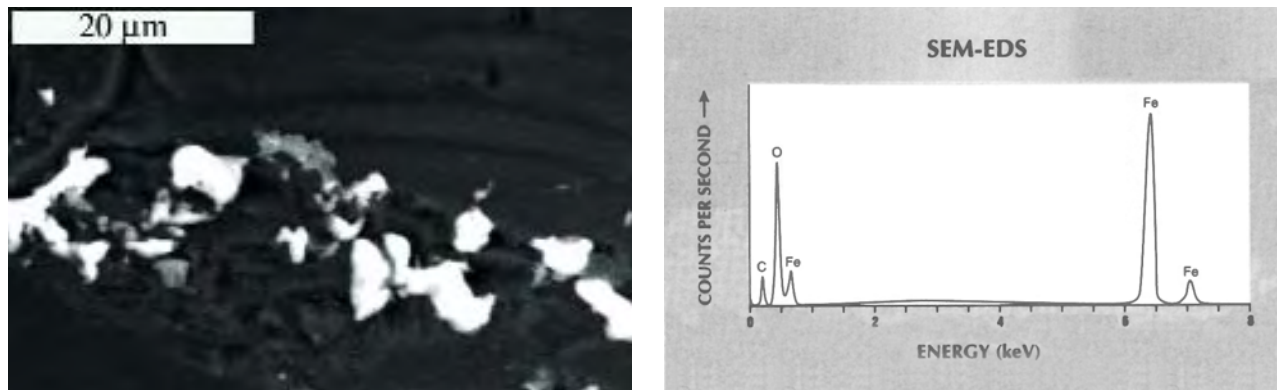


Figure 6. An SEM backscattered electron image (left) of the broken surface of one of the black diamonds studied revealed that magnetite inclusions (bright white spots) occurred as both individual grains and clusters in the diamond matrix (dark area). The energy-dispersive spectrum of such inclusions (right) typically indicated the presence of only Fe and O. The carbon (C) is from the carbon coating on the sample.

ed continuous ring reflections (characteristic of polycrystalline aggregates with random grain orientation) and point reflections (characteristic of single crystals). Processing of these patterns yielded diffraction characteristics typical of the magnetite structure.

**Hematite.** In the two dark gray diamonds (samples 4 and 5), hematite ( $\text{Fe}_2\text{O}_3$ ) inclusions were predominant. SEM images revealed that the hematite inclusions usually formed scale-like particles (figure 8, left). Energy-dispersive spectra of these particles showed peaks for Fe and O, and rarely a weak peak related to Mg impurities (figure 8, right). TEM images revealed that the particles were actually single crystals (figure 9, left) that showed point reflections in the diffraction patterns (figure 9, right); they also formed rounded polycrystalline aggregates (figure 10, left) that gave a discrete-ring type of diffraction pattern (figure 10, right).

**Metallic Elements.** Inclusions of native iron were detected in all six samples, but they were less abun-

dant than the inclusions of Fe oxides. The native iron formed individual isometric grains and clusters (figure 11, left); most were essentially free of impurities (figure 11, right), though some showed minor Cr, Mn, Ni, and/or Cu. In TEM images, native Fe was seen as irregular particles (figure 12, left). Their electron diffraction patterns yielded a series of discrete ring reflections (figure 12, right).

In addition to native Fe, sample 1 contained inclusions of native Cu, sample 2 exhibited inclusions of an  $\text{Fe}_{0.9}\text{Cr}_{0.1}$  alloy, and sample 3 displayed inclusions of native Ag and native Zn.

**Other Dark Mineral Phases.** Inclusions of an exotic phase consisting of Cu (55–65 wt.%), Sn (7–16 wt.%), Ni (4–8 wt.%), and O were found in samples 1 and 2. This mineral filled cracks in the black diamonds and, in some cases, formed irregular grains. Analysis of the elemental distribution within these inclusions—which was obtained using characteristic X-ray radiation of Cu, Sn, Ni, and O—indicated that it was quite homogeneous, rather than a mixture of several phases.

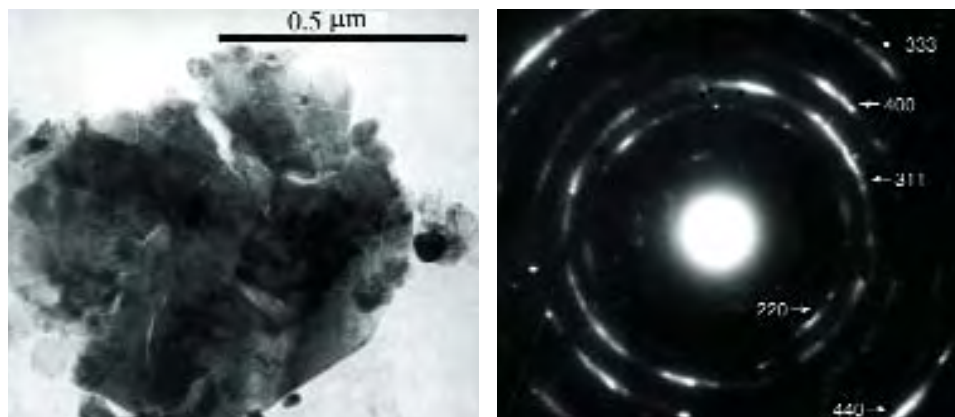


Figure 7. This TEM image (left) of a suspension sample from a black diamond shows that most of the magnetite inclusions consist of irregular aggregates. The electron diffraction pattern (right) of this grain shows a series of discrete ring reflections, which is characteristic of a polycrystalline aggregate with preferred orientation of the grains. The diffraction reflections of the corresponding lattice planes have been indexed.

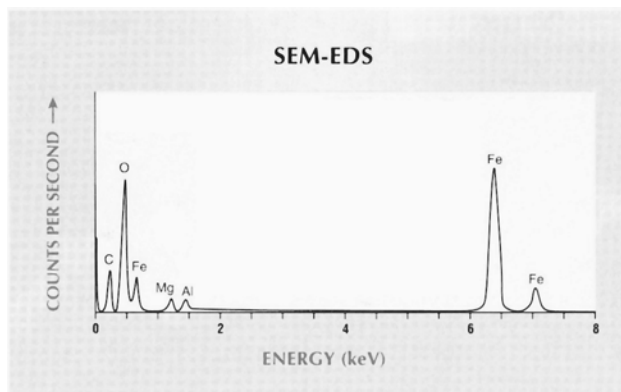
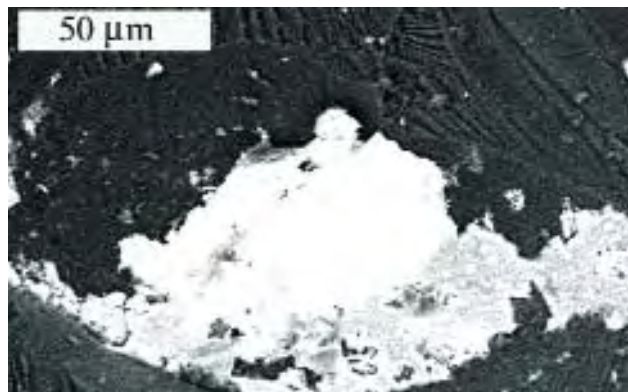


Figure 8. Hematite inclusions, which were most common in the dark gray diamonds, usually occurred as scale-like particles, as shown by the bright white grains in this SEM image (left). The energy-dispersive spectrum of the hematite (right) showed peaks for Fe and O and, rarely, Mg. The Al peak is due to interference, and the C peak corresponds to the carbon coating.

Electron diffraction patterns of this phase showed a series of discrete ring reflections, consistent with a polycrystalline structure. Processing of these electron diffraction patterns revealed structural characteristics that, combined with the chemical composition, have not been reported previously to our knowledge.

In sample 1, small quantities of the sulfide minerals chalcocite ( $\text{Cu}_2\text{S}$ ) and pyrite ( $\text{Fe}_2\text{S}$ ) were detected.

Graphite inclusions were extremely rare in our samples. A few scale-like graphite particles were found, but only in samples 1 and 3.

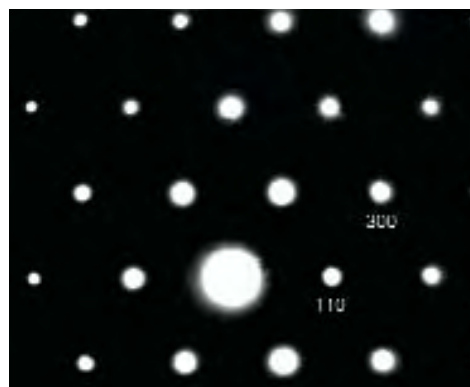
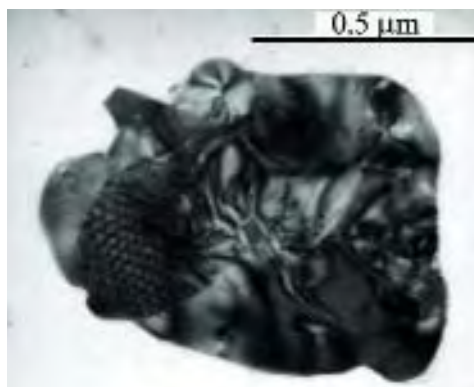
**Non-black Inclusions.** A minor amount of Fe-hydroxide minerals formed inclusions in samples 1, 2, and 6. Calculation of their structural parameters from electron diffraction patterns identified some as goethite (rhombohedral modification of  $\text{FeO}\cdot\text{OH}$ ) and others as akaganéite (tetragonal modification of  $\text{FeO}\cdot\text{OH}$ ).

Inclusions that apparently were not related to the black coloring of the diamonds were also found in the samples. Most of the diamonds contained inclusions of chrysotile ( $\text{Mg}_3[\text{Si}_2\text{O}_5]\text{OH}$ ), which

filled microfractures and microcavities. Also detected were common calcite ( $\text{CaCO}_3$ ) and dolomite ( $[\text{Ca},\text{Mg}]\text{CO}_3$ ), as well as rare olivine ( $[\text{Mg},\text{Fe}]\text{Si}_2\text{O}_4$ ), anhydrite ( $\text{CaSO}_4$ ), fluorite ( $\text{CaF}_2$ ), halite ( $\text{NaCl}$ ), cuprite ( $\text{CuO}$ ), quartz ( $\text{SiO}_2$ ), feldspars, and some other minerals. Most of these have been previously identified as inclusions in diamond (see Harris, 1992; Gorshkov et al., 2000; Titkov et al., 2001).

**Magnetic Susceptibility.** The measured specific magnetic susceptibility of the dark gray and black diamonds varied over a wide range, from  $-0.6 \times 10^{-8} \text{ m}^3/\text{kg}$  to  $+36 \times 10^{-8} \text{ m}^3/\text{kg}$ . (By comparison, pure diamond has a specific magnetic susceptibility of  $-0.62 \times 10^{-8} \text{ m}^3/\text{kg}$ ; Novikov, 1993.) The maximum magnetic susceptibility was measured in sample 1, which also had the darkest black color. However, the relationship between the depth of black color and magnetic susceptibility was not straightforward, because our measurements of the volume magnetic susceptibility were influenced by all of the various mineral inclusions in a sample.

Figure 9. Single-crystal particles of hematite (as shown in a TEM image, left) produced point electron diffraction patterns (right). The  $(001)^*$  index shows the general orientation of the particle.



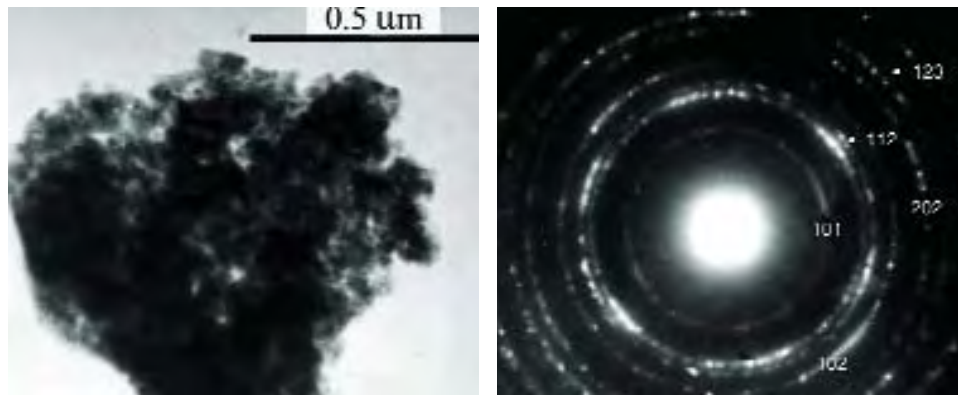


Figure 10. Polycrystalline aggregates of hematite (shown in a TEM image, left) produced a discrete-ring type of electron diffraction pattern (right).

## DISCUSSION

Our results suggest that the color of the black and dark gray diamonds studied was caused primarily by inclusions of magnetite, hematite, and native Fe. Inclusions of Cu-based oxides detected in some samples also may have contributed to the black color of these diamonds. In samples of the darkest color, magnetite was the most common inclusion. In the dark gray diamonds, inclusions of hematite and native Fe were predominant. Further detailed studies of black diamonds from other localities are required to determine whether the presence of magnetite, hematite, and native Fe inclusions are merely a characteristic feature of black and dark gray diamonds from Siberia, or if they are typical of all such diamonds worldwide. Nevertheless, magnetite has been reported as abundant inclusions in some dark gray diamond aggregates from African deposits (Jeynes, 1978).

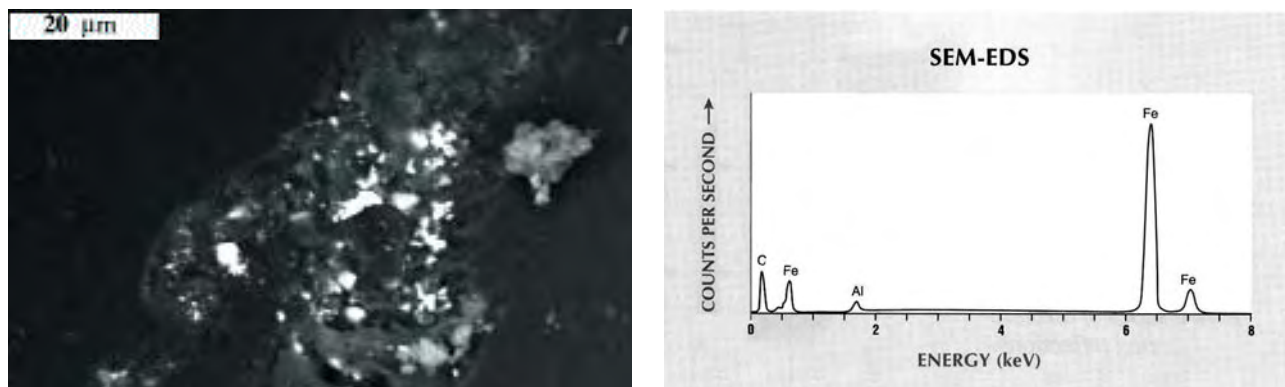
In previous studies, magnetite was observed as isolated inclusions in single crystals of transparent diamond (Prinz et al., 1975; Harris, 1992). Its syngenetic character (i.e., formed at the same time) with diamond was established on the basis of

observations that the inclusions were completely isolated in diamond and were not accompanied by fractures; furthermore, they showed growth steps characteristic of the host diamond (Prinz et al., 1975). Inclusions of native Fe, as well as other native metals, are rather widespread in polycrystalline and translucent diamonds from various deposits worldwide (Gorshkov et al., 2000; Titkov et al., 2001; and references therein), so their appearance in the samples studied was not unexpected.

Graphite, commonly presumed to be the cause of black color in diamonds, was detected in very small amounts in only two of our samples, so it cannot be responsible for their coloring. Sulfide minerals also were very rare, and so they did not have a significant impact on the color of our samples. It should be noted that in transparent single-crystal diamonds, dark sulfides are common (Harris, 1992), but so far they have not been documented in large enough quantities to cause dark gray or black coloration. Sulfides were absent in the opaque single-crystal black diamond studied here (sample 6).

The inclusions of magnetite, hematite, and

Figure 11. Most native-iron inclusions (bright white in the SEM image on the left) were essentially free of impurities, as shown by the energy-dispersive spectrum on the right. The Al peak is due to interference, and the C peak corresponds to the carbon coating.



native Fe apparently contributed to the unusual magnetic properties of the diamonds studied. The wide range of values we measured was probably due to the variable content of magnetic inclusions, and to the presence of numerous inclusions of other minerals. In previous work (Jeynes, 1978), diamond polycrystalline aggregates (e.g., bort) that could be separated from other diamonds by an electromagnet were referred to as Stewartite.

The unusual magnetic properties of these natural-color black diamonds may be useful in separating them from their artificially colored counterparts. Black may be produced by irradiation with neutrons or gamma rays in a nuclear reactor (Collins, 1982), by ion implantation in a linear accelerator (Moses et al., 2000), and by heating in a vacuum to cause internal graphitization (Notari, 2002). None of these processes induces magnetism, and the relatively inclusion-free natural diamonds that are irradiated to produce a black color are not magnetic. Therefore, magnetic properties could provide an important criterion for identifying natural black coloration. It is important to note that anomalously high magnetic susceptibility is also characteristic of synthetic diamonds grown from Fe melts and containing metallic flux inclusions (Novikov, 1993). One magnetic synthetic "black" diamond was described by Reinitz (1999), but its color was actually very dark blue, caused by abundant boron impurities rather than inclusions.

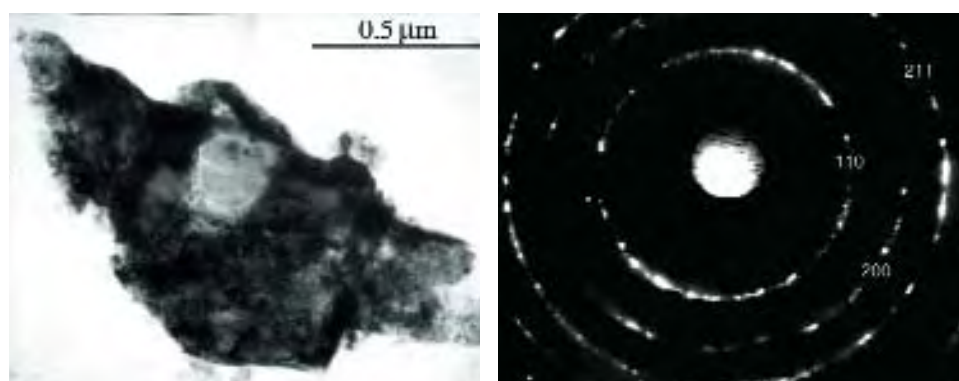
It is interesting to speculate that the weak magnetism of these natural black diamonds may be responsible for the positive health benefits ascribed to black diamonds in ancient times.

The inclusions in natural black and dark gray diamonds are also interesting when we consider the genesis of these diamonds in the earth. The widely accepted hypothesis is that most gem-quality diamonds crystallized from silicate mantle melts (of eclogite and peridotite compositions) at a depth of

about 150 km, and then were carried to the surface by kimberlite or lamproite magma (Orlov, 1977; Kirkley et al., 1991; Harris, 1992). According to this theory, the occurrence of the inclusions revealed in our samples may be explained only as a result of post-growth formation within fractures in the host diamonds. However, most of the black inclusions were entirely surrounded by the diamond matrix, indicating that they were incorporated into the host diamonds during growth. Previous work has also established that magnetite and native-iron inclusions in diamond can be syngenetic (Prinz et al., 1975; Harris, 1992; Gorshkov et al., 2000; Titkov et al., 2001). Furthermore, these black inclusions were abundant in our samples, while inclusions of silicate minerals that are typical of mantle rocks (e.g., garnet, olivine, pyroxene) were nearly absent—despite the fact that silicate inclusions should be present in polycrystalline diamonds if they actually crystallized from silicate melts.

The abundance of magnetite, hematite, and native-iron inclusions in the diamonds that we studied might be better explained by another mechanism of diamond formation. This hypothesis assumes that diamond crystallized as a result of the injection of deep-derived hydrocarbon-bearing fluids into more-oxidized rocks of the lithosphere and their subsequent interaction (Taylor and Green, 1989; Navon, 2000). Most of the inclusions in our samples, in particular native Fe and magnetite, might be products of redox (oxidation-reduction) interactions between hydrocarbon fluids and lithospheric rocks (eclogite and peridotite). In the process of these interactions, the redox potential could change dynamically, causing the formation of inclusions representing very different redox conditions, for native metals on the one hand and for oxide and carbonate minerals on the other. Understanding the occurrence of these inclusions requires further detailed study.

*Figure 12. In TEM images (e.g., on the left), native Fe often appeared as irregular particles. Their electron diffraction patterns (e.g., right) gave a series of discrete ring reflections.*



## SUMMARY AND CONCLUSION

Black diamonds, cut and rough, continue to gain popularity in contemporary jewelry (figure 13). Yet there has been little detailed research to date on the cause of color in these unusual gems. This investigation by analytical electron microscopy has shown that the coloring of the black and dark gray diamonds studied was caused primarily by the presence of inclusions of magnetite, hematite, and native Fe. The diamonds with the darkest black color contained predominantly magnetite inclusions, while the dark gray samples most commonly contained inclusions of hematite and native Fe. These mineral inclusions are responsible for the anomalously high magnetic susceptibility of our samples, which may prove to be of value as a criterion for the natural origin of black color.

Figure 13. Even rough black diamonds have found a niche in contemporary jewelry. This ring, set with a 5.8 ct black diamond, is designed by and courtesy of Pam Keyser.



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# OBTAINING U.S. COPYRIGHT REGISTRATION FOR THE ELARA SQUARE CUT-CORNERED BRILLIANT DIAMOND

Howard B. Rockman

In 2000, the U.S. Copyright Office granted what is believed to be the first copyright registration covering a gemstone design. Previously, the Copyright Office maintained that cut designs lacked artistic or sculptural authorship, and that gemstone faceting was a non-copyrightable array of common geometrical shapes in a three-dimensional object. The application to obtain copyright registration for the Elara—a square cut-cornered brilliant diamond design—was initially rejected on similar grounds. However, the position of the copyright examiner was successfully appealed to the highest level of the Copyright Office, which ultimately decided that copyright registration for the Elara cut was appropriate. This experience shows that there may be a new intellectual property vehicle available for manufacturers to protect proprietary cut designs.

A recent *Gems & Gemology* article (Overton, 2002) stated that U.S. federal courts require more original artistic expression to establish a copyright than exists in diamond cut designs. While court decisions may presently indicate that gemstone designs are not copyrightable, the U.S. Copyright Office recently issued copyright registration No. VA-1-104-147 (effective June 29, 2000) for the Elara square cut-cornered brilliant diamond cut (figure 1), produced and marketed by Kuwayama Europe of Antwerp, Belgium, and its U.S. affiliate, Elara Diamond U.S.A. According to the U.S. Register of Copyrights, the Elara diamond cut is the first gemstone design the Copyright Office has ever registered (M. Peters, pers. comm., Nov. 6, 2001). This article summarizes the background and history of the Elara copyright registration process.

## THE COPYRIGHT REGISTRATION PROCESS

U.S. copyright law protects works of “authorship” such as books and movies, as well as sculptures, computer programs, photographs, and myriad additional media that continually develop as art and technology advance (see U.S. Code, Title 17; information in this article is drawn from that source). The copyright holder has the exclusive right to control reproduction of the expression embodied in his or her artistic creation after it has been fixed in a tangible medium such as the print in a book, the images on a reel of film, or the electronic pattern on a computer disc, CD, or DVD. This includes control over copying of the work, the preparation of derivative works, distribution of copies to the public, public performance, and public display. Only the copyright holder can sell or license these rights to other persons or entities. The term of a copyright begins at the moment of fixation in a “tangible medium of expression” and currently runs for the life of the author plus 70 years. In the case of “works for hire” (those created by employees for their employers or by outside authors working under a written contract), it runs for a total of 95 years.

When considering a work comprised of several elements, such as the facets of a gemstone design, the existence of copyright rests on the originality inherent in the coordination or arrangement of those specific elements that, in total, comprise the new design. While individual components may not be protected

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See end of article for About the Author and Acknowledgments.  
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Figure 1. The Elara diamond is the first diamond cut design to be awarded a U.S. copyright registration. Courtesy of Elara Diamond Corp.

by copyright, such protection may be triggered by the particular way in which the underlying elements combine to arrive at the finished design. It is the originality of arrangement that determines whether or not it is eligible for copyright protection. In other words, while the squares, triangles, and parallelograms that make up a gemstone facet design may not be individually protectable by copyright, an original and innovative arrangement of them may be protectable.

At any time during the term of a copyright, the copyright owner may seek federal registration of his or her claim by applying to the U.S. Copyright Office, paying the designated fee, and depositing a specimen of the work with the application. A copyright examiner will review the application to ensure that it covers a work that is indeed copyrightable subject matter under the law. If all requirements are correctly set forth in the application, and the submitted specimen establishes that the work constitutes copyrightable subject matter, a Certificate of Registration is issued. If the examiner makes a negative finding on any of these issues, registration is refused. This refusal may be appealed to a first level and, if necessary, to a second, higher level within the Copyright Office.

One can hold and own (and transfer and license) a copyright without obtaining registration for it, but a copyright owner must obtain federal registration before taking action to enforce the copyright against an infringer. However, an infringement action can be brought if a copyright registration application has been filed but refused, as long as a copy of the infringement complaint is furnished to the Copy-

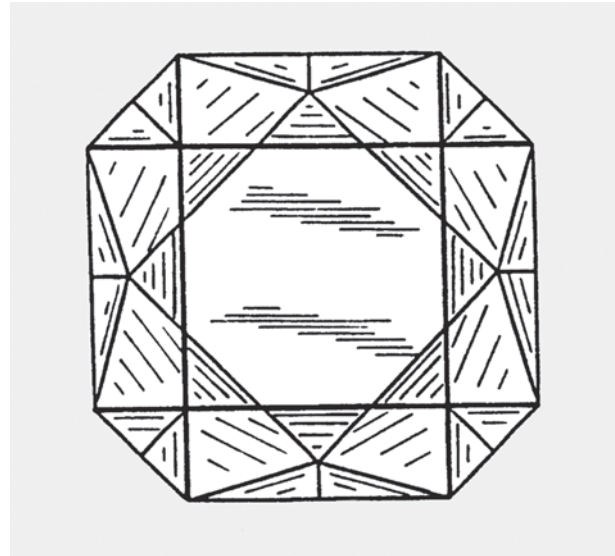


Figure 2. This facet diagram shows the top view of the design of the Elara cut as registered with the U.S. Copyright Office.

right Office. In addition, the timing of the registration application after first publication affects the type of damages that may be recovered. In most foreign countries, there is no comparable registration system; thus, no prior registration is required to enforce a copyright outside the U.S.

#### FIRST APPLICATION FOR REGISTRATION OF THE ELARA DIAMOND AND FIRST APPEAL

The copyright registration procedure for the Elara diamond began on June 29, 2000, when an application (with photos) was filed on behalf of Kuwayama Europe, covering a gemstone design (see figure 2) then known as the Flanders Brilliant (since changed to Elara).

The Copyright Office initially rejected the application (J. H. Ashley, pers. comm., Nov. 13, 2000) and repeated its refusal to register following a request for reconsideration (the first appeal; V. Giroux, pers. comm., May 25, 2001). It stated that the diamond design lacked the artistic or sculptural authorship necessary to support a copyright registration, and based its conclusions on several factors.

First, the examiner believed that the subject of registration was the *process* of faceting the gem, and ideas, concepts, and processes that may be embodied in a work are not subject to copyright protection (see U.S. Code title 17, section 102[b]).

Second, to meet the originality requirement for copyright registration, a work must possess more than a *de minimis* level of creativity. The examiner



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held that, as discussed above, copyright law does not protect familiar geometric shapes or patterns, nor minor variations of them (see Code of Federal Regulations, title 37, section 202.1), and that it was normal procedure to refuse registration for gemstones when the faceting may be perceived to be a combination of standard or common geometrical shapes in three-dimensional form.

Third, the Copyright Office analyzed the design for copyrightability in two ways. First, the top, bottom, front, and side views were treated as separate designs. Second, the entire gemstone was considered as a whole entity. The examiner found insufficient originality in either of these analyses, stating that the overall arrangement of the facets, taken individually or as a unified whole, did not constitute a copyrightable work.

Fourth, the Copyright Office stated that while a work may be unique and distinctive, while considerable time, effort, and expense may have gone into its creation, or while it may be commercially valuable or successful, these facts do not in themselves establish original artistic authorship (V. Giroux, pers. comm., May 25, 2001).

## THE SECOND APPEAL

Prior to receiving the action and comments of the copyright examiner, the creator of the design, Johan d'Haene of Antwerp, had explained to the author the precise steps he took to create the Elara cut. His ultimate aim was to incorporate into a square cut-cornered diamond shape as many of the optical qualities of the round brilliant as possible. Based on this information, the author judged that sufficient creativity and authorship existed in the design to support a second appeal in an effort to reverse the decision of the copyright examiner. On August 1, 2001, the author submitted a response and request for reconsideration of the refusal to register the copyright claim in this design.

The appeal was based on two grounds. First, it maintained that the Elara cut possessed sufficient creative authorship in the origination of its design. Second, it confirmed that registration was not being sought to cover the *process* by which the facets were applied to the rough diamond. Instead, the author argued that the steps taken in extrapolating the standard round brilliant to the Elara design constituted acts of *sculptural authorship*.

The appeal began by describing the basics of the round brilliant cut, as described in Tolkowsky (1919), for maximizing brilliance and fire. As a foun-

ation for the creativity and authorship behind the Elara design, the author's brief set forth Mr. d'Haene's extensive experience with De Beers and the Diamond High Council (HRD) in Antwerp. During the 1980s, while a partner of a Belgian company engaged in selecting and buying diamonds for the Japanese market, he saw the need to design new diamond cuts for Japanese tastes, one of which involved the concept of "squaring the circle."

In creating this design, certain crown facet lines were extended outside of the original circle and connected to form a new, square outline with cut corners, the pattern repeating itself for each quadrant of the crown. The final cut evolved from trial and error through several different designs. The results of Mr. d'Haene's design efforts are shown in figure 2.

## ARGUING THE APPEAL

In pressing the appeal, we argued that each step in the creation of the Elara cut was the result of artistic design efforts, including personal independent creative thoughts that led to certain facet arrangements. We established that design, in this particular case, went far beyond the level of creativity required to support copyright registration. We also specifically pointed out that the final design was motivated in substantial part by an attempt to create an original work that would convey a visual impression that had not been seen before. Moreover, it would present a markedly different visual image compared to other diamond designs on the market at that time. We also argued that the design retained a significant degree of the brilliance that can be produced by the round brilliant cut.

The description of the specific design steps also supported our contention that the design was not based on a familiar geometric shape, but a combination of facet shapes in a specific, complex arrangement providing the finished design with its unique character. We argued that the creative expression embodied in the design was capable of standing alone as an independent copyrightable work, and not an agglomeration of several standard forms or shapes with minor linear or spatial variations. We specifically pointed out to the Copyright Office that the design comprised originality of facet coordination and arrangement, whereby the shape and position of each facet in the total design coordinated with other facet shapes and positions to provide an eye-catching attractive design.

The requisite authorship for copyright registration was shown to be the particular steps taken in

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the extrapolation of the round brilliant to the square brilliant design, as a result of the effort and thought of Mr. d'Haene. We argued that the totality of the subject diamond design, considered as a whole, produces an aesthetic effect and appearance that conveys to the viewer the beauty of design.

## THE DECISION

On November 6, 2001 (M. Peters, pers. comm.), the Register of Copyrights responded to our appeal as follows:

After careful consideration, the Copyright Office Board of Appeals has decided to register the Flanders Brilliant (ELARA) diamond. The registration is only for the three-dimensional faceted stone because of the complexity of the overall sculptural configuration. We rarely see such complexity in gemstones used in jewelry design, and we cannot recall previously making such a registration. The registration of course does not cover any aspect of the faceting process.

In its letter, the Copyright Office also noted that courts have held that copyright protection in this type of work may be limited, particularly where the copyrightable work comprises a unique combination and arrangement of otherwise un-copyrightable elements in the particular design. This means that copyright protection only extends to the design as a whole; others may freely use the individual, un-copyrightable, elements to come up with a new gemstone design having a different overall design and appearance.

## CONCLUSION

It remains to be seen whether the Copyright Office's determination that certain gemstone designs embodying acts of creative authorship are copyrightable sub-

ject matter will be followed by the U.S. federal courts, which have the inherent power to overturn such decisions. And since this is the first gem design to be registered, it is also unclear where the courts will draw the line on infringement, that is, how close competitors may come to a copyrighted gem design without infringing on the copyright. Another unanswered issue is the degree to which published, and thus copyrighted, collections of faceting diagrams for hobbyists provide protection for the designs therein.

Gemstone designers hoping to apply for copyright registration for a new design should record the mental, geometric, artistic, and analytical processes leading to the final design in order to support a conclusion of creative and artistic authorship. It would probably be helpful to retain all preliminary drafts of sketches, drawings, and calculations prepared during the design process, should it be necessary to respond to a denial of registration based on a lack of creative authorship. An applicant must also be able to describe how his or her new design differs from existing gemstone designs.

The copyright registration that was obtained by Kuwayama Europe n.v. and Elara Diamond USA, provides its owners with the ability to prevent others from copying the Elara diamond design in their own gemstone products. (Although the Elara design patent is currently being challenged in a U.S. federal court case [see "Elara diamond design patent invalidated. . .," 2003], this case has no bearing on the validity of the copyright.) Kuwayama believes that it fully understands the limitations of the copyright protection afforded by its registration. Nevertheless, the copyright registration obtained on the Elara cut is a pioneering example of how creative authorship, originality, and creativity can combine to produce a gemstone design that meets the requirements of the U.S. copyright laws to support copyright registration.

### ABOUT THE AUTHOR

Mr. Rockman ([hrockman@btlaw.com](mailto:hrockman@btlaw.com)) is an intellectual property attorney with the Chicago law firm of Barnes & Thornburg. As counsel for Kuwayama Europe n.v. of Antwerp, Belgium, he was instrumental in obtaining the U.S. Copyright registration for the Elara gemstone design.

### ACKNOWLEDGMENTS

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### Dyed Black CHALCEDONY

Relatively common opaque black materials may provide challenging identifications because of their surface condition, their shape, or the way they are set in a piece of jewelry. The West Coast laboratory was recently asked to identify the black carved material in the pendant shown in figure 1.

This black hololith had been inset with numerous transparent near-colorless round brilliants in white metal mountings and was further embellished with a row of what appeared to be small pearls around its periphery. The black material was unpolished and showed a dull luster. It was obvious that only limited stan-

dard gemological testing could be performed on such a piece.

Our initial examination with a microscope showed that the black material was homogeneous. We also noticed a few dull conchoidal fractures. A detailed examination with intense fiber-optic illumination revealed that the black-appearing hololith actually was dark brown in color, and there were indications of a layered structure. Using hardness points in an inconspicuous place, we estimated the Mohs hardness to be approximately 6. Next, we attempted to obtain a refractive index reading by carefully placing the back of the hololith on the refractometer in a small area where the white metal mountings were less obstructive; the result was a vague reading in the mid-1.5s.

On the basis of these properties, we determined that the hololith had been carved out of chalcedony. To support this conclusion, we analyzed the material with the Raman spectrometer. The presence of two distinct peaks, one at  $1600\text{ cm}^{-1}$  and the other centered at  $461\text{ cm}^{-1}$ , identified the black material as chalcedony and

Figure 1. The carved black hololith ( $14.70 \times 4.10 \times 2.90\text{ mm}$ ) in this attractive pendant proved to be dyed black chalcedony.



*Editor's note: The initials at the end of each item identify the editor(s) or contributing editor(s) who provided that item. Full names are given for other GIA Gem Laboratory contributors.*

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indicated the presence of a carbonized compound (sugar). In addition, infrared spectroscopy showed two peaks at approximately 2235 and 2133  $\text{cm}^{-1}$ , which—our research has found—indicate that the color is the result of treatment by sugar and acid (and/or heat). This material is typically known in the trade as black onyx.

*KNH, JIK, Dino DeGhionno,  
and Philip Owens*

### Some Unusual Type II DIAMONDS

In contrast to the more common type Ia diamonds, type IIa diamonds are relatively pure, containing little (if any) nitrogen impurities. By definition, type IIb diamonds contain traces of boron (usually less than 1.0 ppm), but the overall concentration of impurities in type IIb diamonds is typically even less than in type IIa diamonds. Because of their high purity, type II diamonds (both IIa and IIb) display fairly consistent luminescence features in comparison to type Ia diamonds. Natural type IIa diamonds may show a weak-to-moderate blue fluorescence to long-wave UV radiation, and weak blue or yellow fluorescence to short-wave UV; they rarely phosphoresce. The vast majority of type IIb diamonds show no observable fluorescence to either long- or short-wave UV radiation. Of the small number that do show a readily observable fluorescence, the reaction is a weak yellow, chalky blue, or, rarely, red to either wavelength. Type IIb diamonds also commonly phosphoresce to short-wave UV radiation, showing yellow, chalky blue, or red or orange red.

The East Coast laboratory recently examined one type IIa (1.53 ct) and two type IIb diamonds (5.69 and 42.05 ct; figure 2) that displayed unusual luminescence features and photoluminescence spectra, which suggest a new type of lattice defect in diamond. All three diamonds were apparently submitted by coincidence, within a narrow time frame, from two different clients. The smaller type IIb diamond, fashioned as a



Figure 2. These type IIb diamonds (5.69 and 42.05 ct) showed unusual luminescence features and photoluminescence spectra.

cushion brilliant, was graded Fancy grayish blue. The larger type IIb diamond, reportedly from southern Africa, was only partially faceted (and thus not graded). It showed strong blue coloration, and was partially covered by natural resorbed surfaces. Unlike most type IIb diamonds that show luminescence, these two diamonds fluoresced weak orange to long-wave UV, and moderate to strong yellow (with a very strong blue phosphorescence—lasting more than 60 seconds) to short-wave UV (figure 3). The same luminescence features also were observed in the type IIa diamond, which was a D-color pear-shaped brilliant. The two faceted diamonds were free of inclusions when examined with the gemological microscope, up to 60 $\times$ . Our preliminary examination of the larger type IIb blue diamond did not reveal any inclusions. No indications of any coating or overgrowth in these three diamonds were observed.

Nearly identical photoluminescence spectra were recorded from the three diamonds with 514.5 nm laser excitation using a Raman spectrometer at liquid nitrogen temperatures. We recorded more than 20 sharp emission lines in the visible-infrared range, which in our experience is very unusual for type II diamonds. Six point analyses performed on randomly selected spots on the type IIa diamond yielded no observable differences in peak position or relative intensity. This observation also was confirmed

for the two type IIb diamonds. In general, the emission lines could be divided into two groups according to their positions. Eight sharp lines occurred in a narrow region of 725–745 nm, with the four strongest lines at 727.2, 729.2, 734.8, and 736.9 nm. A total of 19 sharp emission lines occurred in the region 768–791 nm, with the four strongest lines at 770.1, 774.4, 781.5, and 782.8 nm. This kind of emission spectrum is quite distinct from the vibronic optical centers that usually occur in diamond, which each consists of a sharp zero-phonon line and a broad side band at the lower energy side. Interestingly, when photoluminescence spectra were recorded using

Figure 3. As shown here for the 5.69 ct stone, the type IIb blue diamonds displayed very strong blue phosphorescence to short-wave UV that lasted more than 60 seconds.



red laser excitation (632.8 nm), the second group of emission lines was absent.

Many of these emission lines, such as those at 780–800 nm, have not been reported in the literature previously; however, the line at 727.2 nm is very close to the well-studied 727.0 nm emission in type Ib synthetic diamonds grown in high pressure/high temperature conditions, which is attributed to Ni-related defects (see, e.g., S. C. Lawson et al., "Spectroscopic study of cobalt-related optical centers in synthetic diamond," *Journal of Applied Physics*, Vol. 79, 1996, pp. 4348–4357). The emission line at 736.9 nm is slightly but clearly shifted away from the Si-related defect at 737.5 nm seen in many synthetic diamonds grown by chemical vapor deposition. Considering that these three diamonds were all type II, and all showed the unique multi-emission lines in a narrow region, it is unlikely that they could contain any detectable Ni or Si impurities. EDXRF analysis of the 5.69 ct blue diamond confirmed that there was no detectable chemical impurity above sodium. Because these emission lines were nearly identical in the type IIa and IIb diamonds, a direct relationship of the defect(s) to boron or a boron/nitrogen complex could also be ruled out.

The physics of the defect(s) responsible for these emission lines remains unclear, but it is reasonable to assume that more than one defect was involved based on the reactions of those emission lines to different laser wavelengths. It is also reasonable to assume that the defect(s) contributed to the uncommon reactions of these diamonds to UV radiation. Based on their spectroscopic data and gemological features, we are confident that these diamonds have not been HPHT treated. To the best of our knowledge, there is no published report that irradiation or ion implantation could produce the unusual spectroscopic features either.

Wuyi Wang, Matthew Hall,  
Christopher P. Smith, and TM



Figure 4. This 6.34 ct colorless leadhillite may be the only faceted specimen of this unusual mineral.

#### A Faceted LEADHILLITE

The West Coast laboratory recently had the opportunity to examine a very rare 6.34 ct faceted leadhillite. According to Cynthia Renée, of Cynthia Renée Co. in Fallbrook, California, this stone was faceted from a specimen featured in John Barlow's *The F. John Barlow Mineral Collection* (Sanco Publishing, Appleton, WI, 1996). In the book, the specimen (reportedly from Tsumeb, Namibia) was described as having "large areas of 'flawless' material," and it was speculated that it could be cut into "the only known faceted gem leadhillite" (p. 303). Leadhillite— $\text{Pb}_4(\text{SO}_4)(\text{CO}_3)_2(\text{OH})_2$ —is typically found as small-to-microscopic tabular pseudo-hexagonal crystals, but it can also be massive and granular. Usually, the material is transparent to translucent, and it may be colorless to white, gray, yellow, or pale green. It is named for the district in Scotland where it was first discovered (R. Gaines et al., *Dana's New Mineralogy*, 8th ed., John Wiley & Sons, New York, 1997, p. 520). Since leadhillite is extremely soft (2½ to 3 on the Mohs scale) and has perfect cleavage in one direction (001), with indistinct cleavage in another (100), faceting it would be quite a challenge.

The stone we examined was a transparent, colorless, modified oval step cut with moderate dispersion (figure 4). Because the R.I. of leadhillite (1.87–2.01) is over the limits of a standard refractometer, and the hemicylin-

der (with a hardness of 4), could potentially scratch the stone, we opted not to attempt to determine the refractive index. The specific gravity (measured hydrostatically) was 6.53, which matches published values for leadhillite. This stone displayed only very weak violet fluorescence to both long- and short-wave UV radiation. Microscopic examination revealed "fingerprints," fractures, twinning, cleavage planes, growth tubes, and strong doubling.

Since our standard gemological examination was limited by the nature of the material, we found it necessary to perform more-advanced testing. Unfortunately, Raman analysis was of little help to us in this identification because, due to its rarity, leadhillite was not in our database. However, the stone did yield a good spectrum, which will be used for future reference. The pattern produced by X-ray powder diffraction of a minute sample (taken with the client's permission) contained several strong lines that matched both leadhillite and susannite (a polymorph of leadhillite).

To help distinguish between leadhillite and susannite, we had to closely observe the optic figures. Leadhillite is biaxial with a small 2V angle (formed by the separation between optic axes in biaxial materials, which is evidenced by the relationship between the two optic figures when the stone is viewed between crossed polarizing filters). Susannite is typically uniaxial, but can be slightly biaxial with a 2V angle of up to 3°. In the polariscope, the optic figures revealed that the stone had a 2V angle of at least 10°, which effectively eliminated the possibility of susannite. On the basis of this and the other findings, we concluded that the stone was indeed leadhillite.

Elizabeth P. Quinn

#### PEARLS

##### Cultured Pearl Mystery

A small lot of 12 undrilled white pearls that recently came into the East Coast laboratory were unlike

any we have seen before. The pearls were symmetrical, primarily off-rounds and oval button shapes, and ranged from approximately 6 to 8 mm in diameter (figure 5). They all showed a very high luster and fine orient, but their most remarkable feature was the transparency of the nacre layer. This particular quality, known among pearl connoisseurs as "water," is not often encountered. An X-radiograph revealed evidence of growth structures associated with tissue and/or bead nucleation, which proved that the pearls were cultured. Testing for luminescence to X-rays produced no reaction in any of the cultured pearls, which indicated that they were of saltwater origin.

However, it remains a mystery as to which mollusk produced these cultured pearls. To our knowledge, the only species that shows this nacre transparency in white pearls is the black-winged pearl oyster *Pteria penguin*. However, this pearl oyster is used primarily to produce the top portion of a cultured mabe pearl assemblage (see, e.g., R. Crowning-shield, "Cultured 3/4 blister pearls," Spring 1982 *Gems & Gemology*, p. 38). We would welcome information from our readers on whether this oyster is now also being used to culture whole pearls.

KNH

#### Treated-Color "Golden" South Sea Cultured Pearl

The 12.7 mm undrilled orangy yellow cultured pearl shown in figure 6 was submitted to the West Coast laboratory for testing. The owner was suspicious that the intense orangy yellow color might not be natural.

Indication of color treatment was observed during an initial low-power microscopic inspection with fiber-optic lighting. Although the color appeared even to the unaided eye, magnification revealed a faint patchiness: Spots of more intense color distributed over the surface produced a subtle "leopard skin" appearance.

Subsequent exposure to long-wave

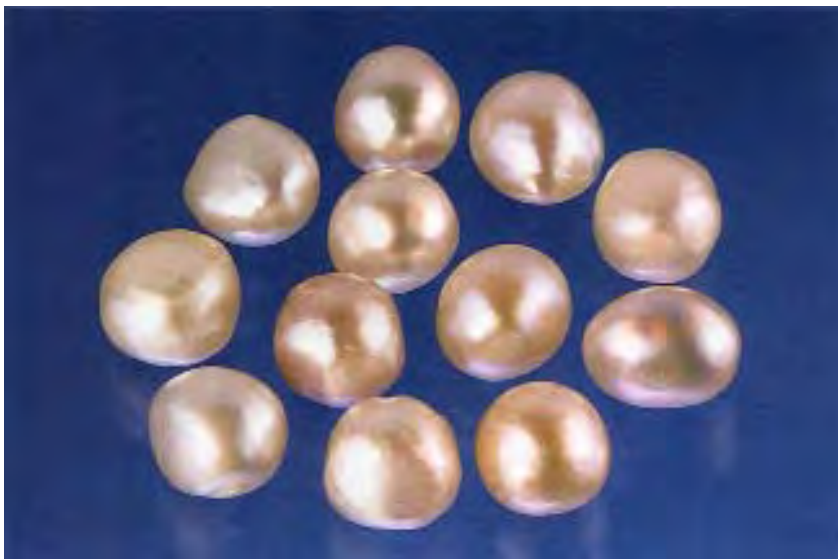


Figure 5. These cultured pearls of unknown origin (approximately 6–8 mm) displayed unusual transparency of their nacre layer.

UV radiation produced a strong, slightly uneven, light greenish yellow fluorescence, with a slightly orangy overtone in some areas. This is uncharacteristic for natural-color strong orangy yellow cultured pearls from the *Pinctada maxima*. However, a strong light greenish yellow fluorescence is typical for light yellow natural-color *P. maxima* cultured pearls, and the orangy component of the fluorescence is indicative of color treatment.

As part of an ongoing study into the identification of treated color in cultured pearls, the sample was then characterized by UV-visible spectroscopy. The UV-Vis spectrum exhibited a prominent broad absorption at 456 nm, which was unlike any previous UV-Vis feature obtained for natural- or treated-color "golden" cultured pearls. The UV absorption between 330 and 385 nm, characteristic of natural yellow color, was absent.

Analysis by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy showed that, in addition to calcium and strontium, iron and trace amounts of sulfur were also present. While Ca and Sr are inherent to the chemistry of nacre, and it is not

uncommon to find traces of sulfur in *P. maxima* shells or cultured pearls, the presence of iron is not consistent with natural color.

In some cases, color treatment can be detected by Raman analysis. However, no spectral signature was observed for this sample, as the Raman signal was masked by the strong fluorescence.

All of these findings are inconsistent with natural-color "golden" South Sea cultured pearls. We believe

Figure 6. The color of this 12.7 mm "golden" cultured pearl is due to treatment.



that these characteristics represent a distinctive type of treatment that is being applied to produce the “golden” color. Unlike many color treatments, which can be difficult to detect, this one exhibits a suspicious long-wave UV fluorescence and is readily identifiable by magnification, UV-Vis spectroscopy, and EDXRF.

*Shane Elen and CYW*

## QUARTZ

### Crystal with “Lizard” Inclusion

Gems and gem-mineral objects that appear to contain small animals or other unusual but recognizable forms are always popular because they serve to stimulate the observer’s imagination. When such features are highlighted by lapidaries and jewelry designers, they often result in

*Figure 7. This 51-mm-long partially polished phantom quartz crystal contains the likeness of a tiny green lizard with an angular dark head that can be seen perched on top of the brown phantom.*



*Figure 8. Raman analysis of similar inclusions revealed that the 1-cm-long “lizard’s” body and tail are composed of chlorite, while its head is an anatase crystal.*

interesting fashioned items and one-of-a-kind pieces of jewelry. A recent example of this seen in the lab was a pseudo-“lizard” in a partially polished crystal from the famous phantom quartz locality near Buenópolis, Minas Gerais, Brazil. The specimen was obtained from Kevin Lane Smith of Tucson, Arizona. Mr. Smith had polished a clear flat window to offer the best possible view of the inclusion scene.

The 51-mm-long quartz crystal was a very light smoky brown (figure 7). It contained a phantom composed primarily of altered brown chlorite that had the appearance of a mound of dirt or brown rock. While such phantoms are well known from this locality, what made this one unique was the 1-cm-long bimineralic “lizard” sitting on the tip of the phantom, the “body and tail” of which appeared to be composed of green chlorite, with an angular dark submetallic gray “head” formed by what looked like a single anatase crystal (figure 8).

The “lizard” was too deep in the host for Raman analysis, but inclusions similar to both of these minerals were exposed on the surface at the base of the crystal. The Raman

spectra of these exposed inclusions confirmed that the green mineral was chlorite, possibly clinocllore, while the crystal that resembled a lizard’s head was anatase. Chlorite is relatively common in quartz, but anatase is not. While these analytical results might take away some of the “magic” of this unusual inclusion construct, the pursuit of the solution to a mystery offers its own rewards.

*JIK and Maha Tannous*

### Unusual Mottled Pink

Two faceted mottled pink and colorless quartz gems were submitted to the West Coast laboratory by Luciana Barbosa, of the Gemological Center in Belo Horizonte, Minas Gerais, Brazil. The rough from which the two stones were cut was reported to have come from the Araçuaí region of Minas Gerais. This is the same locality that produced the distinctly color-zoned pink and colorless quartz that was reported in the Fall 1993 Lab Notes section (pp. 203–204). Magnification revealed that the earlier sample derived its fairly uniform pink face-up color

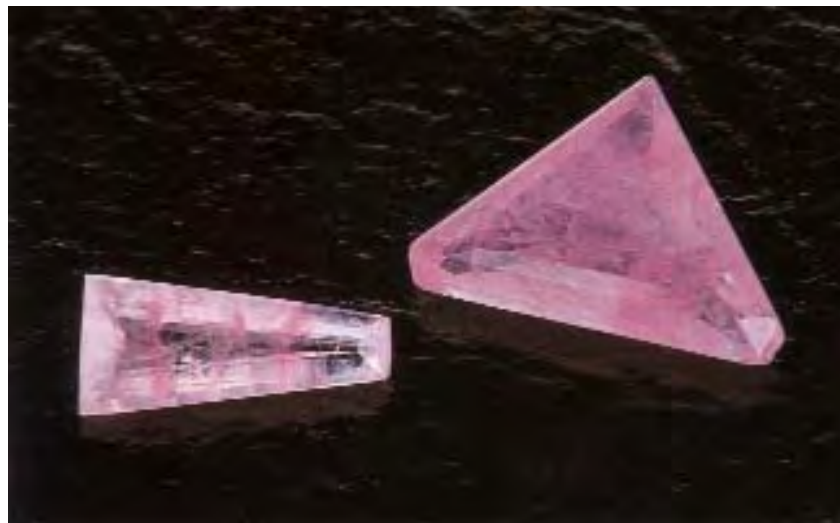


Figure 9. These two faceted examples of pink and colorless quartz (0.98 and 2.67 ct) have an unusual mottled color distribution.

from sharply defined parallel bands of intense pink color in an otherwise colorless stone. The gems examined recently had uneven coloration that was obvious even to the unaided eye (see figure 9). The smaller, 0.98 ct, stone was a trapezoidal step cut; the larger, 2.67 ct, stone was a triangular step cut.

Using standard gemological testing, we first confirmed the identification of these stones as quartz. This was a straightforward procedure with—almost—no anomalies or surprises. The exception was the distribution of color seen with magnification, as shown in figure 10; we had never before seen a roiled appearance such as this in quartz of any color.

For comparison with the quartz reported in 1993 (which contained, and was probably colored by, iron), we performed EDXRF qualitative chemistry on the 2.67 ct stone, since it was the more saturated of the two. Just as with the earlier gem, this testing revealed the expected abundant silicon, as well as iron as the only trace element. This chemistry gave further support to the strong possibility that these two gems did in fact come from the same deposit near Araçuaí that produced the sharply zoned stone examined earlier.

JIK, Maha Tannous,  
and Sam Muhlmeister

#### QUARTZITE Dyed to Imitate Ruby

“If you wish to make a ruby from Crystal . . .” is the beginning of a “recipe” for dyeing colorless quartz to simulate ruby that dates back to at least 400 A.D. (see K. Nassau, “The early history of gemstone treatments,” Spring 1984 *Gems & Gemology*, pp. 22–33). Many of the basic methods and principles used to treat gems have actually been in practice for thousands of years, with written accounts dating



Figure 10. At 10× magnification, the roiled appearance of the coloration in the unusual mottled quartzes shown in figure 9 could be seen.

back almost two millennia. Nevertheless, only occasionally do we encounter these early treatments in the laboratory.

Recently, the East Coast laboratory received a yellow metal necklace with 29 variously shaped semitransparent purplish pink to purplish red beads (figure 11), which ranged from approximately 8.05 × 5.90 × 4.00 mm to 5.80 × 5.25 × 3.90 mm. At first glance, the beads resembled fine ruby or pink sapphire, but closer examination with diffused transmitted light pointed in a very different direction (figure 12). Magnification revealed that each bead was riddled with tiny concentrations of purplish red dye around and between the grains of this aggregate material, as well as in surface-reaching fractures. The beads fluoresced a mottled medium-strong to very weak orange to long-wave UV radiation, and

Figure 11. The 29 beads in this necklace are quartzite that has been dyed to imitate ruby (left). The dye fluoresces orange to long-wave UV radiation (right). The fluorescing dye can sometimes be seen defining the grain boundaries and/or other surface-reaching fractures it fills.







Figure 12. With diffused lighting, dye concentrations can be seen in this bead even without magnification (left). The dye concentrations in this aggregate are found in the spaces between and around the individual quartz grains, as well as in small surface-reaching fractures and fissures within the grains, as seen here at 120× (right).

only slightly weaker to short-wave UV (again, see figure 11). Such fluorescence has been noted previously in purple and red dye used to color quartz in conjunction with quench crackling (see Lab Notes, Spring 1996, pp. 49–50; Fall 1997, pp. 216–217). However, these beads did not have to be quench-crackled to accept the dye, due to the aggregate nature of the material.

No chromium or iron lines were visible in the desk-model spectroscope, as should have been seen if these beads were ruby. However, there was a feature that might have fooled inexperienced gemologists—an absorption band with a maximum at about 570 nm and a “shoulder” at an average of approximately 530 nm. A similar band was reported by K. Schmetzer et al. in a study of corundum dyed to simulate ruby (“Dyed natural corundum as a ruby imitation,” Summer 1992 *Gems & Gemology*, pp. 112–115). The authors concluded that the absorption band of the dye, which mimics the major chromium absorption band in ruby (at about 550 nm), was probably the cause of the convincing color in the imitation.

The beads we tested gave spot refractive index readings of 1.54. Since they also showed an aggregate reaction in the polariscope, and no optic figure could be found, they were identified as quartzite, a crystalline to microcrystalline rock consisting primarily of quartz.

Although we don’t regularly see

dyed quartz in the laboratory, this necklace serves as a reminder, once again, that some of the oldest and simplest gem treatments practiced by ancient alchemists are still being used today.

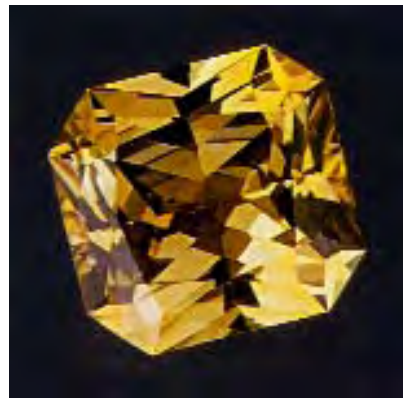
Wendi M. Mayerson

#### Unusual Inclusions in a Beryllium-Diffused SAPPHIRE

The West Coast laboratory recently examined an interesting 4.75 ct light yellow cut-cornered rectangular brilliant that gemological testing proved to be a beryllium-diffused natural sapphire (figure 13).

The refractive indices were 1.761–1.769, and no visible-light spec-

Figure 13. This 4.75 ct light yellow sapphire proved to be beryllium diffused.



trum was observable through the spectroscope. When the stone was exposed to long-wave ultraviolet radiation, a moderate-to-strong orange luminescence was seen; to short-wave UV, it fluoresced a moderate chalky reddish orange with a slightly bluish white overcast. All of these properties are consistent with yellow sapphire.

Microscopic examination revealed straight growth zoning and a small partially healed fracture (“fingerprint”) inclusion. In addition, immersion in methylene iodide showed a yellow surface-conformal color zone around a colorless center, which proved that the stone had been lattice diffusion treated (see, e.g., J. L. Emmett et al., “Beryllium diffusion of ruby and sapphire,” Summer 2003 *Gems & Gemology*, pp. 84–135).

However, as shown in figure 14, this stone also contained numerous very unusual ribbon-like semicircles composed of minute white particles and what looked like stringers and what appeared to be tiny bubbles. We had never encountered this type of inclusion in any corundum, natural or synthetic. Since most inclusions are adversely affected by high-temperature heat treatment, we interpreted these to be a result of the heat treatment this sapphire had undergone during the lattice-diffusion process.

JIK, KNH, and Maha Tannous

Figure 14. These unusual ribbon-like semicircles observed in the 4.75 ct yellow sapphire are made up of minute white particles and what appear to be bubbles. Magnified 40×.



## STICHTITE Flowers

The West Coast laboratory recently examined an interesting 6.97 ct cushion-shaped polished double cabochon that was submitted for identification together with three small rough slabs, each of which had one polished face. The semi-translucent to opaque cabochon, which measured 16.30 × 12.17 × 4.97 mm, showed a mottled texture and very slightly pinkish purple color (figure 15). The three slabs were identical to the cabochon in color, diaphaneity, and texture.

We first used standard testing to acquire the basic gemological properties. The refractive index obtained from a flat polished surface on one of the slabs was 1.52–1.55; specific gravity for the cabochon (determined hydrostatically) was 2.13. A typical chromium absorption spectrum, showing three lines in the red region, was observed with the desk-model spectroscope on all four samples. All of the samples were inert to both long- and short-wave UV radiation.

As seen in figure 16, microscopic examination revealed an almost oolitic structure composed of numerous pinkish purple, circular to ovoid, platy floral masses, some of which had tiny opaque black grains at their centers. The cabochon and slabs were all slightly attracted to a magnet, which we attributed to the presence of the tiny black mineral grains. We surmised that these grains might be either chromite or hematite, although chromite was the first choice because of the chromium spectrum shown by the material. Since all of the visible mineral grains seemed to be at the centers of the pinkish purple “flowers,” we speculated that these grains formed the nucleus for growth of the purple mineral.

One of the slabs was tested with a minute droplet of hydrochloric acid, and it showed a weak carbonate effervescence that was clearly visible through the microscope. When a thermal reaction tester was touched to the edge of one of the slabs, the mineral lost its pinkish purple color and decrepitated to brown particles,



Figure 15. This 6.97 ct cabochon proved to be the ornamental gem material stichtite.

which suggested that it might be hydrated as part of its chemistry.

The gemological properties and general appearance of the samples served to identify them as stichtite, a rather unusual massive gem material with the chemical formula  $Mg_6Cr_2(CO_3)(OH)_{16} \cdot 4H_2O$ . Since we rarely see such material, we decided that advanced testing should be done to get a full documentation for our records. The additional tests performed included X-ray powder diffraction and EDXRF of one of the samples, as well as Raman spectroscopy on both the material itself and the tiny black grains.

X-ray powder diffraction showed a structural match that fit stichtite better than its dimorph, barbertonite; the gemological properties also supported this distinction. EDXRF gave a qualitative composition that was consistent for both stichtite and barbertonite, with Mg and Cr as the two major elements. Raman analysis gave us a good standard pattern for stichtite, and identified the tiny black grains as chromite.

Gem-quality stichtite has been found in Australia, Canada, and South Africa. It occurs in serpentine rocks in association with chromite; this association fits well with the data we obtained from these samples. Although it is unusual, such stichtite has been previously described in *Gems & Gemology*, by R. Webster (“Stichtite, an ornamental stone,” Spring 1955, pp. 149–150, 156), and more recently in the *Australian Gemmologist*, by R. S.



Figure 16. These “flowers” of stichtite appear to have nucleated around minute opaque black crystals of chromite. Magnified 25×.

Bottrill and G. Brown (“Rare Australian gemstones: Stichtite,” Vol. 20, No. 9, 2000, pp. 391–393).

JJK, Dino DeGhionno,  
Philip Owens, Sam Muhlmeister,  
KNH, and Maha Tannous

## Addendum: Cat’s-eye OPAL

In the Summer 2003 Lab Notes (p. 148), we reported on a chatoyant opal with an eye that “opened and closed,” much as cat’s-eye chrysoberyl and many other chatoyant materials do when viewed under two light sources. This phenomenon had apparently not been reported before in those rare cat’s-eye opals with eyes composed entirely of play-of-color.

Note, however, that the 4.59 ct cat’s-eye opal reported in the Spring 2003 Lab Notes (pp. 43–44) also displayed this phenomenon. Since the focus of that report was on the fact that the stone showed a strong cat’s-eye composed of play-of-color, with a full range of spectral colors when it was viewed in the right position, we neglected to report that the eye also opened and closed. SFM

### PHOTO CREDITS

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## DIAMONDS

**Australia's largest diamond crystal found at Merlin.** In March 2002, a 104.73 ct gem-quality rough diamond (figure 1) was recovered from the Gareth pipe at the Merlin project in Australia's Northern Territory (see Summer 1999 Gem News International, pp. 143–144). This piece of rough, which was only recently announced to the public, measures  $38.22 \times 26.20 \times 16.32$  mm, and is the largest diamond ever reported from Australia.

The Merlin project is situated on land owned by the Garrawa and Gurdanjii clans of Australian aboriginal peoples. As such, these clans have bestowed the name for the diamond—"Jungjila Bunajina," which translates to "Star Meteorite Dreaming Stone."

Figure 1. This 104.73 ct diamond, recovered from the Merlin project in March 2002, is reportedly the largest ever found in Australia. Courtesy of Argyle Diamonds.



Since it was purchased in November 2000 from Ashton Mining Ltd., the Merlin property has been 100% owned by Rio Tinto Ltd. and operated by Argyle Diamonds (Perth, Australia). More than 400,000 carats of rough diamonds were recovered from the beginning of trial mining in 1998 until late May 2003, when activities were discontinued because the deposit did not meet the scale and revenue parameters required by Rio Tinto. Argyle estimates that the large crystal can be cut into a pear-shaped stone of 30–35 ct, plus another four or five smaller diamonds.

Thomas W. Overton

**Update on diamond mining and exploration in the Slave Province, NWT, and northern Alberta, Canada.** This contributor joined a field trip held June 14–21, 2003, in connection with the 8th International Kimberlite Conference in Victoria, British Columbia (see Conference Reports below), and collected information on several Canadian diamond deposits. The itinerary included properties in several stages of development, from exploration to full production: Mountain Lake and Buffalo Hills in Alberta; and Snap Lake, Diavik, and Ekati in the Northwest Territories (NWT). The trip leaders were Dr. John Armstrong of the C. S. Lord Northern Geoscience Centre in Yellowknife, Roy Eccles of the Alberta Geological Survey in Edmonton, and Dr. Herbert Helmstaedt of Queen's University, Kingston, Ontario. Participants received a publication that contains more information on the deposits described below (B. A. Kjarsgaard, Ed., *VIIIth International Kimberlite Conference, Slave Province and Northern Alberta Field Trip Guidebook*, June 2003, Geological Survey of Canada, Ottawa). The information provided here updates the comprehensive article in the Fall 2002 issue of *Gems & Gemology* (B. A. Kjarsgaard and A. A. Levinson, "Diamonds in Canada," pp. 208–238).



Figure 2. The Koala kimberlite at Ekati is visible as the dark-colored rock in the center of the open pit. Each bench is about 30 m high. Photo by Mary L. Johnson, June 2003.

*Ekati.* Access to BHP's Ekati mine is solely by air except for six to eight weeks during the winter, when an ice road is maintained over the frozen ground and lakes. About 800 people currently work at the mine. There are at least 168 kimberlites on the property, and exploration is not yet complete. So far, the exploitable kimberlites include Panda (now mostly mined out), Koala, Koala North, Misery, Fox, Sable, Pigeon, and Beartooth. Current diamond production is about 90% from Koala and 10% from Misery.

Construction and mining at Ekati follow strict environmental guidelines. Dams and thermo-siphons (see Diavik section, below) surround the mine pits, since these areas were formerly occupied by lakes or embayments. Twenty-eight lakes have been drained so far, although most of these have been very small. The mine's impact on wildlife (i.e., fish, mammals, and birds) continues to be closely monitored.

The 3 hectare (ha) Panda pipe was the first to be exploited (ore grade 1.1 ct/tonne), and is no longer being mined. The open pit is 1 km across and about 300 m deep. About 8,000–10,000 tonnes of ore remain in the pit, under about 3 m of water, and will be recovered at some point in the future with underground techniques.

At the Koala pipe (figure 2), the ore grade is 1 ct/tonne (at \$96/ct), with a current size cutoff of 3 mm (that is, material smaller than 3 mm is not recovered in the mining process). The top of this deposit is being mined as an open pit, but plans are to go underground when the 220 m level is reached (levels are designated relative to sea level). At

the 300 m bench currently being mined, the ore grade was about 1.5 ct/tonne, and the pipe was about 4.5 ha in size. Koala North is a small (0.5 ha) pipe between Panda and Koala that is ready to be mined with underground techniques.

Misery is the southernmost exploited site at Ekati, about 28 km by road from the main plant and 7 km by air from the Diavik mine. The road to Misery goes over a narrow bridge, so relatively small (70 tonne) trucks must be used to haul the ore. These deliver 2,000 tonnes/day to the main plant. Nine diamondiferous bodies (pipes and sills) are present at Misery. The southernmost body, at 1 ct/tonne, is not economic. The average grade at Misery is 3–4 ct/tonne, but the diamonds are only valued at about \$35/ct.

Fox is a large (17 ha) pipe with ore grades of 0.4 ct/tonne, and total reserves of 6.6 million carats (Mct). It will take about three years to remove the overburden before extraction can begin. The expected mining life of the Fox pipe is about seven years.

Grease tables are used for recovery at Ekati, since some of the diamonds are graphite coated and do not fluoresce sufficiently to X-rays. The feed procedures must be adjusted for each pipe. About 30,000 tonnes of ore are stockpiled in towers at the processing plant, so diamond recovery can continue even when severe weather prevents mining. Within five years, Ekati should be drawing ore from seven pipes for processing. Each pipe has a distinct range of sizes and qualities, which will enable a consistent range of goods.

*Diavik.* As with Ekati, access to the Diavik mine is mainly by air, with a winter road open for a short season. Diavik is owned 40% by Aber Diamond Corporation and 60% by Diavik Diamond Mines Inc. (DDMI), which is wholly owned by Rio Tinto. There are about 500 employees and contractors on site. The claim area is 146,000 ha, and is covered by up to 30 m of glacial till. The kimberlite pipes are small, averaging 0.9–1.6 ha. There are 63 known kimberlites on the property, of which 35 have produced at least one diamond, 26 have undergone bulk (or similar) testing, and four are economic:

*Editor's note: Interested contributors should send information and illustrations to Brendan Laurs at blaurs@gia.edu (e-mail), 760-603-4595 (fax), or GIA, 5345 Armada Drive, Carlsbad, CA 92008. Original photos will be returned after consideration or publication.*

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A154N, A154S, A418, and A21. By 2015, all four pipes are expected to be in production, and the operation is expected to have a 20-year life span. Remediation should be complete by 2025.

All four of the kimberlites were situated under about 10 m of water, making a dam necessary for open-pit mining. This boundary dam is kept frozen (and structurally stable) using liquid-CO<sub>2</sub> thermo-siphons, which withdraw heat from the base of the dam. Including its foundations, the dam is up to 30 m deep. As with Ekati, environmental protection is critical at Diavik.

Reserves are 22.1 million tonnes (Mt) of ore at approximately 4 ct/tonne (for a total of 87.3 Mct) from open-pit mining, and 5.0 Mt of ore at 3.9 ct/tonne (19.5 Mct) from underground mining, totaling 106.7 Mct. The largest diamond found so far weighed 102.58 ct, but was not gemmy. The mine cost C\$1.3 billion to construct, and operation costs are C\$170 million per year. About 70% of costs are paid to northern (NWT, Nunavut, or Yukon) suppliers, and about 40% of the value of mining accrues to governments as royalties and taxes.

The A154S open pit has reached the 370 m level (figure 3). A154N is being stripped of its overburden (up to 25 m of till) in preparation for mining. The tops of the kimberlites are extensively weathered, and the upper half-meter is often mixed with till material.

The processing plant (figure 4) recovers 16,100 carats/day on average, using X-ray sorting for the final diamond separation. Grease tables are used to audit diamond recovery.

The first diamonds from Diavik were delivered in January 2003. Production is divided between the part-

*Figure 3. At Diavik's A154S pit, two orange cranes pump explosives into the 370-m-level bench. The dark rock in the foreground is diamondiferous kimberlite. Photo by Mary L. Johnson.*



*Figure 4. The high-angle conveyor belts in the top of this image carry diamond ore to the gravitational separators at the Diavik processing plant. The ore cannot be seen because it is covered by a second rubber belt. Photo by Mary L. Johnson.*

ners in Yellowknife: DDMI's 60% goes to Rio Tinto Diamonds NV in Antwerp, while Aber's 40% goes to the open market in Toronto, with some committed to Tiffany & Co. The rough is split into 11 lots by diamond weight. Aber gets four lots, DDMI gets six lots, and diamonds in the largest-stone lot (10+ ct) are individually bid on by both partners. The first production—42,619 carats averaging \$96/ct was brought to market in April 2003.

*Snap Lake.* The main kimberlite body at Snap Lake, on average, is a 3.7-m-thick dike (figure 5) that dips about 15° to the east under the surface of the lake, and extends about 3–4 km down dip. Another diamondiferous kimberlite body (CL-186), which has not been evaluated, is a blind pipe (i.e., it does not reach the surface). As mining at Snap Lake will be underground, the site footprint (i.e., the developed area of the mine site) is projected to be only 550 ha, compared to 3,500 ha at Ekati and 1,800 ha at Diavik. The deposit is currently in "maintenance mode," waiting for final permitting, which could allow mine development to start as early as December 2003.

Grades were estimated from 6,000-tonne bulk samples in two locations, which gave very consistent results. Approximately 12,000 carats were extracted, valued at about \$90/ct. The largest diamond found so far (though not gem quality) was about 50 ct. Plans are to remove ore by the room-and-pillar method and move it via 40-tonne trucks to an underground primary crusher. The kimberlite ore grade is 218 ct/100 tonnes, and the mined ore grade (i.e., containing host rock that must be removed with the kimberlite) is expected to be 150 ct/100 tonnes. Mining should produce 3,000 carats/day. Two cross-cut levels have been started: the 320 m level (120 m below the surface of the lake) in 2000, and the 280 m level in 2001.

**Buffalo Hills.** The Ashton/Pure Gold/Encana mine camp is in the middle of a large natural gas field, about 40 km northwest of the town of Red Earth Creek in north-central Alberta, and is accessible by dirt roads. So far, 37 kimberlites have been discovered in this field, of which 24 are diamondiferous, but the area has not yet proved economic for diamond mining. The “core area” for prospecting is about 400,000 ha.

Exploration of this deposit has been previously described (see, e.g., Summer 1998 Gem News, pp. 134–135). Individual kimberlites are small (as at Lac de Gras), and the glaciation history of the region is quite complex, so heavy-mineral-concentration techniques are useful for regional exploration but not for finding individual ore bodies. Therefore, much of the exploration has been performed using geophysical techniques. Presently, time-domain electromagnetic surveying is the geophysical method in use.

Four kimberlites are the most promising: K5, K6, K14, and K252. K5 is a lateral body covering about 40 ha. The K6 kimberlite covers about 15 ha, and is composed of at least two separate pipes. The best diamond found so far was a 0.76 ct yellow diamond from K6. K252 is adjacent to K6, and is buried under about 70–80 m of glacial deposits. This small (2 ha) kimberlite has a grade of 0.55 ct/tonne, with a 0.94 ct diamond being the largest recovered. At K14, further to the north, a 500 tonne drill-core sample contained 18 carats (counting microdiamonds; 11.7 carats without).

**Mountain Lake.** This diamond area is located about 75 km northeast of Grande Prairie in northwestern Alberta, on the Peace River drainage. The Mountain Lake ultramafic bodies were extensively investigated by Monopros (now De Beers Canada) in the late 1980s. In 2000, they allowed the mineral permit to expire, and this claim was re-staked by New Claymore Resources Inc. It is not currently considered to be economic.

There are two pipes, Mountain Lake North and Mountain Lake South; they are not typical kimberlite, and their poor state of preservation makes characterization difficult. Although a few minute diamonds were found here, the indicator-mineral suite is also not typical,



Figure 5. The diamondiferous kimberlite dike at Snap Lake averages only a few meters thick. Here, Dr. Melissa Kirkley, De Beers Canada Exploration, points out a xenolith in the dike; the upper contact of the dike with the host rock is at the level of her head. Photo by Mary L. Johnson.

lacking, for instance, chrome spinels with diamond-inclusion compositions and G10 garnets.

Mary L. Johnson  
GIA Research, Carlsbad

**Profile Cut diamonds.** The Profile Cut was first introduced in October 1961 by Arpad and Peter Nagy of Diamond Polishing Works, London. It is one of the most unusual proprietary cuts to be marketed in the past half century. Recently, this contributor learned that several new shapes are being produced and the faceting is being done with new techniques for better consistency (see, e.g., figure 6).

The process for creating the Profile Cut evolved from Arpad Nagy's patented method originally developed for diamond-tipped tools used for dressing industrial grinding wheels (see E. Bruton, *Diamonds*, 1st ed., Chilton Book Co., Radnor, Pennsylvania, 1970). Using flat gem-quality rough, and sometimes even leftover cleavage fragments, a series of grooves are cut into the base of the stone, each with a 41° angle. These grooves are designed to maximize the surface area of the stone in relation to its weight. The

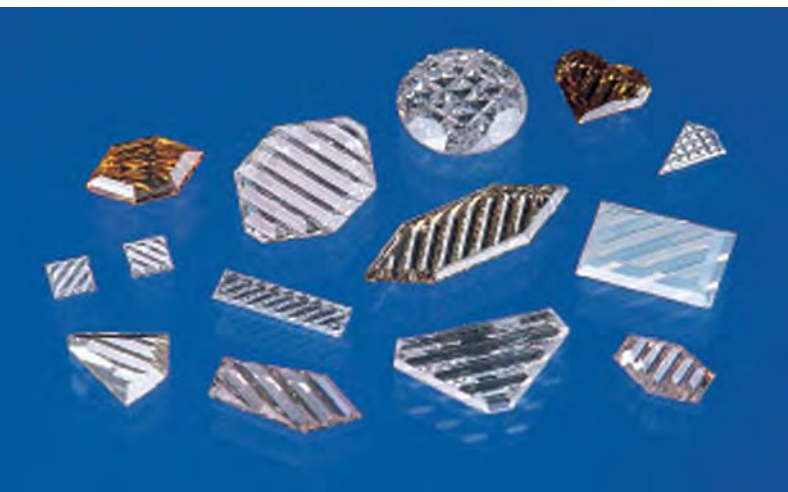


Figure 6. These Profile Cut diamonds (0.03–0.95 ct) represent one of the most unusual proprietary cuts to be marketed in the past half century. Photo by Maha Tannous.

depth of the grooves is standardized according to the thickness of the plates.

The technique for smoothing the grooves was not revealed in patents of the period. Even the heart-shaped diamonds produced at the time had fully curved polished incisions, as opposed to the unpolished faceted grooves in general current production.

Hearts, squares, and rectangles are produced mostly in standardized dimensional sizes, utilizing jig-type dops, while the new contemporary shapes are created using custom-made dops.

Maha Tannous  
GIA Gem Laboratory, Carlsbad

## COLORED STONES AND ORGANIC MATERIALS

**An alexandrite-emerald intergrowth.** This contributor recently encountered several stones that were presented as alexandrite-emerald intergrowths. These cabochons and

polished slabs were translucent to partially transparent, and ranged from 6 to 25 ct. According to the owner, the material was found in Russia a few years ago. In daylight, the stones all appeared a relatively homogeneous bluish green. In incandescent light, certain areas of each stone appeared reddish purple, while the remaining portions stayed bluish green.

One 12.17 ct triangular cabochon (figure 7) was studied in more detail. About 80% of the stone exhibited a very distinct color change, while the remaining 20% was nonphenomenal bluish green. The refractive index, determined by the spot method, was ~1.75 for the color-changing portion and ~1.58 for the nonphenomenal area. The color-changing portion exhibited a weak-to-moderate red luminescence to long-wave UV radiation, as well as a faint yellow emission along the fractures. With short-wave UV radiation, the red luminescence was rather faint, causing the yellow emission along the fractures to appear more distinct. The nonphenomenal portion was inert to both wavelengths. The yellow fluorescence indicated that a foreign substance was present in the fractures.

Reflectance infrared spectroscopy, performed on a Perkin-Elmer Spectrum BXII FTIR spectrometer, confirmed the identity of the color-changing portion as alexandrite and of the nonphenomenal area as emerald. In transmission mode, both portions displayed strong absorption between 3100 and 2800  $\text{cm}^{-1}$ , corresponding to the significant presence of hydrocarbons. This suggested that the sample had been oiled to enhance its appearance. Indeed, microscopic observation revealed dendritic patterns with the appearance of dried oil in the numerous fractures. These findings also explain the yellow luminescence along the fractures of the cabochon; such fluorescence is common for oils and resins. The transmission infrared spectra also showed prominent water-related absorption features, proving natural origin.

Two other cabochons were intergrowths of alexandrite, emerald, and phenakite. The phenakite was visible as a narrow white zone around one edge of each of these samples, and was identified by infrared spectroscopy in both transmission and reflectance modes. However, in these

Figure 7. The alexandrite portion of this 12.17 ct intergrowth with emerald shows a distinct color change from daylight (left) to incandescent light (right). Photos by T. Hainschwang.



samples the color change of the alexandrite was very weak, and therefore not nearly as attractive as in the sample described above.

The association of chrysoberyl ( $\text{BeAl}_2\text{O}_4$ ), beryl ( $\text{Be}_3\text{Al}_2[\text{Si}_6\text{O}_{18}]$ ), and phenakite ( $\text{Be}_2\text{SiO}_4$ ) within emerald deposits of the Ural Mountains in Russia was mentioned by A. F. Lashovenkov and V. I. Zhernakov ("An update on the Ural emerald mines," Summer 1995 *Gems & Gemology*, pp. 106–113). Indeed, intergrowths of alexandrite, emerald, and sometimes phenakite are occasionally found within or near desilicated pegmatites, and their relative abundance may be explained by variations in the temperature and composition (particularly in the amount of silica) within the growth environment (see M. D. Barton, "Phase equilibria and thermodynamic properties of minerals in the  $\text{BeO}-\text{Al}_2\text{O}_3-\text{SiO}_2-\text{H}_2\text{O}$  [BASH] system, with petrologic applications," *American Mineralogist*, Vol. 71, 1986, pp. 227–300). Such intergrowths have also been produced synthetically by Russian researchers (see [http://library.iem.ac.ru/exper/v6\\_2/mineral.html](http://library.iem.ac.ru/exper/v6_2/mineral.html)). In nature, however, attractive intergrowths of these minerals are rare, and it is even more unusual to find them together in polished stones, since they tend to break apart during the shaping process.

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**Amethyst from Nigeria.** Over the past three years, Nigeria has produced some attractive amethyst (figure 8). This material was first brought to these contributors' attention at the 2002 Tucson gem show by Jack Lowell (Colorado Gem & Mineral Co., Tempe, Arizona). As of August 2003, Mr. Lowell had obtained approximately 20 kg of rough. He estimated that about 1% by weight was facetable; the remainder will be marketed as crystals for collectors or polished into carvings and cabochons. So far, stones up to 24.87 ct have been faceted from this production.

According to Charles Dunkwu, a sales manager with



Figure 8. The Taraba State in eastern Nigeria is the source of this amethyst. The crystal is 8.9 cm long, and the faceted stones range from 2.17 to 16.85 ct. Photo by Jack Lowell.

Gos Resources Nigeria, in Lagos, the amethyst was first mined in April 2000. The deposit is located in the eastern part of the country, about 40 km south of Jalingo, which is the capital city of Taraba State. Mining is done by local people in a communal fashion, using only hand tools. Digging takes place during the wet season (generally April to October), since the ground is too hard when it is dry. Approximately 50 miners are active in an area of about 8 km<sup>2</sup>, working in shallow pits that typically do not exceed 1.5 m deep. He estimated the monthly production at 120–150 kg of rough, with the largest pieces ranging up to 1.5 kg. Much of the amethyst shows an attractive deep purple color.

A parcel of 12 stones, ranging from light to dark purple, was examined by one of us (JIK) for inclusions (figure 9). Common were singular to abundant needle-like crystals that were identified by Raman analysis as hematite. Thin,

Figure 9. The most common inclusions observed in the Nigerian amethyst examined were deep red needles of hematite (left, magnified 10×). Thin plates of hematite also were seen occasionally (center, magnified 20×). The primary fluid inclusion on the right (magnified 15×) contains liquid and gaseous carbon dioxide, as shown by cooling and heating experiments. A "tail" of hematite extends from the base of this fluid inclusion. Photomicrographs by John I. Koivula.







Figure 10. Hiddenite from a new find in North Carolina is notable for its relatively large size and high quality. The faceted stones weigh 1.16 and 5.58 ct, and the crystal is 3.7 cm long. Courtesy of Terry Ledford and W. Renn Adams; photo by Maha Tannous.

platy inclusions of hematite (also identified by Raman analysis), sometimes with a skeletal or saw-blade appearance, were observed in some samples. Primary fluid inclusions were less common. Cooling and heating experiments on one such inclusion (figure 9, right) showed that the fluids have the homogenization temperature of liquid-gaseous carbon dioxide (i.e., 31.2°C), indicating that both the liquid and gas phases are composed of CO<sub>2</sub>, which was undoubtedly a fluid carrier of the amethyst's growth nutrients.

BML

John I. Koivula  
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**New hiddenite discovery in historic North Carolina location.** At the August 2003 East Coast Gem, Mineral, and Fossil Show in Springfield, Massachusetts, Terry Ledford (Mountain Gems and Minerals, Little Switzerland, North Carolina) debuted a significant new find of attractive, relatively large crystals of hiddenite from North Carolina. The crystals were recovered in April and May 2003 from the Adams Farm near the town of Hiddenite. Previously known as the Warren Farm, this locality is the original source of hiddenite, which was discovered in the mid-1870s (J. L. Smith, "Hiddenite, an emerald-green variety of spodumene," *American Journal of Science*, Vol. 21, 1881, pp. 128–130). The property has been worked intermittently. It was opened to the public on a fee-dig basis from the early to mid-1970s, and then remained idle. Mr. Ledford and his partner, W. Renn Adams (the property owner), began prospecting on the farm in 2001. The men soon found a few crystals of hiddenite, but it took another two years of digging before they made the latest, much larger discovery.

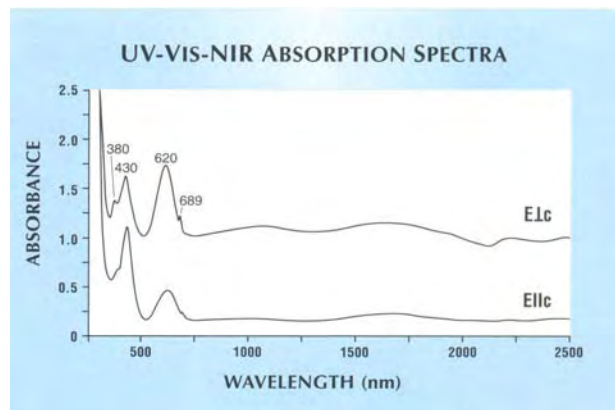
Mr. Ledford told one of us (BML) that the hiddenite was recovered at approximately 4.5 m depth, in a decom-

posed vein within the weathered metamorphic host rocks. The associated minerals were amethyst, rutile, monazite, black tourmaline, and a few small emeralds. He estimated that during this two-month period they recovered about 1,200 crystals of hiddenite, ranging from a few millimeters to 9.0 × 1.0 cm in dimension. Their average size was 2.0–2.5 cm long and 0.5–0.6 cm wide. Nearly all the crystals were etched, as is common for hiddenite, and approximately 5% were facetable. Mr. Ledford and Mr. Adams have selected approximately 60 pieces that they predict will cut 1+ ct stones. The largest stone they have faceted to date weighs 5.58 ct. They loaned this elongated emerald cut, as well as a 1.16 ct round brilliant and a color-zoned hiddenite crystal, to GIA for testing (figure 10).

Examination of the two faceted stones by one of us (EPQ) showed the following properties (information for the 5.58 ct stone is reported before the 1.16 ct sample where there was a difference): color—weak to moderate yellowish green and moderate green; pleochroism—weak to moderate, in yellowish green and bluish green; R.I.—1.660–1.676 and 1.661–1.677; birefringence—0.016; S.G.—3.20 and 3.21; Chelsea filter reaction—pink; fluorescence—inert to both long- and short-wave UV radiation; and an absorption band at 440 nm and a line at 670 nm visible with the desk-model spectroscope. The above observations correlate to the typical values for hiddenite found in gemological reference books (see, e.g., R. Webster, *Gems*, 5th ed., Butterworth-Heinemann, 1994, pp. 186–188). Microscopic examination revealed "fingerprints," straight and angular transparent growth zoning, faint yellowish green color zoning (in the 5.58 ct stone), cleavage fractures, twin planes, and etch tubes. The fractures in the 1.16 ct hiddenite displayed evidence of clarity enhancement.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy of all three samples showed the expected major

Figure 11. Polarized UV-Vis-NIR absorption spectra (shifted vertically for comparison) are shown here for the dark portion of the hiddenite crystal. Most of the absorption features are related to Fe<sup>3+</sup>, Fe<sup>2+</sup>, and Cr<sup>3+</sup>.



elements Al and Si. The 1.16 ct stone contained traces of K, Ca, V, Cr, and Fe. Also, Ca, Ti, V, Cr, Fe, and Ga were detected in the 5.58 ct sample and in the light green portion of the crystal. The darker green area of the crystal contained the same elements, except that Ca and Ti were not detected. This area of the crystal contained approximately five times more chromium than the light green portion, and approximately three times more chromium than either faceted sample.

Polarized UV-Vis-NIR absorption spectra (figure 11) of the 5.58 ct stone and the crystal showed features consistent with coloration due to Cr<sup>3+</sup>, Fe<sup>3+</sup>, and Fe<sup>2+</sup> (F. C. Hawthorne, Ed., *Reviews in Mineralogy*, Vol. 18: *Spectroscopic Methods in Mineralogy and Geology*, Mineralogical Society of America, Washington, DC, pp. 218–223). Specifically, bands were recorded at 369 (Fe<sup>3+</sup>), 380 (Fe<sup>3+</sup>), 430 (Cr<sup>3+</sup>), 431 (Fe<sup>3+</sup>), 437 (Fe<sup>3+</sup>), 510, 620 (Cr<sup>3+</sup>), 689 (Cr<sup>3+</sup>), 1060 (Fe<sup>2+</sup>), and 1650 nm. The 431, 437, and 689 nm bands correlate to the absorptions seen at 440 and 670 nm with the desk-model spectroscope (wavelength differences can be attributed to the lower accuracy of the latter instrument). The intensity of the Cr- and Fe-related bands also were consistent with the relative concentrations of these elements detected by EDXRF.

Mr. Ledford reported that more vegetation will need to be cleared from the mining claim before significant further prospecting can occur. Therefore, it is not likely that additional hiddenite will be recovered from this site in the near future.

BML

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Sam Muhlmeister, GIA Research, Carlsbad  
Edward Boehm, JOEB Enterprises,  
Solana Beach, California

**Update on sapphires, pezzottaite, and other gems from Madagascar.** In July 2003, this contributor visited the Ilakaka area, as well as the pink cesium-beryl (pezzottaite) mine near Ambatovita, to obtain first-hand information on the gem production and geology at those localities.

*Ilakaka area.* Tom Cushman (Allerton Cushman & Co., Sun Valley, Idaho) guided the Ilakaka portion, and we were joined by Edward Boehm (JOEB Enterprises, Solana Beach, California). We flew from Antananarivo to Tulear on the southwest coast, and drove three hours to the gem-trading town of Sakaraha, and then an additional hour to Ilakaka (all on the partially paved Route Nationale 7). For the past several years, Ilakaka has become well known as a source of fine sapphires and related gem materials. In the last two to three years, additional discoveries have significantly expanded the mining activities, making this one of the largest sapphire deposits in the world. All of the mining areas are hosted by the Isalo Formation, in sediments that were originally deposited into the Morondava basin. The

main producing localities are found in the Ilakaka-Sakaraha region and in another district near Bezaha (along the Onilahy River), 118 air-km southwest of Ilakaka. Another area that is rumored to produce similar gems is located 350 km north of Ilakaka, in west-central Madagascar. Called Miandravaso, this area is also underlain by the Isalo Formation, but it remains unclear whether significant deposits have been found there.

The main trading areas for the gems from this region are still Ilakaka and Sakaraha, which have maintained their “Wild West” atmosphere. Security remains a problem, as robberies are common; a gunfight occurred in Ilakaka during the first night of our visit. Most of the buyers in Ilakaka and Sakaraha are Sri Lankan, with Thais comprising a minor percentage; there are only a few European traders. Interviews with gem traders there revealed that production had decreased significantly since Madagascar’s political crisis last year, to perhaps 60% of former levels (see “Madagascar split halts gem trade,” *Colored Stone*, Vol. 15, No. 4, p. 6). Stones traded in Ilakaka are being produced from several areas, most of which are within 40 km of the town; these include Sakalama, Ampasimamitaka, Vohimena, Bekily (not the garnet location), and Manombo Voavoa. Stones from the Bezaha district are traded in Sakaraha.

We visited the Manombo Voavoa deposit, located 38 km west of Ilakaka, which has been mined since February 2003. Approximately 500 miners were active in the gem-rush atmosphere, and the area appeared to be growing—with new temporary shelters being constructed along the highway. Dozens of shallow pits were concentrated on the south bank of the Andongoza River (figure 12). Some of these pits had 1-m-diameter shafts, reportedly reaching 20–30 m deep, that were accessed by primitive windlass systems. This mining method was also seen in the old workings at Ilakaka (figure 13), and was apparently new to this area of Madagascar since Mr. Cushman’s previous visit in early 2002. The gem-bearing gravel was washed in the river, and the stones were removed from the sieves by hand. During our visit, we saw only small sapphires and other waterworn gems (typically less than 1.5 ct; figure 14), but they occurred in a wide range of fancy colors, as well as blue.

*Other sapphire localities.* We also learned of several recently discovered areas that are reportedly being mined for sapphires. A mechanized operation will soon exploit a new deposit on the volcanic island of Nosy Be, located off the northwest coast. Gem-quality reddish orange zircon is also found in association with the blue to greenish blue sapphires. Small quantities of predominantly blue sapphires are produced from the Andilamena region in northern-central Madagascar, at Amboasary, Andrebabe, and Fenerive Est. An alluvial deposit in the Manatenina area near the southeastern coast is reportedly producing blue sapphires that are similar to those from Andranondambo.



Figure 12. Sapphires are being mined from several deposits in the Ilakaka region of southern Madagascar. At Manombo Voavoa, dozens of pits were seen on the south bank of the Andongoza River. The dirt mounds in the foreground are from test pits; the location of the river is marked by the large trees.  
Photo by Brendan Laurs.

*Pezzottaite* mine. In September 2003, the International Mineralogical Association approved a proposal submitted by two independent groups of scientists (from North America and Switzerland) to designate the pink Cs-beryl from Ambatovita, Madagascar, as a new mineral of the beryl group. It has been named *pezzottaite* after Dr.

Figure 14. This parcel of sapphire, ruby, and chrysoberyl (0.48–1.33 ct) was mined in July 2003 from the new Manombo Voavoa deposit in the Ilakaka area. The sapphires occur in a variety of colors; the three chrysoberyls are the yellow-green stones of various tones in the lower right and far left. Photo by Maha Tannous.



Figure 13. Narrow shafts in the Ilakaka region, some reaching 20–30 m deep, are accessed by primitive windlass systems. The miner sits inside a cloth bag, which is also used to raise the gem-bearing gravel to the surface. Photo by Brendan Laurs.

Federico Pezzotta (Museo Civico di Storia Naturale, Milan, Italy), in recognition of his contributions to the mineralogy of Madagascar. Dr. Pezzotta guided this contributor on a five-day expedition to the mine, which is located about 140 air-km southwest of Antsirabe (see Spring 2003 GNI section, pp. 50–54). Mining of the pegmatite for pezzottaite

Figure 15. Some of the bright pink Cs-beryl (*pezzottaite*) that debuted at the 2003 Tucson shows was mined from this tunnel in a pegmatite near Ambatovita, Madagascar. The miner is sitting on material that collapsed from the roof after the tunnel was expanded; photo by Brendan Laurs. The cat's-eye pezzottaite cabochon in the inset weighs 2.92 ct; courtesy of Mark Kaufman, photo by Maha Tannous.



(and tourmaline) continues, but at a slower pace than in earlier months. Approximately 20 people were working the mine, which they refer to as "Sakavalana." Information provided by the miners, as well as our observations of the surface and underground workings, indicated that all the pezzottaite produced to date came from a limited area within a single granitic pegmatite (figure 15). The majority of the gem-bearing zone appears to have been mined out, and the remaining areas are difficult to work with the hand tools available. Small amounts of pezzottaite were available at the mine, as well as elsewhere in Madagascar, but the material shown to us was of low quality.

*Other gem finds.* A significant find of tsavorite occurred in July 2003, within the area near Edjeda in southern Madagascar that has been known to produce this garnet (see Winter 1999 Gem News, p. 218). Several kilograms of small pieces of gem rough were reportedly produced. In the Bekily area, an additional primary deposit of color-change garnet has yielded a small amount of 1+ gram rough, but without the vivid color change shown by some of the material mined previously from this area. Small quantities of grossular garnet (R.I.=1.740), ranging from yellowish green to yellow-orange to pale orange-red, were available from a new skarn deposit in the Antsongombato region of central Madagascar (figure 16). Due to the brecciated nature of the rock, the faceted stones typically range up to just 1.5 ct.

Also in the Antsongombato area, attractive crystals of dark red tourmaline are being mined by a group headed by Dr. Pezzotta. Further south, in Fianarantsoa State of central Madagascar, at least two pegmatites are being mined for carving-quality multicolored tourmaline; small quantities of faceting-quality material are found there as well.

BML

#### Update on mining and marketing gems in Mogok, Myanmar.

This contributor had an opportunity to obtain updated information on gem mining and trading in the Mogok Valley during a two-week visit to Myanmar (Burma) in January 2003. The local gem miners and traders continue to face hardships because of increased military control of the main mines and depreciation of the Burmese currency, which has increased fuel and equipment costs. In addition, many Mogok miners reportedly have moved to Mong Hsu (for ruby) and Hpakan (for jadeite), due to the difficulty of finding stones in Mogok.

Nevertheless, ruby and sapphire continue to be mined from both eluvial and primary deposits. The hard-rock mines exploit corundum-bearing marble (figure 17). Most of the work is done in eluvial workings, which consist of open pits (figures 18–20) or shafts that are supported by wooden framing called "sets." The sets are generally separated by approximately 2 m, and the miners dig out roughly one set per day. The shafts are typically worked by hand (and sometimes dynamite). This contributor visited one such pit that

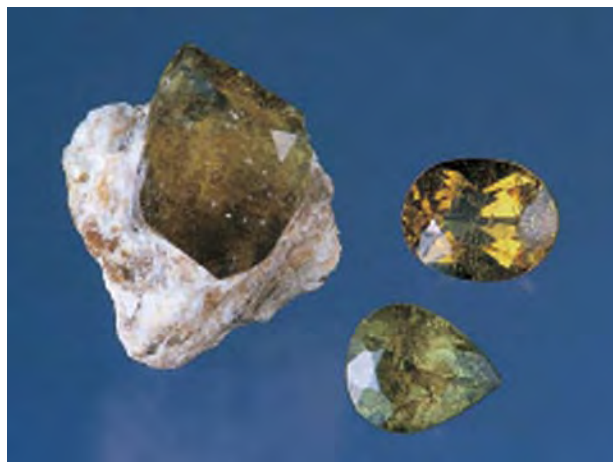


Figure 16. A new skarn deposit in the Antsongombato region of central Madagascar produced these grossular garnets. The faceted stones weigh 0.71 and 0.85 ct. Photo by Maha Tannous.

was reportedly 30–45 m deep, although the depth could not be confirmed because only surface visits were allowed. In areas near water, large open pits employ powerful water cannons. The resulting slurry is pumped into sieves, and the gems are hand-picked from the concentrates.

Mining concessions are granted only by the Burmese government, for a three-year period, although they are sometimes renewable. All construction is strictly controlled—even digging something as simple as a latrine requires official authorization. However, illegal mining remains a problem, and is sometimes done through the floors of private homes.

Where lighting equipment exists and the gem production is likely to justify the fuel costs for the diesel

Figure 17. At Kyauk Sar Hill in Mogok, Myanmar, miners hoist ruby-bearing marble from a deep underground mine. Photo by O. Galibert.





Figure 18. Rubies are recovered from this large pit at the Phau Htoke Khan mine, near Spider Hill in Mogok. The structure in the left center is a headframe used to raise material from the bottom of the pit. Photo by O. Galibert.

generators, the mines may operate up to 24 hours a day in multiple shifts. Mine workers in Mogok usually eat and sleep on site, with dormitory-type accommodations as the rule. The miners are paid either a full cash salary or a reduced salary plus a share of their finds. However,

Figure 20. Workers at the Phau Htoke Khan mine carry boulders out of the pit. The plastic sheeting helps keep mud off their backs. Photo by O. Galibert.



Figure 19. Pools created by water cannons in the pit require the use of pumps at Mogok's Phau Htoke Khan mine. Photo by O. Galibert.

as in other locations, stone theft by the miners is a perpetual problem; most commonly, they hide stones in their mouths or swallow them. Nevertheless, the workers are closely supervised, and the country's strict legal system greatly discourages theft.

The law requires that all stones be submitted to the local office of the Ministry of Mines within 24 hours of recovery. An official group of seven locally elected appraisers meet twice a week to appraise the submitted goods. After paying a tax of 20%, the owner can sell most goods at the government auction, called the Emporium, or on the open market. An additional 10% tax must be paid on the sale price. Exceptional stones can only be sold at the Emporium (see Winter 1993 Gem News, pp. 285–286). Naturally, the heavy taxes encourage smuggling.

Several gem markets operate around Mogok. Pan Chan (or "flower") is the largest. The price of a trading space varies daily, but a single table may cost around \$1 (extra for an umbrella). Le U Quarter and Min Ta Dar markets are only for rough stones; the latter is also almost exclusively for female dealers, who are mostly of Nepalese origin (figure 21). Many of the stones being traded are not even of polishing quality, but are used to make so-called "stone paintings" (collages of tiny stones set into a frame), some of which can be quite stunning. Other markets include Cinema and Pan Ma, which deal in both rough and cut stones. The social aspects of gem trading are critical in Mogok, and they often appear to be as important as the actual buying and selling.

Western notions of per-carat pricing do not exist in Mogok gem markets; stones are usually sold by the piece or parcel, rather than by weight. In addition, government regulations prohibit foreign visitors from making any pur-

chase above \$30. According to William Larson (Pala International, Fallbrook, California), this is because Mogok dealers at these markets are not officially licensed for foreign export, and the \$30 limit is what the government deems acceptable as a tourist purchase (i.e., noncommercial). This contributor also believes that the intent is to prevent disruption of the local market through inflation caused by foreign buyers.

On July 28, 2003, the Burmese Freedom and Democracy Act of 2003 (H.R. 2330) took effect, banning the importation into the U.S. of any article that is produced, mined, manufactured, grown, or assembled in Myanmar. This obviously covers all Burmese gems, jewelry, and mineral specimens. It is illegal to import such materials, even if they come into the U.S. from another country such as Thailand or Hong Kong. For more information, see [www.theorator.com/bills108/hr2330.html](http://www.theorator.com/bills108/hr2330.html).

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**“Star” obsidian.** While obsidian can show interesting and sometimes very colorful reflected-light phenomena such as aventurescence, chatoyancy, and iridescence, asterism is not generally associated with volcanic glass. These contributors were therefore intrigued on hearing of a volcanic glass from the Jemez Mountains in New Mexico that was referred to as “star obsidian.” Nancy Attaway of Sandia Park, New Mexico, sent two examples of this material to GIA for examination: a transparent 6.28 ct dark brown modified round brilliant (figure 22), and a 72.43 ct nodule of similarly colored rough (i.e., an “Apache tear”) with one unpolished flat.

An initial examination showed that the material did not, in fact, display any asterism. Instead, when illuminated at an angle from above, it showed an interesting bright reflective aventurescence, which was visible on both the table of the faceted stone and across the unpolished flat of the nodule after it was covered with a thin layer of sesame oil.

The gemological properties of the faceted stone were consistent with obsidian and confirmed that it was a natural volcanic glass. The refractive index was 1.489; specific gravity (determined hydrostatically) was 2.35. Both samples were inert to long- and short-wave UV radiation, and neither showed a useful spectrum when examined with a desk-model spectroscope. Only very slight strain was visible when they were examined in cross-polarized light, which also revealed numerous tiny inclusions of birefringent crystallites.

With magnification, most of these platelets appeared hexagonal, but some were triangular. They showed bright silvery blue-gray reflections (figure 23, left) and were clearly the source of the aventurescence. Diffused transmitted light revealed that many of the inclusions were transparent to semitransparent; some were red-orange (figure 23, center), while others were dark gray-brown. These inclusions were identified by Raman analysis as, respectively,

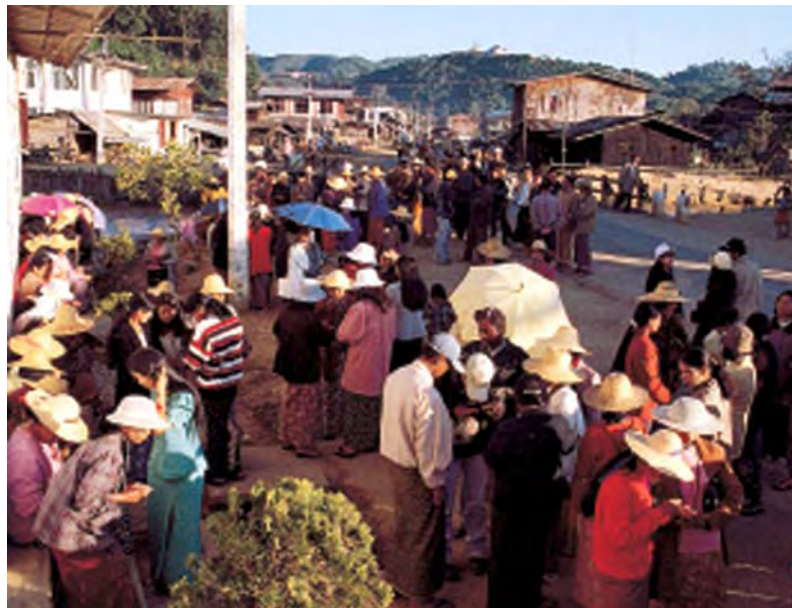


Figure 21. At the Min Ta Dar market in Mogok, the dealers are mostly Nepalese women who sell rough stones. Photo by O. Galibert.

hematite and ilmenite. As seen in surface-reflected light (figure 23, left) and by shadowing (figure 23, right), some of the hexagonal platelets also appeared to have a spoked, trapiche-like structural pattern, which made them look a little like snowflakes or stars.

Although we believe this is the first mention of this type of aventurescent obsidian in *Gems & Gemology*, it is not a recent or new discovery, having been reported by M. O. Murphy in *Lapidary Journal* in 1963 (“Star studded Jemez,” Vol. 17, No. 1, pp. 366–375).

Figure 22. These three aventurescent obsidians—weighing 1.85, 4.11, and 6.28 ct—were all cut from “Apache tears” from the Jemez Mountains in New Mexico. Photo by Maha Tannous.





Figure 23. In reflected light (left, magnified 20×), the aventurescence-causing inclusions in the obsidian appear silvery blue-gray. Diffused transmitted light (center, magnified 20×) shows that many of the inclusions in the aventurescent obsidian have a red-orange color. At higher magnification (right, magnified 80×), both red-orange and dark gray-brown platelets were visible; these were identified as hematite and ilmenite, respectively. Note the trapiche-like spoked appearance of some of the inclusions in the left and right images. Photomicrographs by John I. Koivula.

One of these contributors (JIK) obtained several rough pieces of this obsidian from Dr. Frederick Pough (Reno, Nevada) and Al Huebler (Rio Rancho, New Mexico). From these, two stones were faceted by Leon Agee of Agee Lapidary in Deer Park, Washington. These additional samples (again, see figure 22) weighed 1.85 and 4.11 ct, and showed identical optical and physical properties to the 6.28 ct gem that initiated this examination. Although this material would be more correctly referred to as aventurescent obsidian, because of the appearance of the inclusions it is known in the trade as “star obsidian” or “starred Apache tear obsidian.”

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**An unusual star quartz.** A 380 ct star quartz cabochon with an unusual greenish yellow color (figure 24) was submitted to the SSEF laboratory by Grafgem (Winterthur, Switzerland) for identification. The client was concerned

Figure 24. This 380 ct “lemon quartz” shows a six-rayed star. Although the gem proved natural, the origin of its color is unknown. Photo by H. A. Hänni, © SSEF.

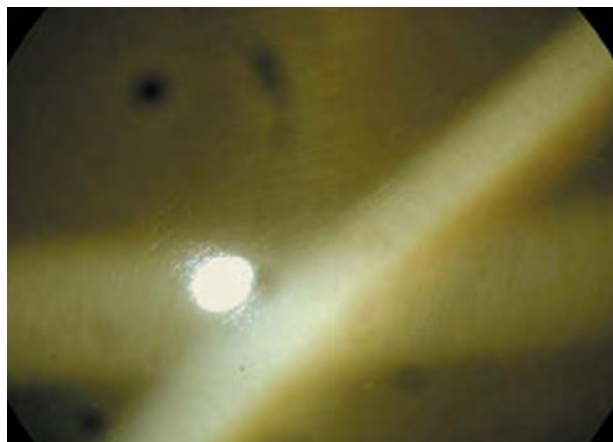


that the sample might be synthetic.

Microscopic investigation of the cabochon showed two different forms of inclusions. One set of long, thin parallel needles was present in three directions within a plane that was perpendicular to the optic axis (figure 25). The other set consisted of short, flat, and sometimes nearly hexagonal inclusions that were inclined to the long needles, relative to the optic axis. The star was formed exclusively by the long needles. Due to the small size of the inclusions, none could be identified by Raman spectroscopy.

Inclusions of microscopic to submicroscopic rutile needles in numerous orientations have been known in quartz for many years (see, e.g., V. Goldschmidt and R. Brauns, “Über Lichtkreise und Lichtknoten an Kristallkugeln,” *Neues Jahrbuch für Mineralogie, Geologie und Paläontologie*, Vol. 31, 1911, pp. 220–242). In addition, submicroscopic sillimanite needles have been identified by electron diffraction in six-rayed asteriated quartz from Sri Lanka (M. Weibel et al., “Sternsaphir und Sternquarz,”

Figure 25. In reflected light, a network of thin needles (probably rutile) can be seen producing the asterism in this quartz cabochon. Photo by H. A. Hänni, © SSEF.



*Schweizerische Mineralogische und Petrographische Mitteilungen*, Vol. 60, 1980, pp. 133–136). The Summer 1984 Lab Notes section (pp. 110–111) also documented several large multi-star quartzes, one weighing over 100 ct, with asterism that may have been caused by sillimanite. Several other types of needles, among them dumortierite and hematite, have also been mentioned in the literature as inclusions in quartz. Recently, the orientation of inclusions (identity not specified) in multi-star quartzes from Sri Lanka was described (K. Schmetzer and M. Glas "Multi-star quartzes from Sri Lanka," *Journal of Gemmology*, Vol. 28, No. 6, 2003, pp. 321–332). Synthetic star quartz has not yet been reported.

Based on the orientation of the inclusions, as well as on the presence of Ti in the 380 ct stone (detected by EDXRF spectroscopy), both types of needles were most likely rutile, which would indicate a natural origin. This origin was confirmed by FTIR spectroscopy, which showed the typical bands for natural quartz: 3596, 3539, 3482, 3378, 3308, and 3197  $\text{cm}^{-1}$  (see P. Zecchini and M. Smaali, "Identification de l'origine naturelle ou artificielle des quartz," *Revue de Gemmologie*, No. 138/139, 1999, pp. 74–83). In particular, three of these bands (3596, 3482, and 3378  $\text{cm}^{-1}$ ) exist only in natural quartz, so this gem could not be synthetic.

The appearance of this cabochon was reminiscent of "lemon quartz" from Brazil, which usually owes its color to a combination of irradiation and heat treatment (see K. Schmetzer, "Methods for the distinction of natural and synthetic citrine and prasiolite," *Journal of Gemmology*, Vol. 21, No. 6, 1989, pp. 368–391). Yellowish green and brownish yellow star quartzes are well known from Sri Lanka and Brazil, in sizes up to 800 ct, and irradiation of such material was performed as far back as the 1960s (K. Schmetzer, pers. comm., 2003).

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**Star sunstone from Tanzania.** The feldspar group shows more different types of phenomena than any other gem. Adularescence, asterism, aventurescence, chatoyancy, iridescence, labradorescence, and schiller are all known to occur in feldspars, and fine examples of any of these are always interesting to study gemologically. In rare instances, feldspars may show multiple phenomena.

Recently, these contributors separately received several interesting reddish brown samples showing asterism that were represented as feldspar from Tanzania (see, e.g., figure 26). The three stones submitted to the SSEF laboratory consisted of two cabochons and one piece of rough, all with eye-visible platy inclusions. With fiber-optic lighting, the cabochons displayed a four-rayed star; a strong but somewhat fuzzy cat's-eye intersected the other, less prominent ray at an angle slightly off  $90^\circ$ . The specific gravity of the samples we examined was 2.60, and the R.I.'s (taken on a polished surface on the rough) were 1.522 and 1.528. The EDXRF spectra showed Si, Al,

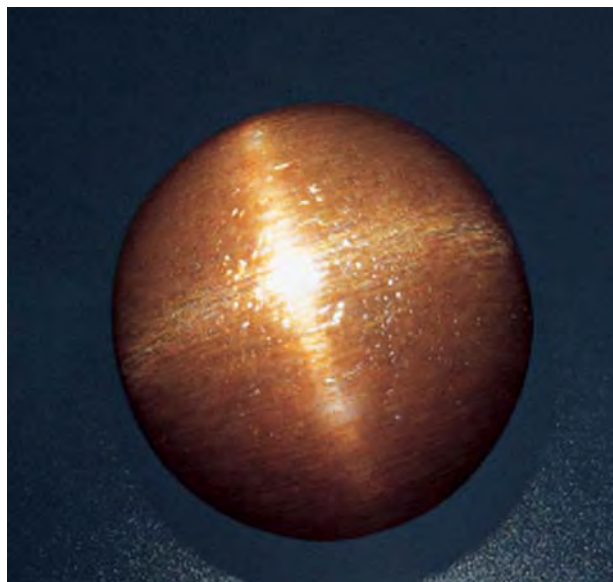
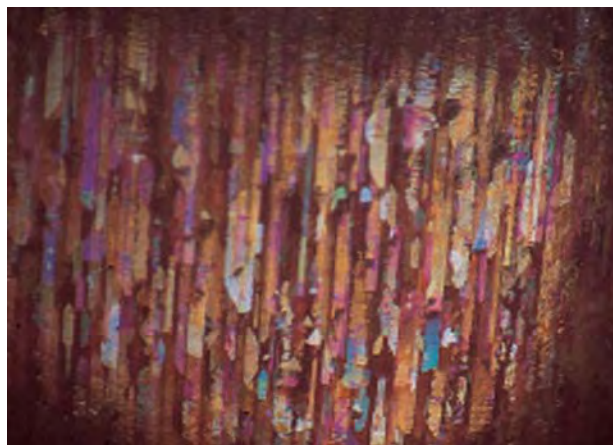


Figure 26. To the unaided eye, this 14.77 ct feldspar cabochon shows strong asterism, as well as aventurescence. Photo by Maha Tannous.

and K, with very little Na. These data are in agreement with a potassium feldspar.

The four-rayed star was apparently produced by flaky to acicular inclusions (figure 27) aligned in two directions. The major set of parallel inclusions (probably hematite) consisted of elongate flakes, while the secondary set was formed by very fine needles (figure 28). The two sets of inclusions intersected at a slightly oblique angle, which is in agreement with the monoclinic or triclinic nature of the feldspar.

Figure 27. The numerous hematite inclusions in the cabochon shown in figure 26 are responsible for the strong, reflective iridescence that is also visible in this feldspar when examined microscopically with fiber-optic illumination. Photomicrograph by Shane F. McClure; magnified 10 $\times$ .





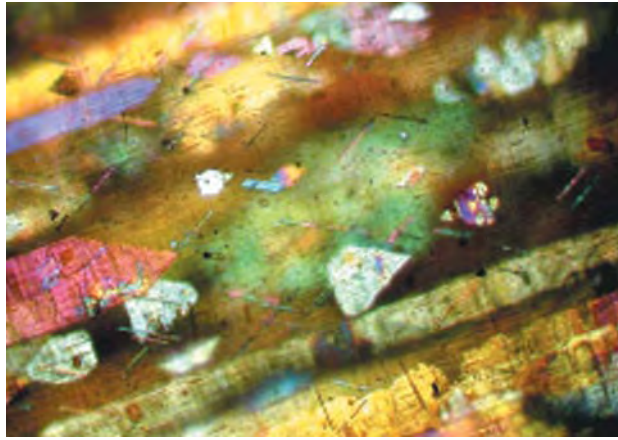


Figure 28. At higher magnification (35×), the inclusions in this feldspar can be seen to consist of both flakes and fine needles. Photomicrograph by H. A. Hänni, © SSEF.

The sample examined in the GIA Gem Laboratory was an attractive, translucent cabochon from Kiran Malhotra of K&K International in Falls Church, Virginia. Like the material described above, this 14.77 ct stone showed a very distinct, bright “golden” brownish yellow four-rayed star (again, see figure 26). The asterism was clearly visible in either direct sunlight or with a point source of illumination. Additionally, iridescence and a strong “silvery” light blue adularescence could be seen close to the girdle edge, aligned along the strongest ray of the star. The latter phenomena suggested that the stone was orthoclase feldspar. This was confirmed by EDXRF analysis (performed by senior research associate Sam Muhlmeister in the GIA Gem Laboratory), which showed abundant K and no Ca.

Gemological testing confirmed that the 14.77 ct cabochon was feldspar. A spot refractive index of 1.53 was obtained from the polished dome of the cabochon, and a specific gravity of 2.59 was measured by the hydrostatic method. The stone was inert to both long- and short-wave UV radiation. It did not show any useful spectrum when examined with a desk-model spectroscope, although a strong general absorption in the blue region was noted, probably due to the inclusions.

Numerous elongated thin platelets of deep orangy red hematite, as confirmed by Raman analysis, were visible with the microscope in the 14.77 ct cabochon as densely packed, precisely oriented parallel layers (again, see figure 27). These inclusions were responsible for the asterism and the apparent red-brown body color of the host, as well as for the aventurescence and iridescence seen when the stone was illuminated from above with a fiber-optic light source. The multiple phenomena displayed by this feldspar made it quite unusual.

HAH

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Figure 29. This 13.90 ct cat's-eye topaz from Myanmar shows a very sharp eye. Photo by Maha Tannous.

**More curiosities from Tucson 2003.** Mark Smith of Thai Lanka Trading Ltd., in Bangkok, Thailand, loaned these contributors a beautiful 13.90 ct cat's-eye topaz (figure 29) from Myanmar for gemological examination. Testing con-

Figure 30. This 1,062.32 ct polished Brazilian rutilated quartz crystal contains a lenticular metallic-looking inclusion that is possibly a carbonate such as calcite, dolomite, or siderite. Photo by Maha Tannous.



Figure 31. As seen here in two orientations (left and right), the 13-mm-long lenticular metallic-looking inclusion in the specimen shown in figure 30 has the general appearance of a flying saucer. Photos by John I. Koivula.



firmed that it was indeed topaz, with all the attributes of a very fine cat's-eye. It was semi-transparent with a very sharp chatoyant band; the "eye" opened and closed dramatically when it was examined between two pinpoint light sources; and it showed a pleasing "milk and honey" effect when a light was directed at the side, parallel to the length of the acicular etch tubes. These reflective tubes caused the chatoyancy, and were so fine that they were virtually invisible without magnification. They were generally of a very constant diameter, which is unusual in topaz. Although cat's-eye topaz was described previously in the Summer 1990 Gem News (p. 164), this gem was superior to that stone in overall quality and larger by more than 10 carats. It is also interesting to note that this is only the second cat's-eye topaz that we have examined.

At 1,062 ct and measuring  $6.8 \times 5.1 \times 4.6$  cm, the polished rutilated quartz crystal shown in figure 30 was much too large to be worn as a jewelry item. It was, however, an interesting natural art object because of the unusual inclusion scene within it. In addition to the randomly scattered, curved, and twisted rutile needles, a large lenticular metallic-looking inclusion also was prominently displayed.

Figure 32. The unusual appearance of this 6.63 ct trapiche emerald, which resembles the head of an insect or space alien, was created by polishing a portion of a crystal that was cut at an angle to the length instead of perpendicular as is typically done. Photo by Maha Tannous.



With close examination, this disk-shaped inclusion appeared to be a carbonate of some type (figure 31). Carbonate inclusions of a similar shape, although much smaller than this 13 mm disk, have been previously identified variously as calcite, dolomite, and siderite in quartz crystals from near Buenopolis in Minas Gerais, Brazil. Buenopolis was the source of the original quartz crystal from which Leon M. Agee (Agee Lapidary, Deer Park, Washington) cut this object. Because this inclusion resembles a flying saucer, the quartz specimen has been given the name "Roswell," after the town in New Mexico that gained notoriety in 1947 as the reputed crash site of a flying saucer.

In a similar theme, Elaine Rohrbach of Gem Fare in Pittstown, New Jersey, had a small number of oddly cut trapiche emeralds from the Chivor mine in Colombia. The cutting style caused these stones to resemble the heads of insects, specifically the praying mantis—or perhaps the heads of very small "space aliens." This appearance was created by cutting through the trapiche crystals at an angle to their length, instead of directly across them, perpendicular to their length. Two dark portions of the trapiche spokes were positioned at opposite sides of the cabochons after they were shaped and polished into their "alien" form. At 6.63 ct, and measuring 12.81 mm across, the example shown in figure 32 could be used by a designer to create a fun and interesting piece of jewelry.

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## SYNTHETICS AND SIMULANTS

**Chemical vapor deposition (CVD): A new source of gem-quality laboratory-created diamond.** High pressure is normally essential for the formation of gem-quality diamonds, whether in the earth's interior or in the laboratory. However, growth of synthetic diamond by chemical vapor deposition (CVD) techniques, which do not require high pressure, is drawing increased attention worldwide. CVD involves the occurrence of a gas-phase chemical reaction above a solid substrate, using a hydrocarbon gas, typically methane, in an excess of hydrogen (see, e.g., J. E. Butler and R. L. Woodin, "Thin film diamond growth mechanisms," *Philosophical Transactions A*, Vol. 342, 1993, pp. 209–224). The silicon or diamond substrate is maintained at a temperature of 730–1130°C, and a reaction causes carbon to be deposited on the surface as a synthetic diamond film. The thickness of the film



Figure 33. These three laboratory-grown diamonds (weighing 0.28, 0.14, and 0.31 ct from left to right) were produced by chemical vapor deposition. Courtesy of Apollo Diamond Inc.; photo by Elizabeth Schrader.

increases layer by layer as a function of time. CVD synthetic diamond has shown great potential for industrial applications in thermal management, cutting tools, optics, and electronic devices. The possible use of CVD to coat gemstones with polycrystalline synthetic diamond was discussed by E. Fritsch et al. ("A preliminary gemological study of synthetic diamond thin films," Summer 1989 *Gems & Gemology*, pp. 84–90), but until recently, the technique has not seen much use in the gem industry due to the difficulty of growing single crystals that are large and thick enough to be faceted. This may now be changing.

Using a patented CVD process (U.S. patent no. 6,582,513), Apollo Diamond Inc. of Boston, Massachusetts, has successfully grown facetable laboratory-created diamonds. Six crystals (0.34–0.87 ct) and seven faceted samples (0.14–1.11 ct; see, e.g., figure 33) were submitted to the GIA Gem Laboratory for examination. The faceted CVD laboratory-grown diamonds ranged from faint brown to dark brown. Clarity was equivalent to VS<sub>1</sub> to SI<sub>2</sub>; some small and irregularly shaped gray-black inclusions were observed in some samples, due to deposition of diamond-like carbon or graphite (as suggested by Raman spectroscopy). Characteristic strain patterns were observed (i.e., dark gray bands), which were different from those seen in most natural diamonds. Also, since no flux is employed in the growth process, the metallic inclusions typically seen in synthetic diamonds grown by HPHT processes are not present in CVD laboratory-grown diamonds. Some of the samples fluoresced a very weak yellow-orange to long-wave, and a weak to moderate yellow-orange to short-wave, UV radiation. The other samples were inert to UV radiation. In addition, three samples (two rough and one faceted) that still contained portions of the HPHT-grown synthetic diamond substrate fluoresced a strong green-yellow to short-wave UV in those areas. As a characteristic feature, some of the CVD synthetic diamonds displayed strong red to orangy red fluorescence while exposed to high-energy UV radiation in the De Beers DiamondView imaging system.

Infrared absorption spectra showed that the CVD laboratory-created diamonds were type IIa, and some contained trace amounts of isolated nitrogen (i.e., with an absorption coefficient of 0.05–0.13 cm<sup>-1</sup> at 1344 cm<sup>-1</sup>). A weak H-related absorption at 3123 cm<sup>-1</sup> (with an absorption coefficient of 0.01–0.06 cm<sup>-1</sup>) was observed in almost all samples in the mid-infrared range. In the ultraviolet to visible range, most samples displayed a smooth spectrum with a gradual increase in absorption toward lower wavelengths (higher energy) starting at about 500 nm. In general, the stronger brown coloration corresponded to a greater increase in this absorption.

Distinct absorption features were recorded in the spectra of a few samples. These included a broad band at around 270 nm and two sharp absorption lines at 268 and 271 nm, that all were related to the traces of isolated nitrogen. Weak but sharp lines at 419, 447, 625, and 637 nm, together with a broad band around 520 nm, also were detected. The 637 nm peak is caused by an N-V center. A weak absorption line at 737 nm, due to trace silicon impurities, also was observed in some samples.

In all samples, photoluminescence spectra suggested the presence of N-V centers, as indicated by very strong emission peaks at 575 and 637 nm. Also observed was a relatively strong photoluminescence emission at 737 nm due to trace impurities of silicon. Such impurities rarely occur in natural or HPHT-grown synthetic diamonds.

The CVD laboratory-created diamond crystals typically showed a tabular form, which is very different from that of both natural rough and HPHT-grown synthetic dia-

Figure 34. This very light brown 0.87 ct CVD laboratory-grown diamond crystal has a dark rim that is composed of diamond-like carbon or graphite. Courtesy of Apollo Diamond Inc.; photo by Elizabeth Schrader.



mond crystals. The crystals may also approach a cubic form when the CVD overgrowth is thick enough (figure 34). Some samples had a dark rim, which was formed by the deposition of diamond-like carbon or graphite, as suggested by Raman analysis.

According to Apollo, gem-quality crystals weighing up to 3 ct could become available in the near future in small numbers. Apollo is cooperating closely with the GIA Gem Laboratory to ensure that these CVD laboratory-grown diamonds are correctly identified before being introduced into the market. Gemological and spectroscopic studies of additional samples will be reported in a future article.

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**“Mermaid Crystal,” an opal simulant.** Azotic Coating Technology Inc. (ACT) of Rochester, Minnesota, introduced a manufactured opal simulant called “Mermaid Crystal” at the 2003 Tucson gem show. It was brought to this contributor’s attention by Renato Rossi of Rossi Gem Evaluation & Match, also of Rochester. This patent-pending material is available in a number of colors, with either pinfire or broadflash “play-of-color.” According to ACT, Mermaid Crystal “is made from a special type of crystal glass with dichroic flakes floating inside.” The individual flakes are composed of “alternating layers of silica and zirconia, each only one quarter of the thickness of a wave of light.” The material is available in colorless (i.e., water opal simulant), white, black, and blue bodycolors.

Mr. Rossi donated several samples to the GIA collection: five colorless (two rough pieces, one cabochon, and two faceted), five white (three rough pieces and two cabochons), one blue piece of rough, one black cabochon, and one black piece of rough (see, e.g., figure 35). The samples weighed 25.25–57.11 ct (rough), 15.79–19.61 ct (cabochons), and 3.31 and 9.46 ct (faceted).

Examination with a gemological microscope and the unaided eye revealed that all of the simulants were constructed of up to seven alternating layers—varying in thickness from approximately 0.5 to 4 mm—of colorless transparent glass and translucent-to-opaque glass, some containing colored flakes of various sizes and shapes. When the sample was rocked back and forth, the color of the flakes was somewhat dependent on the angle of view, as seen in natural play-of-color opal. However, the color of the flakes was not as sensitive to the viewing angle, nor did the flakes appear to change shape or size when rocked and tilted, as is the case with play-of-color patches in natural opal. The flakes were yellow, pink, blue, “lilac,” purple, green, and orange. Their colors were apparently caused by interference phenomena when light partially reflected off the microlayers in the flakes. The blue and black pieces had opaque bases (of the same color), as did one of the



Figure 35. “Mermaid Crystal” is a new manufactured opal simulant that is available with either pinfire or broadflash “play-of-color.” The cabochons shown here range from 15.79 to 19.61 ct. Courtesy of Renato Rossi; photo by Maha Tannous.

white pieces of rough. No glue lines were visible in any of the samples. Flow lines and numerous gas bubbles, some visible to the naked eye, were present in all samples. ACT reportedly has improved the manufacturing process to reduce the visibility of the gas bubbles.

The face-up diaphaneity of the samples varied from transparent (for the water opal simulant) to translucent or opaque for the other samples. Specific gravity, determined hydrostatically for four samples (a colorless emerald cut, as well as colorless, black, and white cabochons), varied from 2.48 to 2.50, which is in the low range for manufactured glass. In addition, four samples had the following refractive indices: 1.521 for a faceted water opal simulant, 1.518 for the flat polished base of a cabochoned water opal simulant, and 1.52 spot readings for the domes of both white and black cabochons. All the samples were inert to long-wave UV radiation, except for two pieces of rough that showed small patches of yellow or white fluorescence. Short-wave UV radiation produced even or uneven moderate to moderately strong yellow fluorescence. No chalky fluorescence or phosphorescence was noted in any of the samples. Infrared and EDXRF spectroscopy of one of the “white” opal simulants yielded results that were consistent with a silica glass.

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**Synthetic spinel with unusual inclusions.** A 5.99 ct blue oval brilliant (figure 36) was submitted to the SSEF laboratory for identification. Its bright color, as well as its red fluorescence to long-wave UV radiation, raised suspicion that it could be synthetic. A synthetic origin also was supported by strong anomalous birefringence seen with a polariscope. The refractive index was 1.727, which is typical for synthetic spinel. However, the specific gravity



Figure 36. This 5.99 ct blue synthetic spinel contained unusual inclusions. Photo by L. Kiefert, © SSEF.

(determined hydrostatically) was 3.61, which is more consistent with natural spinel than its synthetic counterpart. In addition, oriented inclusions were observed with the microscope, which are somewhat unusual in synthetic spinel. The inclusions consisted of parallel elongated cavities in two directions, intersecting at approximately 135° (figure 37).

Similar gas inclusions, arranged in hexagonal arrays (i.e., intersecting at 120°), have been previously documented in blue flame-fusion synthetic spinel (see E. J. Gübelin and J. I. Koivula, *Photoatlas of Inclusions in Gemstones*, ABC Edition, Zurich, p. 514). In addition, our sample contained rounded negative crystals with hexagonal growth lines (again, see figure 37), which also were pictured by Gübelin and Koivula (p. 514) in blue flame-fusion synthetic spinel. As pointed out by those authors, such features serve as an important reminder that synthetic stones can have natural-appearing inclusions. EDXRF analysis revealed that cobalt was the cause of the blue color in this synthetic spinel.

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## TREATMENTS

**HPHT-processed diamonds from Korea.** Iljin Diamond Co. Ltd., of Seoul, Korea, is the world's third largest producer of synthetic diamonds for industrial applications. At the July 2003 JA Show in New York, Iljin introduced their HPHT-treated natural diamonds to the trade through the Nouv company (figure 38). The diamonds are reportedly treated at temperatures of approximately 2000°C and pressures of 60 kbar.

This contributor visited the Iljin factory in March 2003, and subsequently Iljin sent 167 faceted HPHT-processed diamonds to EGL USA's laboratories in Vancouver and New York for evaluation and certification. According to EGL USA's policy, each diamond was laser inscribed to indicate that it was HPHT treated. The diamonds weighed



Figure 37. Elongated cavities in the synthetic spinel were oriented in two directions, at approximately 135° to one another. Also present were rounded negative crystals. Photomicrograph by H. A. Hänni, © SSEF; magnified 50×.

0.21–1.80 ct, and ranged from Fancy Intense yellow-orange to Fancy Vivid yellow-green (figure 39, left). About 60% of the stones were round brilliants, and the fancy shapes included princess cuts, rectangular step cuts, and various brilliants (i.e., oval, pear, and modified octagonal shapes). Clarity ranged from VVS<sub>2</sub> to I<sub>2</sub>, with most VS<sub>1</sub> to SI<sub>2</sub> (figure 39, right). Microscopic observation revealed inclusions that were typical of HPHT-treated diamonds in approximately 50% of the stones studied, including graphitized feathers and stress fractures around mineral inclusions (see, e.g., T. M. Moses et al., "Observations on GE-processed diamonds: A photographic record," Fall 1999 *Gems & Gemology*, pp. 14–22).

Infrared spectroscopy indicated that all of the diamonds were type Ia, although Iljin has also processed near-colorless type IIa diamonds on an experimental basis. Most of the diamonds showed a moderate amount of nitrogen, with B aggregates dominant over A aggregates. The majority (87%) of the diamonds exhibited typical HPHT absorption features in the visible spectrum at 415, 497, 503, and 986 nm (see B. Deljanin and G. E. Sherman, *Changing the Color of Diamonds: The High Pressure High Temperature Process Explained, Techniques and Identification*, EGL USA Press, New York, 2000, 12 pp.).

The diamonds that did not show such absorption lines did show other indications of HPHT treatment, such as mid-infrared absorption due to single nitrogen at 1344 cm<sup>-1</sup> (see A. T. Collins et al., "Colour changes produced in natural brown diamonds by high-pressure, high-temperature treatment," *Diamond and Related Materials*, Vol. 9, No. 2, 2000, pp. 113–122). In addition, fluorescence varied from inert to strong for both long- and short-wave UV radiation, with a blue to green to yellow reaction to long-wave and (for the majority of the diamonds) greenish yellow to short-wave UV. The long-wave fluorescence was typically stronger than for short-wave. Green transmission (i.e., luminescence excited by visible light) was concentrated in

the yellow graining in most of the diamonds.

In general, the gemological properties of the Iljin HPHT-treated natural diamonds appear to be similar to those from Russia, the U.S., and Europe (see E. Fritsch and B. Deljanin, "Les diamants de type I traités a HPHT: Novatek, General Electric, Russes et Suédois," *Revue de Gemmologie*, Vol. 141/142, 2001, pp. 54–58). The presence of brown graining in the diamonds before treatment was likely due to nanometer-size domains of disordered (perhaps even amorphous) carbon. It appears that during HPHT treatment, these zones recrystallized as diamond, liberating vacancies. The green color component seen in many of the stones we examined was apparently produced when vacancies, either preexisting or created during the annealing of the amorphous carbon zones, combined with the A aggregates to form H2 (986 nm) and H3 (503 nm) centers.

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**Tourmaline with an iridescent coating.** Although iridescent coatings have been applied for years to topaz and quartz (see review by S. F. McClure and C. P. Smith, "Gemstone enhancement and detection in the 1990s," Winter 2000 *Gems & Gemology*, pp. 336–359), little has been published about their use on other colored stones. Therefore, GIA was interested in examining several sam-



Figure 38. Iljin Diamond Co. is producing a range of colors through the HPHT treatment of type Ia diamonds (here, 0.4–2.0 ct). Photo © Robert Weldon/Professional Jeweler.

ples of coated tourmaline that were donated by John Patrick (El Sobrante, California). Faced with a stock of near-colorless tourmaline from Nigeria that was not readily marketable because of its pale color, Mr. Patrick supplied the stones to Azotic Coating Technology Inc. (ACT) of Rochester, Minnesota. Azotic produced a variety of surface colors, apparently by using different "recipes" for the

Figure 39. Most of the HPHT-treated Iljin diamonds ranged from yellow-green to greenish yellow (left). The clarity of most samples ranged from VS<sub>1</sub> to SI<sub>2</sub> (right).

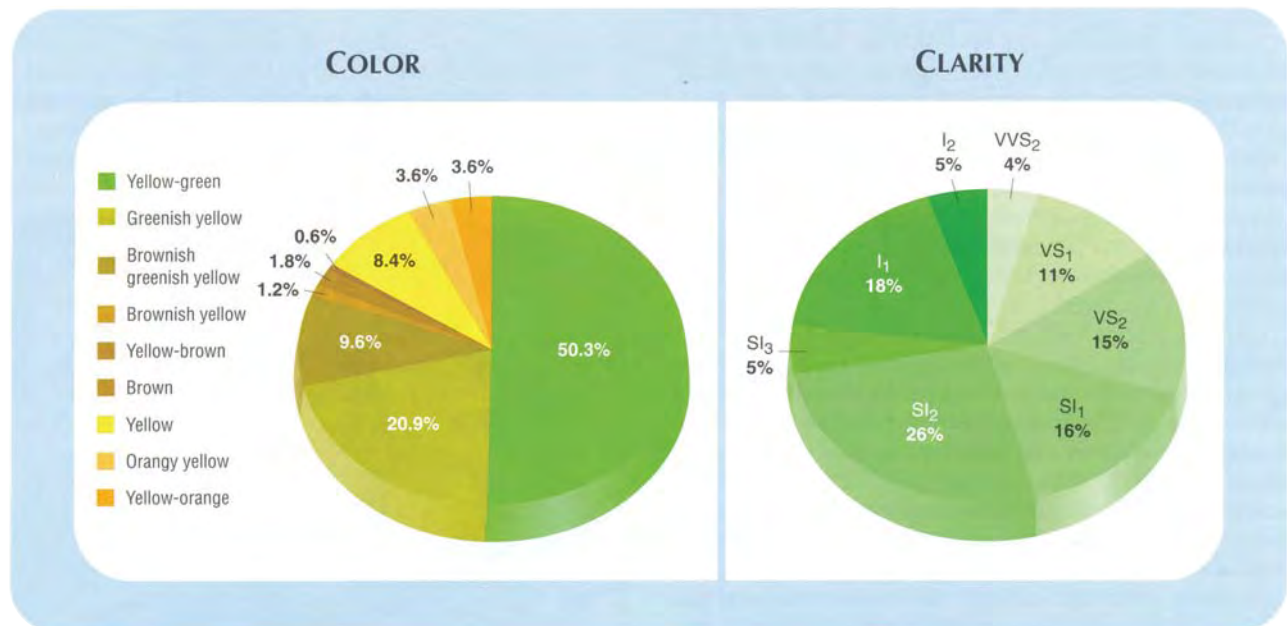




Figure 40. These tourmalines (0.33–2.47 ct) have an iridescent coating on the pavilion of the faceted stones and on the domed surface of the cabochon. The coating produces flashes of iridescent colors, which can be seen face up in the faceted stones and as concentric rainbow colors on the cabochon. Courtesy of John Patrick; photo by Maha Tannous.

iridescent coatings. According to company president Ron Kearnes, Azotic can produce more than 280 different colors, using patented (or patent pending) coating technology. These have been applied to topaz, beryl, synthetic cubic zirconia, sapphire, tourmaline, quartz, and various types of glass, which are being marketed by Azotic as “surface-enhanced designer gemstones.”

Seven of the coated tourmalines were examined by one of us (EPQ): six faceted and one cabochon, ranging from 0.33 to 2.47 ct (figure 40). The colors included brownish orange, greenish blue, purplish pink, grayish purple, greenish yellow, and orange, with several of the stones displaying iridescent flashes. The R.I. values were  $n_o=1.640\text{--}1.642$  and  $n_e=1.624\text{--}1.627$ ; the cabochon yielded a spot reading of 1.63. Birefringence was 0.014–0.016. Specific gravity, determined hydrostatically, was 3.06–3.09. The stones were inert to both long- and short-wave UV radiation, and no absorption features were observed with the desk-model spectroscope. Only the purplish pink stone had a weak pink reaction to a Chelsea filter. Microscopic examination revealed inclusions of transparent colorless crystals, needles, “fingerprints,” and fractures.

All the stones had an iridescent coating with a sub-metallic luster, which was confined to the pavilion facets of the faceted stones and to the domed surface of the cabochon. The coating on the purplish pink stone was spotty and was not quite as lustrous or iridescent as on the others. This, along with the Chelsea filter reaction, suggested that this stone was coated by a different method from that used for the other samples (e.g., sputtering). The R.I.’s reported above were taken from areas where the coating was absent (i.e., from the table of the faceted stones and from the base of the

cabochon). Most of the coated surfaces did not register an R.I. on a standard refractometer. One of the stones did show a very vague reading around 1.70, and the purplish pink stone displayed a shadow edge around 1.63 and another edge at about 1.77. Since the R.I. values of tourmaline and topaz may overlap, this new coated tourmaline could potentially be misidentified as topaz, which is more commonly coated. Careful examination of the optic character, birefringence, and S.G. will separate the two gem materials.

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BML

## MISCELLANEOUS

### Heat treatment and gem cutting facility in Madagascar.

While in Madagascar in July 2003, this contributor visited an ambitious heat-treatment and gem-cutting facility in Antananarivo. Operated by an Italian father-and-son team, Antonio and Guiseppe Pocobelli of Magic Stone Madagascar, the facility initially opened in December 1999. Recently, they have expanded from 16 to 30 gem cutters (see, e.g., figure 41), who are being trained by an expert lapidary from Sri Lanka. Custom-designed machines enable the stones to pass through the entire preforming, cutting, and polishing procedure using the same stone holder. They are working only with Madagascar gems, mostly sapphires from Ilakaka, but also rubies from Andilamena and Vatomaniry. After preforming and any heating that may be necessary to enhance the color/clarity of the corundum, the stones are sorted according to seven color grades and three clarities.

For stones weighing less than 1 ct, once the cutting

Figure 41. At the recently expanded facility owned by Magic Stone Madagascar, sapphires and rubies from that country are being cut using customized equipment. Photo by Brendan Laurs.





Figure 42. This is one of five furnaces used by Magic Stone Madagascar to heat treat corundum. Photo by Brendan Laurs.

team is fully trained, Magic Stone plans to generate 20,000 preforms/day that will be polished in China. In addition, they plan to produce up to 2,000 carats/month of 1+ ct faceted stones at their facility, which will be marketed primarily in the U.S. Strict quality control and production standards are maintained at the Madagascar facility by a computerized tracking system that monitors each step of the cutting process.

Magic Stone has purchased or independently developed five units for heat treating Madagascar corundum (see, e.g., figure 42); the company uses a variety of temperatures and atmospheres (but not Be diffusion treatment), depending on the characteristics of the material and its locality. Eventually, the team plans to cut calibrated tsavorite and color-change garnets as well. Considering the underdeveloped nature of the gem-cutting industry in Madagascar, this small but ambitious operation provides a good example of value-added activities and vertical integration in this gem-rich country.

BML

**Plans for a gemological institute in Madagascar.** The government of Madagascar has undertaken an ambitious initiative to improve the capacity and operating environment of the gem industry in that country. This plan is part of a larger project, to be financed by the World Bank with the assistance of the U.S. Agency for International Development (USAID), that is called PGRM (Projet de Gouvernance sur les Ressources Minérales, or Mineral Resources Governance Project; see <http://www4.worldbank.org/sprojects/Project.asp?pid=P076245>). The project will be overseen by the nation's Ministry of Energy and Mines. It has several components, including: a Gemological Institute of Madagascar (Institute de Gemmologie de Madagascar, IGM), a gemstone exchange in Antananarivo, a "One-stop Shop" to expedite mineral exports, and a system of micro-financing for artisanal miners. In addition, the initiative will sponsor geologic mapping and geophysical surveys of selected areas with high mineral potential.

Tom Cushman (tom-igm@wanadoo.mg) has been selected to be the international consultant in charge of creating and coordinating the development of the IGM project. For the past 12 years, he has been a frequent visitor to Madagascar in his capacity as a gem dealer. The country intends to create the first internationally recognized gemological institution in the African region, which is envisioned to offer three primary services:

1. *Instruction in Gemology.* Students will be trained for employment in the private sector (e.g., stone buying and selling, banking, appraisal, and consulting), in education (e.g., working as instructors at the IGM in Antananarivo or in satellite offices in other Madagascar cities), or in government administration (e.g., in the Mines Department, customs, or the One-stop Shop). As a first step, the IGM has scheduled a GIA extension course in gem identification for December 2003 in Antananarivo.
2. *Instruction in Lapidary Arts.* Experts from within and outside Madagascar will teach gem cutting to international standards, with the goal of raising the quality of Malagasy cutting and its acceptability in the world marketplace. In addition to increasing local employment, this value-added activity should enhance profitability in the mineral sector and make Madagascar a more desirable destination for foreign buyers.
3. *Laboratory Services.* A laboratory capable of issuing internationally recognized certificates will increase buyer confidence in gems available in Madagascar.

The IGM is scheduled to commence its own instruction and laboratory services in 2004. Its success will depend on input and cooperation from all elements of the mineral sector in Madagascar. Mr. Cushman welcomes the comments and assistance of persons interested in improving the quality and profitability of the gem industry in that country.

BML



## CONFERENCE REPORTS

**Gem presentations at the GAC-MAC-SEG meeting.** On May 26–28, 2003, the Geological Association of Canada, Mineralogical Association of Canada, and Society of Economic Geologists hosted a geoscience meeting in Vancouver, British Columbia, Canada. The conference featured special sessions on diamonds and colored stones, and was attended by this contributor. Some of the new gem-related information presented at this meeting is highlighted here. Searchable abstracts of all the poster and oral presentations are available at [http://gac.esd.mun.ca/gac\\_2003/search\\_abs/program.htm](http://gac.esd.mun.ca/gac_2003/search_abs/program.htm).

The diamond presentations focused mainly on Canadian localities. Unfortunately, there was only a modest amount of new data reported, with most presenters offering reviews of the exploration and mining of various properties. **L. P. Boyer** of the University of British Columbia, Vancouver, and coauthors reported that 36 kimberlites have been found in the Buffalo Hills province of Alberta; diamonds have been recovered from 24 of them. **B. C. Jellicoe** of Kensington Resources, Saskatoon, Saskatchewan, and coauthors summarized diamond exploration activities in Saskatchewan's Fort à la Corne kimberlite field, which have involved a variety of geophysical and drilling techniques; the Star kimberlite is being bulk-sampled by Shore Gold, with the goal of obtaining at least 3,000 carats from up to 25,000 tonnes of kimberlite. **R. Boyd** of Ashton Mining of Canada, Vancouver, British Columbia, and coauthors reported that eight diamondiferous kimberlites (known as the Renard cluster) have been found on Foxtrot property in the Otish Mountains region of Quebec. A 0.92 ct diamond was recovered from a 609 kg bulk sample at the Renard 6 kimberlite. **N. S. Lefebvre** of the University of British Columbia and coauthors examined the unusual geology of diamond-bearing alkali volcanoclastic rocks at Wawa, Ontario; from a bulk sample weighing 4,080.5 kg, 22,235 diamonds (presumably micro-sized) were recovered. In addition to the Canadian diamond localities, 69 alluvial diamonds from Juina, Brazil, were characterized by **P. C. Hayman** (University of British Columbia) and coauthors, who confirmed previous research suggesting that the diamonds likely originated from great depths (i.e., >410 km, in the lower mantle or transition zone).

Significant progress has been made on diamond exploration techniques using geophysics and indicator minerals. **Dr. H. Helmstaedt** of Queen's University, Kingston, Ontario, proposed that the assessment of the diamond potential of a craton should involve a complete examination of the physical (craton size, shape, and boundaries), geophysical, and geologic parameters, so that the tectonic history can be reconstructed and the major geologic events can be evaluated according to their possible influence on the preservation or destruction of a potentially diamondiferous Archean lithosphere. **Dr. A. G. Jones** of the

Geological Survey of Canada, Ottawa, Ontario, discovered a geophysical anomaly under the Lac de Gras kimberlite field by using deep-probing electromagnetic surveys (i.e., natural-source magnetotellurics); this technique could be used to explore other areas of the Canadian Shield for diamonds. **Dr. P. T. C. Hammer** and colleagues from the University of British Columbia described the successful application of seismic reflection techniques for imaging the Snap Lake kimberlite dike, at depths of 60–1,300 m and over a lateral distance of 5,700 m. These results demonstrate the potential of using seismic methods for the exploration, subsurface mapping, and detailed imaging of kimberlite dikes. **Dr. T. E. McCandless** of Ashton Mining of Canada presented work he did with H. T. Dummett (deceased) on two compositional trends of chromite indicator minerals; conditions that are conducive to diamond stability occur when Fe is mostly in the ferrous state, indicating a lower oxygen fugacity. **Dr. R. L. Flemming** and **M. A. Hollis** of the University of Western Ontario, London, Ontario, analyzed garnets by X-ray microdiffraction and found that the peak positions for diamond-indicating G10 garnets were shifted (due to a smaller d-spacing) when compared to eclogitic and crustal garnets that are not affiliated with diamonds. Their microdiffraction technique, therefore, offers another potential tool for evaluating garnets as diamond indicator minerals.

Colored stone presentations included much new information about Canadian sources, as well as other localities worldwide. **Dr. L. A. Groat** of the University of British Columbia summarized new Canadian occurrences for emerald (Regal Ridge in Yukon Territory—figure 43, Lened in Northwest Territories [NWT], and Taylor in Ontario), aquamarine (southeastern British Columbia), and

*Figure 43. These emeralds were recovered from the Regal Ridge deposit in Canada's Yukon Territory. The upright prism in the center measures 1.5 × 0.6 cm and weighs 2.44 g. Courtesy of True North Gems; photo © Stephen J. Krasemann.*



tourmaline (the O'Grady batholith in NWT). **H. L. Neufeld** of the University of British Columbia and coauthors characterized the geology of the Regal Ridge emerald deposit, and reported highlights of the 2002 field season; these included the discovery of new mineralized zones to the west and southwest of the original showing, and the recovery of 65 kg of emerald-bearing concentrate from a 120 tonne bulk sample. **Dr. D. C. Murphy** of the Yukon Geological Survey in Whitehorse and coauthors observed that mid-Cretaceous granite and mafic/ultramafic rocks are locally juxtaposed in the Regal Ridge area, and elsewhere throughout the Yukon Territory, providing numerous targets for emerald exploration. **Dr. D. D. Marshall** of Simon Fraser University, Burnaby, British Columbia, and coauthors reported that quartz-carbonate-emerald veins at the Lened locality formed by contact metamorphism between a granitic pluton and sedimentary rocks (i.e., black shales). **H. Falck** of the Northern Geoscience Centre, Yellowknife, NWT, and coauthors used a portable gamma-ray spectrometer to identify favorable conduits for emerald mineralization at the Lened property.

**Dr. G. Giuliani** of the Centre de Recherches Pétrographiques et Géochimiques, Nancy, France, and coauthors studied the Monte Santo emerald deposits in Tocantins, Brazil; they found that emeralds are found both in desilicated pegmatitic/aplitic dikes and in biotite-rich altered rocks developed at the contact with the amphibolite host rocks. **Dr. M. A. Wise** of the Smithsonian Institution, Washington, D.C., and coauthor described the emerald- and hiddenite-bearing vein assemblages at the Rist property in Hiddenite, North Carolina. While hiddenite formed in simple veins containing calcite, emerald occurred with more complex assemblages of rutile, siderite, quartz, graphite, and chabazite.

**Dr. G. Giuliani** and coauthors presented isotopic and inclusion studies of Vietnamese rubies and pink sapphires from Luc Yen and Yen Bai (in Yen Bai Province) and Quy Chau (in Vinh Province). While corundum from the former province is known to have been derived from Cambrian metasediments (i.e., marbles), rubies from Quy Chau are found only in placers; their marble-derived affiliation was ascertained from fluid inclusion and oxygen isotopic evidence. **V. Garnier** of the Centre de Recherches Pétrographiques et Géochimiques, Nancy, and coauthors assembled age data of Asian marble-hosted ruby deposits, and found a direct link with Cenozoic mountain-building events during the collision of the Indian and Asian plates.

**Dr. D. W. Baker** of Little Belt Consulting Services, Monarch, Montana, and coauthors presented evidence that the sapphire deposit at Yogo Gulch, Montana, formed as a result of three plate-tectonic events that led to the volcanism of low-volume, CO<sub>2</sub>-rich magmas that originated from the asthenosphere. **Dr. M. I. Garland** of London, Ontario, traced the alluvial sapphires from western Montana to metamorphic rocks that were eroded from the area near the Bitterroot lobe of the Idaho batholith. These rocks were



*Figure 44. Amethyst from Thunder Bay, Ontario, fades with prolonged exposure to sunlight, but the color can be restored by X-ray irradiation. This color behavior is quite common for amethyst. The particularly fine example of Thunder Bay amethyst shown here is from the Panorama mine, and weighs 5.92 ct. Courtesy of Brad Wilson.*

uplifted to the surface by early Tertiary time, and subsequently eroded; Quaternary reworking of the sapphire-bearing sediments formed the present-day placer deposits.

In other presentations on colored stones, **Dr. A. Ohnenstetter** of the Centre de Recherches Pétrographiques et Géochimiques, Nancy, and coauthors correlated the formation of trapiche textures in Colombian emeralds and Vietnamese rubies with carbonate-shale-evaporite-bearing metasedimentary formations. **A. M. Cade** and colleagues from the University of Western Ontario studied the origin of color in blue and green lapis lazuli from Baffin Island, Nunavut, Canada. Oxidation appears to influence color, since the blue lazurite contained relatively more sulfide and the green lazurite contained more sulfate. **Dr. S. A. Kissin** of Lakehead University, Thunder Bay, Ontario, found that amethyst from Thunder Bay (see, e.g., figure 44) progressively lost color with sunlight exposure (i.e., as examined at intervals of two months, six months, and one year); the amethyst color could be restored by X-ray irradiation. **This contributor** and colleagues confirmed that end-member species of elbaite-liddicoatite and rhodizite-londonite cannot be separated by practical gemological methods. Instead, electron-microprobe analysis of polished samples is necessary, and these analyses frequently reveal fine-scale chemical zoning of the two species in each series.

*BML*

**8th International Kimberlite Conference.** This conference, held approximately every four years, is the most important professional meeting dealing with the occurrence and genesis of diamonds. This year it was held in Victoria, British Columbia, Canada, on June 22–27, and was attended by these contributors. About 275 presentations (both oral and poster) were delivered, and 590



Figure 45. These gem-quality diamond crystals, which were photographed on a colorful piece of kimberlite, are from Canada's Ekati mine. Courtesy of BHP Billiton Diamonds.

attendees registered for the meeting. Given the recent prospecting rush and resulting diamond finds in Canada (figure 45), many of the presentations focused on those deposits. Overall, this conference marked a shift in opinion that many kimberlite magmas could be generated from melted crustal rocks arising along ancient subduction zones, rather than being derived solely from magmas originating deeper in the mantle. These ancient subduction zones may be found along the edges of cratons, or in "suture zones"—areas where rocks of different types are juxtaposed—within cratons.

Here we summarize the results of presentations that might hold the most interest for *G&G* readers. Extended abstracts are available on CD-ROM from the Mineralogical

Society of America ([business@minsocam.org](mailto:business@minsocam.org)), and conference proceedings will be published in two future issues of *Lithos*, a mineralogy and petrology journal.

Because of concern over—and international sanctions on trade in—diamonds that are being mined to fund conflicts in a number of African countries, identifying sources of diamonds has become an important quest in the scientific community. **Eva Anckar** of the University of Cape Town, South Africa, and coauthors described possible techniques for fingerprinting run-of-mine parcels of diamonds. Multivariate statistical analyses employing infrared spectra, size distributions, and physical characteristics proved useful for this identification, based on parcels of 1–2 mm rough diamonds available from three primary deposits in South Africa and Canada. Ms. Anckar pointed out the need for samples of known "conflict diamonds" for their database.

**Dr. Lawrence Taylor** of the University of Tennessee, Knoxville, and coauthors discussed criteria for establishing the syngeneses of diamonds and their inclusions. Inclusions can be protogenetic (have formed prior to the diamond; figure 46, right), syngenetic (have formed at the same time as the diamond host; figure 46, left), or epigenetic (e.g., due to post-growth alteration). Protogenetic inclusions have their own morphologies, while the shape of syngenetic inclusions is influenced by the host diamond. The once-widespread assumption that most inclusions in diamond are syngenetic with their host is now seriously questioned.

**Dr. Larry Heamon** of the University of Alberta, Edmonton, Canada, and **Dr. Bruce Kjarsgaard** of the Geological Survey of Canada, Ottawa, discussed the temporal evolution of North American kimberlites (figure 47).

Figure 46. On the left (magnified 35×), the stepped triangular development of this purplish pink pyrope inclusion in a peridotitic diamond from Siberia reveals the syngenetic influence of the host diamond. On the right, the shape and seemingly random orientation of the pyrope and olivine inclusions in this 4.60 mm peridotitic diamond macule suggest that they are protogenetic. Strain is revealed using polarized light. Photomicrographs by John I. Koivula.

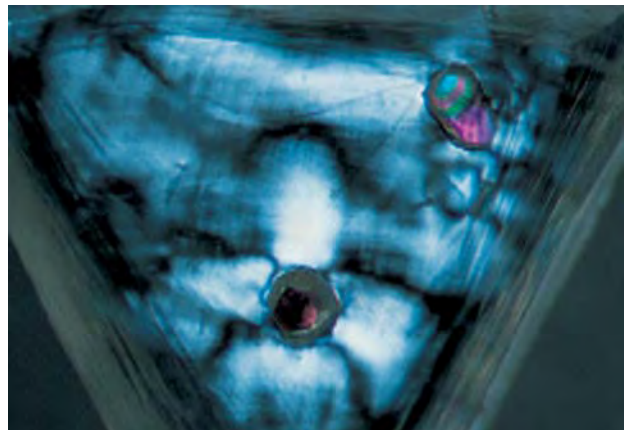
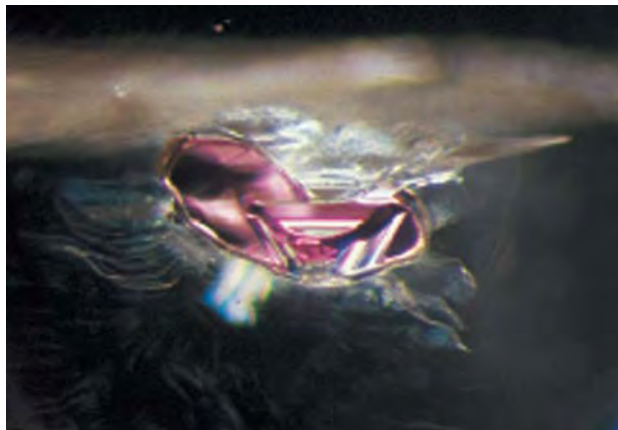


Figure 47. Age relationships between North American kimberlites and related rocks are shown in this map. Yellow names refer to kimberlite clusters or fields, whereas black labels indicate individual kimberlite bodies. Circles represent kimberlites, triangles refer to lamproites, and rectangles indicate other kimberlite-like units such as olivine melilitite or lamprophyre. Black symbols refer to Middle Proterozoic kimberlites, and white symbols indicate unknown age. Modified from L. M. Heaman and B. A. Kjarsgaard, "The temporal evolution of North American kimberlites," 8th International Kimberlite Conference Extended Abstracts CD-ROM, #0099, Victoria, B.C., Canada, June 22–27, 2003.



Precise dates for kimberlites help constrain the origin and triggering mechanisms of kimberlite magmatism, show temporal patterns of diamond deposits, and help with diamond prospecting. Suggested kimberlite production mechanisms include decarbonation of subducted oceanic crust (from which we would expect corridors of kimberlite magmatism parallel to subduction zones), or crystallization from small-volume melts associated with mantle plumes (from which we would expect narrow corridors showing ages in progression). Examining U-Pb ages from perovskite, an accessory mineral in kimberlite, Drs. Heaman and Kjarsgaard found that kimberlites tend to become younger from east to west across North America (early Cambrian in the northeast; Jurassic in the east; Cretaceous in a central belt; and mixed ages, from 48–615 million years [My], in a Western belt). **Grant Lockhart** of BHP Billiton Diamonds and coauthors indicated that of the five kimberlite fields known in the Slave Province, the Lac de Gras field is the youngest.

**Dr. Tom Nowicki** of Mineral Services Canada, Vancouver, and coauthors reviewed the geology at Ekati. Most of the kimberlite pipes are about 3 hectares (ha) in area and 400 m in depth. One exception is the Fox pipe, which covers 17 ha and is about 1 km deep. **Darren Dyck** of BHP Billiton Diamonds and coauthors explained diamond resource and reserve estimation at the same

deposit. As of June 2003, 25% of the kimberlites at Ekati had been sampled, and the resource was 10 pipes with 114 million tonnes of ore at 1.3 ct ¼ tonne (range 0.1–5); the reserve (i.e., the amount that can be mined economically with high certainty) was half this amount. **Dr. John Gurney** of Mineral Services, Pinelands, South Africa, and coauthors described the characteristics of bulk samples of Ekati diamonds, based on their examination of about 32,000 diamonds from 13 kimberlites. They typically formed octahedra (including macles) and dodecahedra; sometimes formed cubes, fibrous cubes, and cuboctahedra; and mainly were white and brown (rarely yellow). Different clusters of pipes showed different population trends. **Dr. Robert Creaser** of the University of Alberta, Edmonton, and coauthors examined Rb-Sr ages for phlogopite megacrysts from 27 kimberlites at Ekati. The period between 51 and 53 million years ago was the most productive for diamond emplacement.

**Kimberley Webb** of De Beers Canada Exploration, Vancouver, and coauthors discussed the geology of the Victor claim in Attawapiskat, Ontario. The kimberlite bodies are mainly pyroclastic and lack diatreme roots. **Adrian Berryman** of De Beers Canada Exploration, Toronto, and coauthors described the geology of the Fort à la Corne deposit in Saskatchewan, where about 70 kimberlites (60% diamondiferous) have been found. **Roy Eccles** of the Alberta

Geological Survey, Edmonton, Canada, and colleagues described the petrogenesis of late Cretaceous diamondiferous rocks (Mountain Lake, Buffalo Hills, Birch Mountain) in Alberta. These bodies are mostly small, from less than 1 to 48 ha.

Several presentations covered African kimberlites. The geology of the Mwadui kimberlite in Tanzania was described by **Dr. Johann Stiefenhofer** of the De Beers Geoscience Centre, Johannesburg, South Africa, and coauthor. This represents the largest diamondiferous kimberlite ever mined, and it exhibits an almost perfectly preserved example of a crater-fill deposit (i.e., erupted material that fell back into the volcano's crater). **Dr. Stephan Kurszlauskis** (also of the De Beers Geoscience Centre) and coauthor explained that the Venetia kimberlite pipes in South Africa formed along preexisting faults and fractures in the host rocks as the result of several violent volcanic phases separated by periods of relative inactivity. **Clare Appleyard** of De Beers Geoscience Centre and coauthors explained that eclogitic diamonds from the Finsch mine in South Africa show a wide range of nitrogen contents, but they found no type IIa diamonds (i.e., those without any detectable nitrogen). The inclusions in these diamonds are consistent with eclogite formation from a subducted slab protolith ("parent" rock). **Dr. Pierre Cartigny** of the Institut de Physique de Globe, Paris, and coauthors concluded that reaction of subducted material with fluids (metasomatism) could be responsible for the formation of Namibian diamonds.

Many other speakers also presented evidence that some diamonds form through mantle metasomatism. **Dr. Thomas Stachel** of the University of Alberta and coauthors examined trace elements—especially rare earths and chromium—in garnet inclusions in diamonds from the Birim River, Ghana. The trace-element patterns can be explained if both silicate melts and oxidizing "CHO" (carbon/hydrogen/oxygen) fluids, from down-going crustal slabs, were involved in the garnet genesis. **Dr. Jeffrey Harris** of the University of Glasgow presented his group's work on some unusual inclusions in small (2–4 mm) Namibian diamonds. This suite of inclusions and the formation of the host diamonds could be explained by a peridotitic source that had undergone "extensive carbonation." **Dr. Ray Burgess** of the University of Manchester, United Kingdom, and co-authors discussed the different  $^{40}\text{Ar}$ - $^{39}\text{Ar}$  ages of clinopyroxene inclusions in Venetia (South Africa) and Orapa (Botswana) eclogitic diamonds. They suggested that the Orapa diamonds are significantly older (990 My) than the host kimberlite (eruption age about 93 My), but that some of the Venetia diamonds are about the same age as their host kimberlite (about 520 My). According to **Dr. Dorrit Jacob** of the University of Greifswald, Germany, trace-element and isotopic evidence suggests that mantle eclogites may have been formed from seawater-altered, subducted oceanic crust.

**Dr. Oded Navon**, of the Hebrew University, Jerusalem, and colleagues provided a review of what has been learned

from fluid inclusions in diamonds. Most diamonds precipitated from fluids, and some trapped these fluids in microinclusions (e.g., in "clouds"). Four types of fluids are seen: a potassium chloride brine; a carbonatitic melt containing Mg, Ca, and Fe; a hydrous silicic melt containing Si and Al; and a sulfide melt. Previous work has shown that diamonds can be grown from a carbonatite melt; carbon isotopic data are also consistent with some diamonds growing from this source in nature.

**Dr. Catherine McCammon** of the University of Bayreuth, Germany, and coauthor discussed mantle oxygen fugacity and diamond formation. Oxygen fugacity (a measure of how oxidizing the system is) changes phase relations and compositions of melts and fluids, and affects the stability of diamond. Oxidizing conditions can stabilize ferropericlase, a diamond inclusion mineral that otherwise requires mid- to lower-mantle pressure to form. Therefore, diamonds with syngenetic ferropericlase inclusions did not necessarily form at deep levels (e.g., the lower mantle), as has been suggested by previous workers. **Dr. Gerhard Brey**, of the University of Frankfurt, Germany, and coauthors also examined the stability of ferropericlase coexisting with other inclusions in diamonds. Very high pressure is not needed for ferropericlase-bearing inclusion suites from São Luis, Brazil, and many from Kankan, Guinea.

**Dr. Mahesh Anand** of the University of Tennessee, Knoxville, and colleagues dissected eclogite nodules from the Udachnaya pipe in Yakutia, Russia. They found that some diamonds occur along linear features in the nodules and that diamonds occur in and around altered clinopyroxene. **Dr. Stephen Haggerty** of Florida International University, Miami, described kimberlite-type rocks in the Dharwar craton, India. Currently, the only primary diamond mine is Majhgawan, in the Bundelkhand craton, which produces several tens of thousands of carats per year from 10 ct/100 tonnes of ore.

The 9th International Kimberlite Conference will be held in Hyderabad, India, in October 2006.

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## ANNOUNCEMENTS

**John I. Koivula wins AGS Liddicoat journalism award for G&G article.** GIA chief research gemologist (and *Gems & Gemology* contributing editor) John I. Koivula has received the American Gem Society's Richard T. Liddicoat Journalism Award in the Jewelry Industry/Trade Reporting division for his Spring 2003 *Gems & Gemology* article "Photomicrography for Gemologists." This award was developed in remembrance of GIA Chairman Richard T. Liddicoat, to honor journalists who have made exceptional contributions to the understanding of gemology, as well as the ideals of ethics, education, and consumer protection. The award was presented at AGS's Circle of Distinction Dinner on July 29, 2003, during the JA New York Show.

Also honored at this event was longtime *G&G* contributor G. Robert Crowningshield, who received the 2003 AGS Lifetime Achievement Award.

**Visit *Gems & Gemology* in Tucson.** Meet the editors and take advantage of special offers on subscriptions and back issues at the *G&G* booth in the Galleria section (middle floor) of the Tucson Convention Center during the AGTA show, February 4–9, 2004.

GIA Education's traveling Extension classes will offer hands-on training in Tucson with "Diamond Grading" (February 2–6) and "Advanced Gemology" (February 7). To enroll, call 800-421-7250, ext. 4001. Outside the U.S. and Canada, call 760-603-4001. GIA will also present two free seminars on Sunday, February 8, a "*Gems & Gemology* 2003 Recap" and "Business for Jewelers."

The GIA Alumni Association will host a dance party in Tucson on February 6, featuring a silent auction, an industry awards presentation, and a live auction. To reserve tickets, call 760-603-4204 or e-mail [events@gia.edu](mailto:events@gia.edu).

The theme of this year's Tucson Gem & Mineral Show (February 12–15) is gold, which will be the topic of a one-day symposium on February 14. For more information, visit [www.tgms.org](http://www.tgms.org).

## Conferences

**Québec Exploration 2003.** This conference, which will take place November 24–27, 2003, in Québec City, Canada, will feature a session on "Early-stage Assessment of Kimberlites Using Indicator Minerals, Petrography and Microdiamonds." A November 24 workshop called "Diamonds and Kimberlites" will provide an opportunity for hands-on examination of kimberlite samples, indicator minerals, and diamonds. Visit [www.quebecexploration.qc.ca](http://www.quebecexploration.qc.ca), e-mail [info@QuebecExploration.qc.ca](mailto:info@QuebecExploration.qc.ca), or call 418-627-6392.

**Gems at the MRS Fall Meeting.** On December 1–5, 2003, the Materials Research Society will convene in Boston, Massachusetts. The meeting will include a symposium titled "The Science of Gem Materials." For more information, visit [www.mrs.org/meetings/fall2003/symp\\_ii.html](http://www.mrs.org/meetings/fall2003/symp_ii.html), e-mail [info@mrs.org](mailto:info@mrs.org), or call 724-779-3003.

**PDAC 2004.** The 2004 Prospectors and Developers Association of Canada international convention on March 7–10, 2004, will include a special session on diamonds that will consider the use of microdiamonds in exploration, project development, and diamond recovery methods. In addition, an update on diamond resource/evaluation methods will be provided. For more information, visit [www.pdac.ca](http://www.pdac.ca), e-mail [info@pdac.ca](mailto:info@pdac.ca), or call 416-362-1969.

## Exhibits

**Chanel Collection Privée.** The Chanel 2003 "Collection Privée," a 150-piece fine jewelry collection, will be on display beginning in November at the Chanel Fine Jewelry boutique in New York City (733 Madison Avenue). Among the themes represented will be reproductions of original Chanel jewelry from the 1930s. In 2004, the collection will travel to Chanel boutiques in Beverly Hills, California; Honolulu, Hawaii; and Palm Beach, Florida. Contact Amy Horowitz at [amy.horowitz@chanelusa.com](mailto:amy.horowitz@chanelusa.com) or 212-715-4747.

**Treasures of ancient Egypt at the New Orleans Museum of Art.** "The Quest for Immortality," the first exhibition of artifacts from the Egyptian national collection to tour the U.S. since the Tutankhamen exhibition during the 1980s, will be on display at the New Orleans Museum of Art from October 19, 2003 through February 25, 2004. Among the many items to be exhibited are gold and jeweled funeral relics from the royal tombs at Tanis, as well as a complete reconstruction of the tomb of Thutmose III, who ruled Egypt during the 15th century BC. For more information, visit [www.noma.org](http://www.noma.org) or call (504) 488-2631.

## ERRATUM

On p. 146 of the Summer 2003 issue, the fluorescence description provided in the Lab Note on the glass imitation of tsavorite garnet should have read, "Garnets are usually inert to short-wave UV radiation, but some tsavorites may fluoresce weak reddish orange to long-wave UV." *Gems & Gemology* thanks Dr. Jaroslav Hyrsl for bringing this error to our attention.

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# GEMS & GEMOLOGY.

## CHALLENGE WINNERS

This year, 292 dedicated readers participated in the 2003 GEMS & GEMOLOGY Challenge. Entries arrived from all corners of the world, as readers tested their knowledge on the questions listed in the Spring 2003 issue. Those who earned a score of 75% or better received a GIA Continuing Education Certificate recognizing their achievement. The participants who scored a perfect 100% are listed below. Congratulations!

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**Answers (see pp. 67–68 of the Spring 2003 issue for the questions):** 1 (d), 2 (a), 3 (b), 4 (c), 5 (c), 6 (b), 7 (b), 8 (b), 9 (d), 10 (c), 11 (a), 12 (a), 13 (c), 14 (d), 15 (b), 16 (a), 17 (d), 18 (b), 19 (c), 20 (b), 21 (d), 22 (a), 23 (d), 24 (a), 25 (b)



## EDITORS

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Jana E. Miyahira-Smith  
Stuart Overlin

### The Eras of the Diamond

By Jules Roger Sauer, publ. by Amsterdam Sauer, Rio de Janeiro, Brazil, 2003, price available on request. E-mail: [julesauer@amsterdamsauer.com](mailto:julesauer@amsterdamsauer.com).

The author is an elder statesman of the gem trade who began cutting diamonds in Belo Horizonte, Brazil, in 1941. In this beautifully illustrated book, Mr. Sauer pays tribute to the rich lore of diamonds with a nontechnical approach by someone who has sincerely loved them through the years.

The early chapters focus on the lore of gemstones and ancient myths surrounding rough diamonds (such as one 1243 lapidary work that postulated that brown diamonds were male, and female diamonds were "white and beautiful of color like crystal"). These chapters also include sections on the formation of diamonds and principal deposits worldwide.

The second section, on gem cutting, features an analysis and history of cutting and grading gem diamonds. It offers interesting details on how the art has changed over the centuries, from the European table cuts of the 16th century to the many contemporary cuts.

Indian diamonds, of course, played the predominant role in the early trade. They are mentioned in Sanskrit texts as old as 3,500 years, though some of these early references may actually have been to other gemstones. A millennium later, diamonds were actively traded along the legendary Silk Route—westward through Afghanistan, Persia, Syria,

and Turkey, and finally from Constantinople to Rome, as well as eastward to China.

The author vividly describes India's ancient citadel of Golconda, which was the center of the diamond world during the 16th and 17th centuries. Merchants gathered there to buy and trade gemstones. Among the famous diamonds to come from that region are the 45.52 ct Hope, the 787.5 ct Great Moghul, and the 440 ct Nizam.

At the heart of the book are the chapters on Brazil, which supplanted India's dominance after diamonds were discovered there in the early 18th century by gold prospectors (who did not recognize those crystals as objects of value). The book describes how the ensuing diamond rush overwhelmed European gem markets for a time. The book also provides a portrait of the *garimpeiros*, the independent diggers who form the backbone of the Brazilian diamond industry. It describes the different diamond-producing regions of the country, recounting stories of how famous Brazilian diamonds, such as the 726.8 ct Presidente Vargas, were unearthed. This stone was recovered from the Santo Antonio River in Minas Gerais in 1938 by two such *garimpeiros*, who sold it to a dealer for \$56,000. The diamond eventually found its way to Harry Winston, who reportedly paid \$600,000 for it. At the end of this section is a table listing the notable diamonds found in the country.

The author reviews other producing countries and offers a chapter on De Beers's role in the market. Unfortunately, much of the information in

that chapter is quite outdated. The closing chapters feature reports on the growing popularity of colored diamonds, notes on synthetics and treatments, and an update on prospecting efforts in Brazil.

The author does not delve into great detail in this book, but does offer an attractive overview of diamond production and an insider's look at Brazil's diamond production—which many authors ignore. For that, it's worth a read.

RUSSELL SHOR

*Gemological Institute of America  
Carlsbad, California*

### Jadeite Jade, A Stone & A Culture

By Chiu Mei Ou Yang, 184 pp., illus., publ. by the Hong Kong Institute of Gemmology, 2003. US\$45.00

A notice in the book's preface should prepare readers for what is to come. The author writes, "Although this book has been edited and corrected many times, this book may still contain some typing mistakes and/or there may be missing phrases." Indeed, this new book in English is littered with hundreds of typos, missing letters, and misspellings that make careful reading a chore. There are even two such errors in the short dedication: "grestest teachers" and "This book is dedicate to them."

There are a number of interesting new photographs of contemporary pieces and a very useful selection of photographs showing some of the many materials carved in China and



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sold as jadeite. Unfortunately, the educational value to readers of seeing the many imitations is muted by the author's use of potentially confusing trade names, such as Serpentine "jade," Aventurine "jade," Australian "jade," and even Green Grossular Garnet "jade."

Although China's relationship with nephrite jade (the original Stone of Heaven) has spanned more than 5,000 years, many in modern-day China seem to believe that only jadeite jade is historic, valuable, and worthy of reverence. This book does little to correct such misconceptions. Also, instead of the usually accepted story of China's introduction to jadeite in the 1780s with the arrival of some colorful material as part of a new trade pact, the author describes Chinese traders discovering jadeite pebbles inside Burma—with no historical evidence provided to support this theory.

It is interesting to read how the Chinese classify different types of jadeite cobbles and boulders from secondary deposits. Western dealers and buyers rarely encounter such colorful terms as "New Mine Skinless Stone," "Mountain Stone," "Surface Water Stone," "River Stone," or "Surface Stone," so the author's descriptions here may be helpful.

The author calls dyeing "artificial treatments" and attributes the increased prevalence of treated jade to a growing population of better-paid consumers. I believe she is referring to the population of China. She writes on p. 98, "With the rapid growth of populations and the improvement of economic living standards, people are increasingly in pursuit of a better cultural living standard too. A result has been, a growing demand for the enhancement of the beauty of jadeite jade ornaments, for either enjoyment or appraisal." I believe the author is much too kind to those who dye jadeite, usually without disclosure. In most cases, gem materials are treated primarily to increase their potential sale value, and such is undoubtedly the case with dyed jadeite.

Nevertheless, the section on treatments is well done and should help buyers better understand how jadeite is enhanced today. In my experience, the treatments are many and disclosures are few, so this could be the book's most useful chapter. It certainly should help buyers know what to look for and show specialists how to detect various jadeite treatments.

As a final comment, although there is some useful information in this book, it deserves a better presentation. Before another edition, the entire text should be edited, typographic and grammatical errors removed, and the whole book reviewed by a qualified English text editor. It would be very difficult to recommend this English version in its current state.

FRED WARD

Bethesda, Maryland

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### **Pegmatology: Pegmatite Mineralogy, Petrology and Petrogenesis**

*By William "Skip" Simmons, Karen L. Webber, Alexander U. Falster, and James W. Niamoff, 176 pp., illus., publ. by Rubellite Press, New Orleans, LA, 2003. US\$47.50*

"Pegmatites are among the most fascinating of all igneous rock types." So say the authors of this welcome tome, and I—having spent my entire professional career intrigued by these dramatic deposits—could not agree more. Pegmatites are characterized, at least in part, by very coarse crystalline texture; indeed, some of the largest crystals known have been found in pegmatites. Some types of pegmatites also contain a diverse suite of rare minerals, including gem materials such as tourmaline, aquamarine, kunzite, topaz, and spessartine.

There have been many recent advances in the scientific understanding of pegmatites, but this is the first contemporary book on the topic. To gain a reasonable perspective on the nature of pegmatites, it was heretofore necessary to comb the geologic

literature for relevant scientific papers, assimilate all the information, weigh the interpretations of a variety of researchers, and integrate it all into a cohesive package. The authors of *Pegmatology* have done all that, and the result is an authoritative and very readable publication.

This book grew out of a guidebook written for the Maine Pegmatite Workshop, first held in May 2002. In the authors' words, "This book is not intended for the professional mineralogist or petrologist, but does contain a sufficiently comprehensive coverage that the serious reader can develop a thorough understanding of pegmatite mineralogy and genesis." In recognition of their intended audience, namely miners and serious mineral collectors interested in learning more about pegmatites, the authors have endeavored to limit scientific jargon to that necessary to explain clearly the mineralogical and geologic concepts and processes. In general, they have succeeded well, although readers with little or no background in geology and mineralogy will probably find themselves a bit lost at times. At the other extreme, the authors' disclaimer notwithstanding, professional mineralogists and petrologists will find this book a great place to start getting up to speed on recent advances in the study of pegmatites.

Chapter one provides a brief overview of what a pegmatite is and how pegmatites are classified. Chapter two explains key geologic and mineralogical concepts (e.g., plate tectonics, the composition of the earth's crust, the atomic structure of minerals, and the rock cycle) that are essential to the subsequent explanation of pegmatite formation. Chapters three through eight take the reader through the genesis of pegmatites: magmatic differentiation, origin of magma, plate tectonic setting for magma generation, granite to pegmatite, zonation of pegmatites, and pocket formation.

Chapter nine, by far the book's largest, is titled Pegmatite Mineralogy. It describes the most important and/or scientifically significant pegmatite

minerals. The descriptions, for the most part, focus on those aspects of the minerals that pertain to their occurrence in pegmatites. Although the treatment is very uneven, with some minerals or mineral groups receiving much more attention than others, this approach was followed because of the special insights that certain minerals provide. Still, it does seem a bit lopsided to devote 18 pages to the tourmaline group and just one paragraph to topaz.

The last six chapters pick up where the first eight left off. They cover classification of pegmatites, pocket indicators, volatiles in pegmatites, cooling and crystallization of pegmatites, petrogenic indicators, and geophysical and geochemical exploration methods. I must admit that I don't quite understand the rationale for separating the last six chapters from the first eight (with the mineral descriptions in between). After reading the first eight chapters, I thought there were a few aspects of pegmatite formation that the authors had neglected. Of course, I came across these later in the book, but not until I had spent some time worrying about why they hadn't been addressed. Perhaps the authors would consider placing the Pegmatite Mineralogy chapter last in subsequent editions.

The book concludes with a list of references and an appendix. I sometimes skip right to the reference list to get a quick gauge of how thorough, comprehensive, and authoritative a publication is; *Pegmatology* passed this test with flying colors. The appendix includes several pages on basic crystallography, a periodic table, a list of elements with crustal abundances, and a diagram showing igneous rock classification. The authors apparently found these resources useful while teaching the pegmatite workshop. Two additions that I would recommend in future editions are an index and a glossary of terms.

I have a few final words concerning the overall presentation. First, except for a few typos, the text is

remarkably error free. Second, the text is liberally illustrated with well-chosen photos, diagrams, and tables; however, the overall quality of these illustrations could be much better. Last, little is said of the fascinating history of pegmatite study, and the addition of a chapter on this topic would add flavor to the book and put the modern studies into better context.

This book may not be for everyone, but certainly anyone with an interest in pegmatites and the wonderful diversity of minerals and gems that come from these remarkable deposits should not be without it.

ANTHONY R. KAMPF  
*Natural History Museum of  
Los Angeles County  
Los Angeles, California*

## OTHER BOOKS RECEIVED

**At the Bench: An Illustrated Guide to Working with Gold & Silver.** By Gregg Todd and Greg Gilman, 116 pp., illus., publ. by MJSA/AJM Press, Providence, RI, 2002, US\$28.50.\* More than a guide to working with these two metals, *At the Bench* is an essential resource for every bench jeweler. The 8.5 × 11 in. soft cover begins with a section on Bench Preparation and Practices that covers critical safety matters, discusses proper tools and accessories, and offers suggestions to maximize workflow. The next chapter addresses take-in procedures, giving useful tips about visual inspection and communication between jeweler and customer.

The bulk of the book provides comprehensive instruction on a range of repair and fabrication processes, from basics like dovetail sizing and pavé setting to more complex tasks like fabricating silver filigree and repoussé. More than 200 detailed photos accompany the step-by-step directions. A chapter on The Do's and Don'ts for Polishing Success gives necessary attention to one of the bench jeweler's least desirable tasks. The book closes with a section called

Bench Resources that highlights some of the industry's leading suppliers and educators.

ANGELA LOCKHART  
*Gemological Institute of America  
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**Auction Market Resource, June 2003, Vol. 10, No. 1.** Publ. by Gail Brett Levine, P.O. Box 7683, Rego Park, NY 11374-7683. Tel: 718-897-7305. Available by subscription: \$195.00 in the U.S., \$250.00 elsewhere. E-mail: 76766.614@compuserve.com. Since 1994, *Auction Market Resource* has compiled data on jewelry items sold at major national and international auctions. This subscription-based guide is published semi-annually (June and December), and an adjunct pay-for-information website is available at [www.AuctionMarketResource.com](http://www.AuctionMarketResource.com). The June 2003 edition includes nearly 550 listings of antique to modern jewelry and watches sold by more than a dozen leading auction houses between May 2002 and April 2003. Each listing provides a black-and-white photo of the piece plus detailed auction data. Specially featured in this edition is an expanded section on watches. This section contains brief, independently written articles on watch appraisals, American railroad pocket watches, hand engraving on jewelry and watches, and buying watches at auction online.

JANA E. MIYAHIRA-SMITH  
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*\*This book is available for purchase through the GIA Bookstore, 5345 Armada Drive, Carlsbad, CA 92008. Telephone: (800) 421-7250, ext. 4200; outside the U.S. (760) 603-4200. Fax: (760) 603-4266.*

# Gemological ABSTRACTS

## 2003

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### COLORED STONES AND ORGANIC MATERIALS

**The effect of co-cultivation on the pearl yield of *Pinctada martensi* [sic] (Dumker).** M. Wu, S. K. K. Mak, X. Zhang, and P.-Y. Qian, *Aquaculture*, Vol. 221, 2003, pp. 347–356.

This study investigated the effect of the co-cultivation (i.e., involving both animal and plant species) of the pearl oyster *P. martensii* in the presence of the red alga *Kappaphycus alvarezii* on the production rate and quality of saltwater cultured pearls in Hainan Province, China. Production rate was determined by nucleus retention, and quality was judged by the thickness and number of nacre layers.

Survival and nucleus retention rates were very similar under both mono-culture (involving the oyster only) and co-culture conditions. However, co-culture conditions produced a consistently higher yield of premium- to medium-quality cultured pearls with thicker and more homogenous nacre. This and previous studies suggest environmental factors (e.g., pH and concentrations of O<sub>2</sub>, CO<sub>2</sub>, and N in the seawater) have a significant influence on the biomineralization process of nacre growth.

Algae can consume CO<sub>2</sub> and N waste products that are released by oysters, while releasing O<sub>2</sub>, thus creating a favorable environment for calcification. Bio-fouling (by bacteria, shell inhabitants, or parasites) was less problematic under co-cultivation conditions, as evidenced by the surfaces of co-cultivated oysters, which were consistently much cleaner than the mono-cultured oysters. The co-culture system was also favorable for the growth of the red algae, which is potentially an important revenue source for pearl farmers. The positive long-term environmental and economic aspects of the co-culture method could apply to the Southeast Asian and South Pacific regions as well. CT

*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.*

*Requests for reprints of articles abstracted must be addressed to the author or publisher of the original material.*

*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.*

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**Freshwater pearl culture technology development in India.** K. Janakiram, *Journal of Applied Aquaculture*, Vol. 13, No. 3/4, 2003, pp. 341–349.

India is developing the technology and expertise to culture freshwater pearls. Several common freshwater mussels have been identified as important species suitable for cultured pearl production: the pond mussel *Lamellidens marginalis*, the paddy field mussel *L. corrianus*, and the riverine mussel *Parreysia corrugata*. The mussels are fed prepared and natural diets such as finely powdered rice bran and peanut oil cake, cultured green algae, and blue algae. Nuclei implantation procedures being perfected include mantle-cavity and mantle-tissue implantations (60–70% success rate for each) and gonad implantation (25–30% success rate). Shell beads of  $\geq 6$  mm, obtained mostly from Japan, are used for mantle-cavity implantation. The pond culture phase is normally 12 months.

CT

**Production and grow-out of the black-lip pearl oyster *Pinctada margaritifera*.** I. Lane, C. Oengpepa, and J. Bell, *Aquaculture Asia*, Vol. 8, No. 1, 2003, pp. 5–7.

Pacific Ocean countries such as Fiji, Tonga, Marshall Islands, and Solomon Islands are attempting to develop a black cultured pearl industry owing to the success of this activity in French Polynesia, where it generated \$200 million in export earnings in 2000. This article outlines the methods being used in these countries to collect and grow the black-lipped pearl oyster, *P. margaritifera*, preliminary to black pearl farming. A major consideration is that a farm must have enough oysters (~5,000–10,000) to attract a technician to perform the seeding operation.

Wild spat collection is the least expensive and simplest method to obtain juvenile black-lipped pearl oysters, but if they are scarce, hatchery spat production—though more difficult and costly—can be used to produce a large number of juveniles. Spat enter into the juvenile grow-out phase at 5 mm in length; they are transferred to the main grow-out system when the shells reach 50–60 mm. The oysters are nucleated with a shell bead and a graft of mantle tissue when they reach 90–120 mm in length. The density of the oysters in each system is reduced as they grow, and a four- to six-week cleaning cycle is maintained throughout the 18–24 months that it takes to produce the cultured pearls. Oysters that produce a good-quality cultured pearl may be reseeded.

CT

**Quality grading method of China sea-cultured pearls on the basis of fuzzy evaluation.** B. Kong, J. Zou, J. Chen, and Y. Liao, *Journal of Guilin Institute of Technology*, Vol. 23, No. 1, 2003, pp. 60–64 [in Chinese with English abstract].

Grading systems or models for determining the quality of Akoya cultured pearls have been investigated by gemologists and jewelers for several decades. Most are based mainly on descriptive comparisons of several important

characteristics, but the use of these systems or models by the jewelry industry has been limited. In this article, the authors attempt to use mathematical techniques to develop a quantitative model for grading the quality of Chinese Akoya cultured pearls.

The model contains three hierarchies, six conditions, and 12 factors. The three hierarchies (“target quality layer,” “conditional layer,” and “factor layer”) are the basis of the model. The conditional layer, for example, consists of six characteristics: color, size, shape, surface defects, luster, and thickness of the nacre layer. The 12 factors are: body color, surface color, transparency, minimum diameter, difference between the maximum and minimum diameters, symmetry, type of surface defects, area and number of the surface defects, quality of the luster, crystallinity, mineral type of the nacre layer, and measured or estimated thickness of the nacre layer. These conditions and factors are calculated into different “weighting indices.” Finally, these indices are mathematically calculated using “fuzzy logic” evaluation techniques. As a result, Chinese Akoya cultured pearls can be classified into five grades: extraordinary [*sic*] fine, first, second, third, and fourth.

TL

**X-ray diffraction study of nacre in shell of *Hyriopsis cumingii* [*sic*] (Lea).** G. Zhang, X. Xie, S. Qi, and P. Hu, *Journal of Mineral Petrology*, Vol. 22, No. 4, 2002, pp. 8–11 [in Chinese with English abstract].

The nacre layer of a shell or pearl consists mainly of aragonite crystals with some organic components. The structural characteristics of the nacre layer give rise not only to beautiful colors, including iridescence, but also to its mechanical properties. Using X-ray diffraction techniques, the authors studied nacre from *H. cumingi*, the major source of Chinese freshwater cultured pearls. Two preferred crystallographic orientations of aragonite crystals in the nacre layer were found. In the first the [001] axes were perpendicular to the nacre layer, whereas in the second the [012] axes were normal to the nacre layer; the latter type of orientation had not been previously reported in the literature. Overall, the preferred orientation of the aragonite crystals varied considerably throughout the nacre layer of *H. cumingi* shells, which accounted for the variable mechanical characteristics exhibited by this layer.

TL

## DIAMONDS

**Characters [*sic*] of brown spot [*sic*] on diamond from Hunan Province and its implication.** M. Yang and Y. Gao, *Journal of Gems and Gemmology*, Vol. 4, No. 4, 2002, pp. 15–19 [in Chinese with English abstract].

Many of the diamond crystals from the alluvial deposit at Yuanjiang, Hunan Province, China, have brown (and also

yellow or black) spots on their surface. The spots range in size from 10 to 200  $\mu\text{m}$ , penetrate 20–50  $\mu\text{m}$ , and usually have sharp boundaries.

The brown spots appear dark in cathodoluminescence images of the diamonds. Raman spectra of the spots have weak peaks at 1636.4, 1631.4, 1493.4, and 1444.6  $\text{cm}^{-1}$ , while the characteristic diamond peak at 1332  $\text{cm}^{-1}$  is shifted toward a lower wavenumber. These features indicate damage to the diamond crystal structure. The authors conclude that the brown spots are caused by radiation from naturally radioactive mineral(s) in the alluvial environment. *TL*

**Diamond economics of the Prairie Creek lamproite, Murfreesboro, AR, USA.** D. P. Dunn, *Ore Geology Reviews*, Vol. 22, No. 3/4, 2003, pp. 251–262.

Although discovered in 1906, and commercially mined intermittently until 1931, the true economic potential (i.e., grade of the ore and value of the diamonds) of the Prairie Creek lamproite was never determined. To evaluate the potential of this occurrence as a commercial mine, the Arkansas State Parks Commission conducted a two-fold assessment of the lamproite, which since 1972 has been administered under the Crater of Diamonds State Park. Phase 1, conducted in 1990, identified and mapped the main rock types. Phase 2, completed in 1997, tested the rock types for their *in situ* diamond contents. The diamond grades were determined from 600 tonne bulk samples collected from 14 trenches throughout the lamproite, about 3 m below the naturally enriched surface overburden.

The four main rock types and their diamond contents are: (1) hypabyssal olivine lamproite with insignificant diamond content; (2) epiclastic sediments barren of diamond; (3) phlogopite-rich tuff with an average diamond grade of 0.11 ct/100 tonnes; and (4) olivine-rich lapilli tuff, the majority of which has a diamond grade of 1.1 ct/100 tonnes. The value of the stones averaged \$12.30/ct. The diamond content is insufficient to warrant large-scale commercial mining. However, some park areas hold promise for further tourist development. Tourists currently recover approximately 500 diamonds (totaling nearly 50 carats) annually from the naturally enriched surface layer. Calculations show that the diamondiferous tuffs have undergone <50 m of erosion, liberating ~93,000 carats of diamonds. Of these, ~58,000 carats were contained in the enriched surface deposit and about half (i.e., ~29,000 carats) remain; ~35,000 carats are believed to occur in eluvial and alluvial deposits adjacent to the existing tourist area. *CT*

**Evolution of growth sectors in natural diamond crystals as revealed by cathodoluminescence topography.** S. V. Titkov, G. V. Saporin, and S. K. Obyden, *Geology of Ore Deposits*, Vol. 44, No. 5, 2002, pp. 350–360.

Diamond crystals can have a complex growth history in the earth. Polished plates cut from 180 diamond crystals from Yakutia were studied by both optical and scanning

electron microscopy to investigate this history. When exposed to a beam of electrons, many diamonds exhibit cathodoluminescence, and the spatial pattern of this luminescence provides an important means of elucidating changes in crystal form as the diamonds grew.

Most of the diamonds exhibited a change in the development of octahedral {111} and cubic {100} faces during their growth. Within the majority of the crystals, the authors found the following evolution in growth form: cube  $\rightarrow$  cube + octahedron  $\rightarrow$  octahedron. Cubic sectors tend to grow out of existence, so the shape of most natural diamonds is dominated by octahedral faces. In rare instances, cubic growth follows octahedral growth, but the resulting cube faces are imperfect and contain numerous inclusions. The authors suggest that temperature was the main factor in controlling the development of various growth sectors in the diamonds. *JES*

**An infrared investigation of inclusion-bearing diamonds from the Venetia kimberlite, Northern Province, South Africa: Implications for diamonds from craton-margin settings.** K. S. Viljoen, *Contributions to Mineralogy and Petrology*, Vol. 144, No. 1, 2002, pp. 98–108.

The 533-million-year-old Venetia kimberlite cluster lies within the Limpopo Mobile Belt at the junction of the Kaapvaal and Zimbabwe cratons in southern Africa. This location is geologically somewhat anomalous given the general correlation of diamondiferous kimberlites with old stable cratons. This infrared spectroscopy study of approximately 200 inclusion-bearing diamonds from the Venetia mine provides data on nitrogen content and nitrogen aggregation state—the latter information can reveal something of the conditions in the earth's mantle subsequent to diamond crystallization.

The diamonds exhibited a wide range of nitrogen contents, with significant heterogeneity. The nitrogen aggregation state also varied from almost pure type IaA diamonds (poorly aggregated nitrogen) to pure type IaB diamond (highly aggregated nitrogen), with the majority of the studied diamonds falling in the latter category. The unusually aggregated nature of the nitrogen in most of the diamonds is interpreted to result from the ambient mantle residence temperatures, which are concluded to be higher than those of most other kimberlites in the interior of the Kaapvaal craton. The diamonds displayed comparatively low levels of degradation of nitrogen platelets, suggesting that they experienced limited deformation (as compared, e.g., to the typical brown diamonds from the Argyle mine in Australia). The author suggests that the apparently consistent association of diamonds possessing unusually aggregated nitrogen with kimberlites (or lamproites) intruded into craton margins or adjacent mobile belts may provide a means for recognizing the contributory sources of diamonds in alluvial deposits through the characteristics of their infrared spectra. *JES*

**World diamond deposits.** A. P. Akimov and A. S. Marfunin, *Gemological Bulletin* (Gemological Society of Russia), No. 5, 2002, pp. 51–56 [in Russian].

A map of World Diamond Deposits (scale 1:25,000,000) was published in September 2001. It shows almost 400 localities, of all sizes and levels of importance, in which diamonds are known or mined. The deposits are classified into five economic and eight geologic (genetic) types that are clearly designated (with numbers and symbols) on the map. The deposits are also listed in a supplementary table. The economic significance of each of the eight different geologic types is presented. VD

## GEM LOCALITIES

**Characterization of beryl (aquamarine variety) from pegmatites of Minas Gerais, Brazil.** R. R. Viana, H. Jordt-Evangelista, G. Magela da Costa, and W. B. Stern, *Physics and Chemistry of Minerals*, Vol. 29, 2002, pp. 668–679.

Eight samples of aquamarine from four pegmatites in the Governador Valadares and Araçuaí regions of Minas Gerais were characterized by several techniques to better understand the variations in physical properties with chemical composition and crystal structure. Many cations can be incorporated into the beryl structure either in tetrahedral or octahedral sites, or in structural channels parallel to the *c*-axis. Several properties are influenced by these cation substitutions, and by the presence of water and alkali elements in the channel sites.

Based on chemical composition data, a negative correlation was found between aluminum content and the sum of ( $\text{Fe}^{2+} + \text{Fe}^{3+} + \text{Mg}^{2+}$ ) in octahedral sites. A positive correlation was found between total alkali elements in channel sites and refractive indices. No correlation was noted between specific gravity and the type or amount of cations in channel sites or in octahedral or tetrahedral sites. A contraction in the *c* and *a* unit-cell parameters occurred with increasing temperature (for measurements made up to about 1000°C). Evaluation of infrared spectra revealed a weak negative correlation between the 1200  $\text{cm}^{-1}$  band position and the amount of water in the type II position in the channels. Visible spectra are related to the color of the beryl, and the authors attribute spectral features in the eight aquamarine samples to the following causes: 370 and 420 nm bands—octahedral  $\text{Fe}^{3+}$ ; a broad diffuse region of absorption from about 450 to 700 nm (maximum near 600 nm)— $\text{Fe}^{2+}$  in channel sites; and a broad absorption centered at 800 nm—octahedral  $\text{Fe}^{2+}$ . The color of each of these beryls is believed to be dictated by the proportions of  $\text{Fe}^{3+}$  in the octahedral sites and of  $\text{Fe}^{2+}$  in the channel sites. Deep blue samples have little  $\text{Fe}^{3+}$ , whereas greener samples have more  $\text{Fe}^{3+}$  or less channel-site  $\text{Fe}^{2+}$ . JES

**Chrysoberyl, beryl and zirconian spinel mineralization in granulite-facies Archaean rocks at Dowerin, Western Australia.** P. J. Downes and A. W. R. Bevan, *Mineralogical Magazine*, Vol. 66, No. 6, 2002, pp. 985–1002.

Small amounts of gem chrysoberyl (including the variety alexandrite), beryl, and zinc-rich (hercynite) spinel are found in metamorphic rocks near Dowerin, about 150 km northeast of Perth. These rocks are part of the Yilgarn craton of Archaean age (2.6 billion years ago). Mineralization occurs in a plagioclase-quartz-biotite-garnet gneiss, and near cross-cutting, subvertical to vertical, tourmaline-plagioclase veins associated with bodies of amphibole-mica schist. Crystals of chrysoberyl are found embedded in almandine or plagioclase, and are closely intergrown with biotite and/or hercynite in the host gneiss. Beryl occurs in trace amounts between crystals of chrysoberyl, plagioclase, and almandine. Workings presently comprise a 3.5-m-deep pit and two adjacent trenches that expose only a small volume of rock within the soil profile. The poor exposure and deeply weathered condition of the rocks limit geologic mapping and make the interpretation of field relations difficult.

Textural and mineral chemistry evidence suggests that the chrysoberyl and zirconian spinel formed during granulite-facies regional metamorphism, and probably pre-dated the formation of the tourmaline-plagioclase veins during the same metamorphic event. Be, B, and Zn required for the gem minerals may have been released by reactions involving aluminous sedimentary rocks during the regional metamorphism. The deposit is unusual geologically because of the formation of the Be-B-Zn minerals at high metamorphic grade. JES

**Edelsteine aus dem Gebiet nördlich von Araçuaí (Minas Gerais, Brasilien): Vorkommen, Eigenschaften und Behandlungsmethoden [Gemstones from the region north of Araçuaí (Minas Gerais, Brazil): Occurrences, characteristics and treatment possibilities].** J. Karfunkel, J. Quéméneur, K. Krambrock, M. Pinheiro, G. O. Dias, and R. Wegner, *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 51, No. 4, 2002, pp. 171–183 [in German with English abstract].

This article provides a summary of the geologic characteristics of the area between the cities of Araçuaí and Itinga in northeastern Minas Gerais. For more than a century, occurrences of the following gems have been known: tourmaline (red, green, blue, multicolored), beryl (colorless, blue, pink, yellow), spodumene (colorless, yellow, green), quartz (rock crystal, smoky, citrine), amblygonite, petalite, and andalusite.

Most of these gems have been mined from granitic pegmatites (e.g., Urubu, Maxixe, and Cachoeira), all of which are located in the Oriental Pegmatite Province, which lies north of the Piauí River in eastern Brazil.

Treatments, such as gamma irradiation and heating, and their positive effect on colorless and light-colored gem materials are discussed. Such treatments are considered key to increased gem availability and trading in this region in the future. CD

**Geology, geochemistry and Ar–Ar geochronology of the Nangimali ruby deposit, Nanga Parbat Himalaya (Azad Kashmir, Pakistan).** A. Pêcher, G. Giuliani, V. Garnier, H. Maluski, A. B. Kausar, R. H. Malik, and H. R. Muntaz, *Journal of Asian Earth Sciences*, Vol. 21, No. 3, 2002, pp. 265–282.

Ruby was found in the Nangimali area in 1979. The deposit outcrops in the Shontar Valley in the southern part of the Nanga Parbat massif, a large north-south trending body of metamorphic rocks at the northwestern end of the Himalayas. In this area, gneisses, amphibolites, and marbles form large synclinal structures that are exposed on mountain ridges. Ruby mineralization, found over an area of about  $1.8 \times 0.5$  km, occurs within a narrow zone of the rock sequence in small (0.1–2 cm thick) veins that cut across dolomitic marbles and carbonate-bearing bands. Associated minerals in these veins include pyrite, phlogopite, rutile, margarite, pargasite, and carbonate.

Ruby crystals can range up to about 40 grams; their color varies from pinkish red to deep red (~20% of the production). Mining between 1990 and 1994 yielded about 70 kg of rough ruby per year. Geochemical data suggest that mobilization of aluminum and chromium in the marbles by metamorphic fluids could form the ruby deposit along preferential zones within the rock sequence. Argon-argon age dating gives a minimum age of ruby formation of 16 million years ago. JES

**Green nephrite jade from Canada.** L. Mi, *Journal of Gems and Gemmology*, Vol. 5, No. 1, 2003, pp. 10–13 [in Chinese with English abstract].

Green nephrites from Canada (locality not specified but presumably British Columbia) and China (Hetian and Xingjiang) were found to have different textural and physical properties (e.g., luster and transparency). Canadian nephrite samples consisted mainly of tremolite, with minor amounts of actinolite, diopside, epidote, clinzoisite, magnetite, and pyrite. Of the five textures observed in Canadian nephrite, the most common was fibrous crystalloblastic, with fiber widths in the range of 0.005–0.020 mm. Variations in the mineral components, texture, luster, and appearance determine the quality of Canadian nephrite. Chinese nephrite jade was similar in many respects, but the fibers, also with a fibrous crystalloblastic texture, were commonly less than 0.001 mm in width; this results in a typical waxy luster and characteristic feeling to the touch. TL

**Optical and Mössbauer study of Brazilian emeralds.** G. C. B. Braga, V. K. Garg, A. C. de Oliveira, J. A. Freitas Jr., E.

Kuzmann, and R. Garg, *Physica Status Solidii*, Vol. A194, No. 1, 2002, pp. 36–46.

Gem-quality emeralds from two localities in Brazil—Campos Verdes in Goiás State and Salinhas in Bahia State—were characterized by photoluminescence and Mössbauer spectroscopy techniques, X-ray diffraction, electron microprobe analysis, and optical methods. The relative amounts of chromium, iron, and vanadium influence the color and other properties of emeralds from different sources. Results obtained from this study indicate that  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  substitute in both the octahedral aluminum and tetrahedral beryllium sites in the crystal structure. Their distribution between the two sites is suggested to be characteristic of the source location. JES

**Sangu garnet deposit, Eastern Province, Zambia.** A. V. Seifert and S. Vrána, *Bulletin of the Czech Geological Survey*, Vol. 78, No. 1, 2003, pp. 3–8.

The geology, petrology, and mineralogy of the gem-quality pyrope-almandine garnet deposit at Sangu, in the Lundazi District of Zambia, are described. The garnets occur in plagioclase segregation veins confined to mafic granulite, as nodules up to 10 cm in diameter. The garnet consists mainly of pyrope (46–47 mol%) and almandine (39–40 mol%), with grossular (9–10 mol%) and andradite (2–3 mol%) components. R.I. varies from 1.760 to 1.763, and S.G. ranges from 3.87 to 3.94.

The garnet is characterized by abundant minute acicular rutile crystals oriented in two directions; they intersect at  $\sim 60^\circ$ . However, the mineral appears notably free of inclusions when viewed with the unaided eye or a  $10\times$  loupe. The color is strong red to brownish red and is best observed in faceted stones 2 ct or smaller, as larger stones appear too dark. Mine production primarily consists of fractured pieces weighing 0.5–2 grams. The authors estimate present annual production may reach 400–500 kg, of which only up to 5% is facetable; most is cut in India. CT

**The Santa Terezinha–Campos Verdes emerald district, central Brazil: Structural and Sm–Nd data to constrain the tectonic evolution of the Neoproterozoic Brasília belt.** L. J. H. D'el-Rey Silva and L. de Souza Barros Neto, *Journal of South American Earth Sciences*, Vol. 15, No. 6, 2002, pp. 693–708.

The Santa Terezinha–Campos Verdes emerald district was discovered in 1982 in the state of Goiás in central Brazil. Emeralds are recovered from talc schists that are included in the Santa Terezinha sequence of Middle Proterozoic-age metavolcanic-sedimentary rocks (approximately 1.5 billion years old). This study focused on the geology and geologic history of this particular area relative to the regional geology of this portion of Brazil. The area was affected by three events of ductile deformation during greenschist facies metamorphism associated with the Brasiliano orogeny (about 640–520 million years ago). The Santa Terezinha rock sequence is interpreted as being the record of a

Proterozoic-age sedimentary basin located between a magmatic arc to the west and the margin of a continental plate to the east. JES

**Sapphires: The central Queensland gemfields.** P. Moran and N. Rains, *Australian Geographic*, July-September, No. 67, 2002, pp. 56–71.

This article describes the colorful people, culture, and history of the Central Queensland Gemfields (CQG), a 9,300 ha area in Australia composed of four townships, one of which is Anakie, where thousands meet annually to celebrate the sapphire industry (Gemfest). Geologists believe the sapphires of the CQG formed in the earth's mantle between 20 and 200 million years (My) ago and were brought to the surface (along with zircon, spinel, and garnet) as a result of volcanic activity approximately 15–65 My ago. The sapphires were released from their basalt hosts by weathering, transported across the landscape by ancient streams, and concentrated in layers of gravel known as wash. This wash, mined intermittently since the 1880s, is now commercially mined by both hand and modern machines. Certain wash areas are reserved for mineral collectors.

The majority of the sapphires found in the CQG are medium-to-dark blue in color; prized finds are yellow, green, or particolored. In 2000–2001, the official value of Australian exports of rough sapphire was at least \$9 million, with \$3.6 million attributed to the CQG. Until 1988, Australia produced about 70% by volume of the world's sapphires. Currently, Australia's contribution has been reduced to <20% (due to competition from other sources, mainly Madagascar, Tanzania, and Nigeria), about half of which comes from the CQG. CT

**The topaz-bearing rhyolites from the San Luis Potosi area (Mexico): Characteristics of the lava and growth conditions of topaz.** J. L. Leroy, R. Rodriguez-Rios, and S. Dewonck, *Bulletin de la Société Géologique de France*, Vol. 173, No. 6, 2002, pp. 579–588.

In Mexico, topaz-bearing rhyolites mainly occur in the San Luis Potosí area as domes related to Tertiary tectonism. Three of these domes in the San Luis Potosí volcanic field were selected for study based on characteristics (e.g., size) of the topaz crystals they contained. Crystals were compared with respect to their growth environment, habit, color, chemical composition, and electron paramagnetic resonance characteristics. The study was undertaken to investigate the crystallization conditions of the lava and causes of color in the topaz (i.e., colorless and "amber").

The lavas comprising all three domes are high-silica, high-alkali rhyolites that are enriched in fluorine and certain lithophile elements (e.g., Rb, Cs, Ta, U, Th), with magmatic minerals including sanidine, quartz, oligoclase, and annite. Topaz, hematite, and quartz are vapor-phase minerals that occur in voids and fractures. Two basic relationships between crystallization conditions and color

were determined. Colorless topaz crystallized above 500°C from fluids enriched in elements leached from the lavas, whereas "amber"-colored topaz crystallized below 500°C from fluids richer in volatile elements (e.g., arsenic). AI

**Trace-element contents and cathodoluminescence of "trapiche" rubies from Mong Hsu, Myanmar (Burma): Geological significance.** V. Garnier, D. Ohnenstetter, G. Giuliani, P. Blanc, and D. Schwarz, *Mineralogy and Petrology*, Vol. 76, No. 3–4, 2002, pp. 179–193.

Mong Hsu rubies with the characteristic trapiche growth sectors and skeletal arms are occasionally sold in Burmese and Thai gem markets. However, they have never been observed *in situ* in primary deposits. To determine if any relationship exists with the more common type of Mong Hsu rubies, six small (4–6 mm in diameter) trapiche rubies were studied by scanning electron microscopy, electron microprobe, and cathodoluminescence techniques. The results were then compared with those obtained from the common type of Mong Hsu rubies that are marble hosted.

The results showed that: (1) Cr and V are the main chromophores in both types of rubies; (2) both ruby types contain the same solid inclusions (e.g., calcite, dolomite, rutile, mica, and diaspore); (3) the presence of bastnäsite in the trapiche rubies and fluorite in the "normal" rubies indicates they both crystallized from F-bearing solutions; and (4) the trace-element contents are similar in both types of rubies. Thus, these chemical and mineralogical similarities indicate that both Mong Hsu ruby types are genetically related and that they crystallized in the same geologic (marble-type) environment, which is distinct from that of the rubies and sapphires hosted in the basalts of Southeast Asia. CT

## INSTRUMENTS AND TECHNIQUES

**Diamond potential estimation based on kimberlite major element chemistry.** V. B. Vasilenko, N. N. Zinchuk, V. O. Krasavchikov, L. G. Kuznetsova, V. V. Khlestov, and N. I. Volkova, *Journal of Geochemical Exploration*, Vol. 76, No. 2, 2002, pp. 93–112.

Based on a study of samples from Yakutia, a statistical method has been developed that will predict diamond grade (in carats per 10 tons) using major-element chemistry data obtained from the host kimberlite. The kimberlite sample, weighing on the order of one ton, needs to be rather uniform (i.e., xenoliths must be removed). From 25 to 30 samples are randomly collected for X-ray fluorescence chemical analysis. By means of correlation analysis, the chemical composition data are subdivided into a number of groups. Regression analysis is then carried out between mean major-element oxide concentrations of each group and the corresponding predicted average diamond content values. The authors suggest that their method allows a kimberlite sample to be placed into one



of three grade categories (corresponding to a deposit that is highly, moderately, and slightly diamondiferous) with an approximately 90% certainty. *JES*

**Nondestructive identification of pearls.** Y. Gan, and W. Cui, *Acta Scientiarum Naturalium, Universitatis Pekinensis*, Vol. 38, No. 3, 2002, pp. 400–403 [in Chinese].

The near-infrared spectra (4,000–650  $\text{cm}^{-1}$ ) of six varieties of natural and cultured black and gray pearls, mostly Chinese freshwater, were studied to develop nondestructive criteria by which gamma-irradiation and dye treatments can be identified. A weak absorption peak at 1472  $\text{cm}^{-1}$  was found in all but one of the treated (both irradiated and dyed) samples; thus, this peak could be useful for separating treated black pearls from their untreated counterparts. In two gamma ray-irradiated samples, one cultured saltwater and the other freshwater, the protein-related peaks (1650 and 1100  $\text{cm}^{-1}$ ) were relatively weak, suggesting that gamma-ray irradiation damages the protein components in the pearls. If this observation is substantiated, it may be useful in identifying irradiated specimens. *TL*

**Nontraditional genetic classification of gem corundum deposits.** E. P. Melnikov, A. V. Vasiliev, and M. A. Victorov, *Gemological Bulletin (Gemological Society of Russia)*, No. 5, 2002, pp. 7–18 [in Russian with English abstract].

Based on mineralogic and geologic research on corundum occurrences in Russia, and published data on corundum localities occurring elsewhere, it is emphasized that regional metamorphism of different rock types (e.g., marble, gneiss) is the major factor controlling the formation of corundum deposits and determining the quality of the gems they contain. The chemical and physical properties of the metamorphic host rocks ultimately determine the characteristics of gem corundum. The sapphires from Kashmir and rubies from Myanmar, which formed in metamorphic environments, are cited as examples. The superb gems from these deposits had the appropriate chromophoric elements available during their formation, under the proper metamorphic conditions. Characteristic mineral inclusions are considered indicative of specific genetic types of corundum, and, for alluvial stones, the inclusions can be used to infer the origin of the gem corundum. Gem corundums originating from other geologic sources (e.g., igneous or metasomatic) are likely to be of lower quality than those of metamorphic origin. *VD*

## JEWELRY HISTORY

**Roman intaglio gemstones from Aelia Capitolina.** O. Peleg, *Palestine Exploration Quarterly*, Vol. 135, No. 1, 2003, pp. 54–69.

A dozen Roman engraved gemstones (intaglios) recovered

at the foot of the southern and western enclosure walls of Jerusalem's Temple Mount are described in detail. The pieces date from the first century BC to the third century AD. For the most part, the carvings are of fine quality and unique, exhibiting labor-intensive and therefore expensive work, probably cut to order for the wealthy. The gemstones represented are banded agate, carnelian, jasper, onyx, and Nicolo paste (glass representing onyx). The diverse figures depicted are gods, goddesses, heroes, animals, and religious symbols. Some of the images are one of a kind and therefore have broadened our understanding of ancient times. *CT*

## JEWELRY RETAILING

**Why, what, where & when. Jewelry.com finds out.** *Idex Magazine*, Vol. 18, No. 159, July 2003, pp. 76–79.

Jewelry.com, an online marketer of diamonds and diamond jewelry, surveyed 6,000 jewelry consumers (68% female, 32% male) to determine buying habits and preferences. Among the findings were that 95% of women have purchased jewelry for themselves; 17% said they typically spent \$200 to \$499 on each purchase; 5% responded that they typically spent between \$500 and \$999; while 2% typically spent over \$1,000. The remaining 67% spent under \$200.

The survey found that 97% of men and 95% of women give jewelry as gifts, with 42% of men and 46% of women buying jewelry more than twice yearly. Nearly half the men who said they planned to buy a diamond anniversary ring said they planned to spend over \$1,000, with 25% of those men indicating they would top \$2,500. Of the men planning to buy an engagement ring within a year, 26.2% noted they would spend over \$2,500, and 12.1% were willing to go over \$5,000.

National retail jewelry chains remain the most popular jewelry shopping destinations for both men and women, with 28.8% of consumers saying they "usually buy" from these operations. Another 16.7% said they usually buy from local independent jewelers, 18.6% from discounters, 12.6% from mass merchandisers, 8.5% from department stores, 1.6% from club stores, and 1% from luxury retailers. (The article did not state where the remaining 12.2% of respondents shopped.) *RS*

## SYNTHETICS AND SIMULANTS

**Channel structures observed in natural diamonds and synthetic moissanite and synthetic quartz.** T. Lu, J. E. Shigley, and J. I. Koivula, *Proceedings of SPIE [Society of Photo-Optical Instrumentation Engineers]*, Vol. 4779, 2002, pp. 125–131.

This article compares the distinguishing features among channel structures (open tubes) in natural diamonds, pol-

ished synthetic moissanite, and chemically etched synthetic colorless quartz. It describes the microstructures of the channels, internal imperfections in growth patterns, and the relationship between the channels and various lattice defects. The channels in all three materials were compared on the basis of their appearance (similar), associated defects (different), visibility under various illumination conditions (similar), and possible formation mechanisms (different, although they all appear to be related to dislocations). These results may aid in accurate gem identification, particularly in distinguishing between some natural and synthetic gem materials. *CT*

**The diamond wars have begun.** J. Davis, *Wired*, September 2003, pp. 96–105, 145–146.

Two companies are poised to aggressively market synthetic diamonds in the U.S. Gemesis, a Florida-based firm headed by retired army officer Carter Clarke, uses Russian-built diamond presses to manufacture yellow synthetic diamonds by high heat/high pressure methods. Apollo Diamond, a Boston-based company, claims it can create gem-quality material using the chemical vapor deposition (CVD) method.

Gemesis started in 1996 by importing Russian machines and technicians to Florida. The company spent four years upgrading and refining the technology to produce attractive synthetic diamonds. Gemesis plans to call them “cultured” and is banking on the belief that many consumers will choose a larger, attractive synthetic diamond over a smaller natural diamond.

While Gemesis discloses the nature of its product, and detection equipment can identify synthetics, the vast majority of smaller stones could slip through the system because secondary suppliers might not disclose the true origin of the Gemesis diamonds, and such stones rarely go through laboratories.

Apollo Diamond’s founder, Robert Linares, a researcher in semiconductor materials, claims he has discovered a “sweet spot” that allows him to grow gem-quality, colorless synthetic diamonds by the CVD process. The “sweet spot” is the exact combination of gas composition, temperature, and pressure that creates single crystals instead of the polycrystalline aggregates that are typical of the CVD process. The article claims that CVD-grown synthetic diamonds have no inclusions and thus are much more difficult to detect than other synthetics. The company is currently producing 10 mm “wafers” but predicts it will achieve crystals an inch square by year’s end at a production cost of about \$5/ct. [*Editor’s note:* See the Gem News International section in this issue for more information about Apollo CVD synthetic diamonds.] *RS*

**Maybe mabe.** R. Weldon, *Professional Jeweler*, Vol. 5, No. 9, 2002, pp. 38–40.

A mabe cultured pearl is formed by introducing a piece of mother-of-pearl into the tissue next to the shell of a mol-

usk. When covered with nacre, the resulting cultured pearl is cut from the shell. Recently, it has been discovered that assembled fake mabe pearls (e.g., with plastic caps) were released into the U.S. market. Magnification is essential for separating fake from genuine mabes by observing such features as shape and color, and by looking at their backs. Fake mabes are mostly uniform in all characteristics (shape, color, and outline), whereas real mabes, for the most part, are irregular. Air bubbles or ripples around the junction with the backs are indicative of fake mabes. Last, fake mabes have plastic backs whereas real ones have mother-of-pearl backs. *JS*

**Modeling natural diamond generation in high-pressure chambers.** S. V. Digonskii and N. N. Shatagin, *Moscow University Geology Bulletin*, Vol. 57, No. 1, 2002, pp. 49–51.

Synthetic diamond formation at high temperatures and pressures is often thought to be the result of carbon crystallizing from a metal solution under the influence of a temperature gradient. Based on their analysis of growth conditions, the authors suggest that the very rapid heating produces a situation where gasification of the source materials takes place in the closed-volume growth chamber. Diamonds are thought to then crystallize from this gaseous phase, rather than from the metal solution itself. The authors conclude that their analysis is consistent with the views of some geologists who explain the genesis of natural diamonds in kimberlites by gas-phase crystallization in relatively near-surface conditions. *JES*

**Open channels in near-colorless synthetic moissanite.** T. Lu, J. E. Shigley, and J. I. Koivula. *Journal of Gemmology*, Vol. 28, No. 3, 2002, pp. 129–135.

Introduced to the jewelry market as a near-colorless diamond substitute in 1997, synthetic moissanite initially caused jewelers a great deal of concern. Many of its physical properties are similar to those of diamond, but its double refraction, specific gravity, and distinctive inclusions enable trained gemologists to separate synthetic moissanite with simple testing instruments.

Some of the most common and noticeable inclusions found in low-clarity synthetic moissanite are subparallel needle-like open channels. These channels usually have a hexagonal outline and are elongated in a direction parallel to the optic axis of the host crystal. They can either reach the surface or terminate against other internal inclusions or defects. Their appearance differs from similar features that are rarely observed in natural diamonds. The channels are believed to result from the relaxation of strain around enlarged screw dislocations generated during growth. The authors also believe that channels in both synthetic moissanite and natural diamond are formed in association with dislocations but by different processes and, therefore, appear different under magnification. *JEC*

**Synthetic coral. Coral or imitation?** A. V. Fedorov, *Gemological Bulletin (Gemological Society of Russia)*, No. 5, 2002, pp. 62–63 [in Russian].

The structural pattern of specimens apparently intended to simulate coral aroused suspicion and were subsequently tested by various techniques. Density varied from 2.09 to 2.24 g/cm<sup>3</sup>. Only one R.I. of 1.63 could be measured. X-ray diffraction yielded a pattern for barite (BaSO<sub>4</sub>), although microscopic study showed that the material consisted of two phases. The “veining” in the samples was probably composed of an amorphous plastic and, therefore, would not be detected by X-ray diffraction. Imitation coral has been known, and available in the trade, for decades, and careful attention to the structural pattern is the first step in distinguishing natural coral from imitations. [Editor's note: An imitation coral consisting of barium sulfate with a plastic-type binder was described in the Summer 1990 Lab Notes, pp. 153–154.]

VD

## TREATMENTS

**Coloration of natural beryl by iron ion implantation.** R. I. Khaibullin, O. N. Lopatin, F. G. Vagizov, V. V. Bazarov, A. I. Bakhtin, I. B. Khaibullin, and B. Aktas, *Nuclear Instruments and Methods in Physics Research B*, Vol. 206, 2003, pp. 277–281.

Natural colorless beryl from the Ural Mountains, when implanted with 40 KeV iron ions at room temperature, became dark gray, but was subsequently changed to yellow or yellow-orange by thermal annealing. Ion fluences (i.e., the number of ions traversing a unit area per unit of time) used were in the range of 0.5–1.5 × 10<sup>17</sup> ions/cm<sup>2</sup>. The samples became slightly less transparent after ion bombardment, and became darker gray at higher fluence levels—both effects are thought to result from radiation damage to the crystal structure of the beryl. The thermal annealing was carried out in oxygen at 600°C for 30 minutes; the more yellow-orange coloration was found in darker gray samples subjected to higher fluence levels. The similarity in visible spectra between natural yellow beryl and the implanted samples suggests that their absorption in the blue-violet region (which increases in the treated samples implanted with greater numbers of iron ions) is due to the same oxygen–iron charge-transfer mechanism.

JES

**The influence of pressure on high-pressure, high-temperature annealing of type Ia diamond.** F. De Weerd and A. T. Collins, *Diamond and Related Materials*, Vol. 12, 2003, pp. 507–510.

The authors exploit current laboratory high pressure/high temperature (HPHT) annealing techniques to investigate the kinetics of point-defect dissociations in diamond. This article details initial studies coupled with results of prior investigations to determine the influence of pressure on the dissociation rate of A centers (two nearest-neighbor nitro-

gen atoms) to C centers (single-substitutional nitrogen atoms).

Results indicate that the dissociation of A centers into C centers is dependent on both temperature and pressure during HPHT annealing. For example, at 2300°C, the dissociation rate is approximately 10 times greater when a pressure of 5–6 GPa is used instead of 8.5 GPa. Additional experiments are underway to provide more detailed analysis of the influence of pressure on the dissociation of nitrogen aggregates.

SW

**A model of HPHT color enhancement mechanism in natural gray diamonds.** V. G. Vins and O. V. Kononov, *Diamond and Related Materials*, Vol. 12, 2003, pp. 542–545.

Six natural gray diamonds were investigated before and after HPHT processing. Ultraviolet, visible, and infrared spectra were recorded pre- and post-processing in a “split-sphere” type apparatus. Two samples were processed at each of three temperature/pressure regimes: 1800 ± 50°C and 6.0 GPa; 1950 ± 50°C and 6.5 GPa; and 2100 ± 50°C and 7.0 GPa.

Natural gray diamonds owe their color to numerous microscopic graphite inclusions. [Editor's note: See the article by S. V. Titkov et al. in this issue about black diamonds colored by inclusions other than graphite.] Pre-processing absorption spectra indicated the presence of A centers, N3 centers, and CH groups in all test samples; the CH groups were trapped at the edge face of graphite crystals and were the source of the hydrogen in the samples. In addition to the gray coloration, some samples also displayed greenish, yellowish, or brownish hues, which were not associated with any peculiar absorption features. HPHT processing changed all samples to a yellow color (the gray component was removed), with a dramatic increase in the 2.988 eV absorption (N3 centers) and the appearance of hydrogen-related absorption bands in the IR region.

The authors posit that these changes result from polymorphic transformation of the graphite inclusions into diamond and the concomitant transition of hydrogen atoms (in the CH groups) from graphite to diamond. The proposed mechanism for this transformation is:

1. Under conditions exceeding the diamond-graphite equilibrium line, the C-H bonds are split.
2. Hydrogen atoms diffuse to the nearest structural defects in the diamond lattice with uncompensated negative charges.
3. Loss of hydrogen from the surface of graphite inclusions weakens interatomic bonds, resulting in carbon atoms at the edge splitting from the graphite matrix.
4. Depending on the character of the graphite-diamond fusion boundaries, free carbon atoms diffuse and become trapped at vacancies, dislocations, or along internal or external surfaces of the diamond crystal.

SW