E. Gübelin

Dr. Edward J. Gübelin
(1913–2005)

Gems & Gemology

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ABOUT THE COVER

The work of Swiss gemologist Dr. Edward J. Gübelin (1913–2005) forever changed the study of gems. Best known for his research in the area of gemstone inclusions, Dr. Gübelin wrote extensively on virtually every aspect of gemology. He was also an innovator in gem-testing instruments, an influential educator, and a global ambassador of gemology. Accompanying this picture of Dr. Gübelin at work in the laboratory are three photomicrographs from his Photoatlas of Gemstone Inclusions *(1986, with John I. Koivula). Top to bottom: An inclusion of muscovite in aquamarine from Pakistan (magnified 20×), a pair of scorpions in Dominican amber (magnified 35×), and devitrite inclusions in green glass (magnified 50×). Photo courtesy of Edward W. Boehm; photomicrographs used with permission from Opinion Verlag, Basel, Switzerland.*

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One Hundred Issues and Counting...

Winter 2005 marks the 100th issue of the "new" *Gems & Gemology*, which was introduced in 1981 with a full peer-review process, new sections, and a radical redesign from the smaller format that had defined the journal for more than 45 years. Over the last quarter century, the relaunched *G&G* has witnessed a virtual revolution in the science of gemology.

In the early 1980s, heating of rubies and sapphires and "oiling" of emeralds were the most prevalent treatments, but of relatively little concern to the trade. Over the next two decades, less-identifiable treatment methods such as irradiation and new processes such as surface diffusion had a greater impact in the market. More recently, the use of different emerald fillers, of lead-glass fillers in rubies, and the diffusion of light elements such as beryllium into corundum have raised the bar on the technology being used to treat colored gems—and to identify those treatments. At the same time, the onset of new and better synthetics has made virtually every gem material suspect.

Also in the early 1980s, there were virtually no treatments for colorless diamonds and very few (mainly irradiation/annealing and coating) for their fancy-colored counterparts. With the advent of fracture filling in the late 1980s and high pressure/high temperature treatment in the late 1990s, diamantaires were rocked by the realization that they, too, must rely on gemological research to protect the integrity of their products. This was reinforced by developments in synthetic diamonds: Whereas less than a dozen faceted synthetic diamonds were even known in the early 1980s, today fancy-colored synthetic diamonds are commercially available in the marketplace. Diamond dealers and retailers worldwide now recognize that the role of the gemologist in understanding these developments and knowing how to identify a gem—or when to send it to a well-equipped laboratory—is more crucial than ever.

Gems & Gemology has been at the forefront of virtually all of these developments, advising and informing, often first in Lab Notes or Gem News International and then in comprehensive articles that build on one another to explain the scope of the problem and identify possible solutions. In addition, we have brought our readers updates on classic gem localities and introduced them to new sources, described new gem materials, and examined innovative lapidary techniques as well as the intricacies of evaluating diamond cut.

The Gemological Abstracts section has been critical in exposing our readers to developments in other publications and scientific disciplines, while our Book Reviews have kept the *G&G* audience up to date on must-haves (and must-nots) for the contemporary gemological library.

Radical advances in computer capability and access have aided many of the technical developments in gemology over the last 25 years, and the rapid expansion of the Internet has provided new opportunities for communication that go far beyond the printed page. In keeping with these breakthroughs, I am pleased to announce that beginning in early 2006, every issue of *Gems & Gemology* from 1934 to the present will be accessible online at www.gia.edu. The 1934–1980 issues will be available free of charge (see "The Last Page" on p. 388 for more), while there will be a small charge for the issues since 1981. Because it is impossible to ensure the accuracy of the color reproduction on a computer monitor, we strongly recommend that readers continue to use the printed version as reference for color-critical images.

As a final note, it is particularly appropriate that this 100th issue leads off with a tribute to the late Dr. Edward J. Gübelin, one of the most influential gemologists of the 20th century. Dr. Gübelin wrote the lead article, on peridot from Zabargad, in our first large-format issue. As the fascinating tribute article points out, Dr. Gübelin published his first *G&G* article in 1940 and his last in 2003, the longest association with the journal—63 years—of any single person. Gemology is fortunate to command such loyalty and passion, and we are all richer for it.

Alice S. Keller
Editor-in-Chief

Mark your calendar for the

GIA®

Gemological Research Conference

2006   August 26–27

**Manchester Grand Hyatt Hotel
San Diego, California**
Sponsored by Charles & Colvard, Ltd.

THE SCIENCE OF GEMOLOGY is expanding in many exciting directions that encompass not only mineralogy and geology, but also fields such as physics, chemistry, and materials science. At the GIA Gemological Research Conference, a multidisciplinary approach will explore the challenges posed by new synthetic and treated gem materials, as well as the characterization of natural gems from traditional and new sources. Invited lectures, submitted oral presentations, and a poster session will explore a diverse range of contemporary topics in gemology and related sciences.

Call for Abstracts

Prospective oral and poster presenters are invited to submit abstracts for the GIA Gemological Research Conference. Abstracts should be submitted to gemconference@gia.edu (for oral presentations) or ddirlam@gia.edu (for poster presentations). The abstract deadline for all submissions is March 1, 2006. Abstracts of oral and poster presentations given at the conference will be published in a Proceedings Volume.

Pre-Conference Field Trip

A field trip to the world-famous Pala pegmatite district in San Diego County will take place August 25, 2006. No more than 50 participants can be accommodated. The field trip fee will include ground transportation from the Manchester Grand Hyatt Hotel in San Diego, a light breakfast, and a boxed lunch.

Keynote Speakers

Geology of Gem Deposits
- **Dr. Jeff Harris,** University of Glasgow, UK
  Diamond occurrence and evolution
- **Dr. David London,** University of Oklahoma, Norman
  Geochemical cycle of certain elements that form gems

Gem Characterization Techniques
- **Dr. George Rossman,** California Institute of Technology, Pasadena   *Characterization of nanofeatures in gem materials*
- **Dr. Emmanuel Fritsch,** IMN, University of Nantes, France
  Review and forecast of important techniques in gemology

New Gem Localities
- **Dr. Lawrence Snee,** U.S. Geological Survey, Denver
  Mapping of gem localities in Afghanistan and Pakistan
- **Dr. Federico Pezzotta,** Museo Civico di Storia Naturale, Milan   *Update on gem localities in Madagascar*

Gem Synthesis
- **Dr. James Butler,** Naval Research Laboratory, Washington, DC   *Growth of CVD synthetic diamond*
- **Dr. Ichiro Sunagawa,** Tokyo   *Growth, morphology, and perfection of single crystals: Basic concepts in discriminating natural from synthetic gemstones*

General Gemology
- **Shane McClure,** GIA Laboratory, Carlsbad
  Genetic source type classification of gem corundum
- **Menahem Sevdermish,** Advanced Quality A.C.C. Ltd., Ramat Gan, Israel   *Color communication: The analysis of color in gem materials*

Diamond and Corundum Treatments
- **Ken Scarratt,** GIA Research, Bangkok
  Corundum treatments
- **Dr. Mark Newton,** University of Warwick, Coventry, UK
  Diamond treatments

Eight additional speakers for each session will be selected from submitted abstracts.

NAVIGATING THE
CHALLENGES AHEAD

The GIA Gemological Research Conference will be held in conjunction with the 4th International Gemological Symposium, which will take place August 27–29, 2006. For further information on participating in or attending the GIA Gemological Research Conference, contact the organizing committee at:

E-mail: gemconference@gia.edu
Dr. James E. Shigley, Phone: 760-603-4019
Brendan M. Laurs, Phone: 760-603-4503
Fax: 760-603-4021
Web: www.gia.edu/gemsandgemology
    or www.symposium.gia.edu

LETTERS

MORE ON SPECTROSCOPY OF YELLOW DIAMONDS

I read with interest "Characterization and grading of natural-color yellow diamonds" by John King and collaborators in the Summer 2005 issue (pp. 88–115). It is an informative text putting together a lot of useful gemological and spectroscopic data. I was a little surprised in reading the description of Group 2 that this category of yellow diamonds was not recognized as belonging to the "brown to grayish-yellow family" of hydrogen-rich diamonds defined by myself, Ken Scarratt, and Alan Collins in 1991 (see E. Fritsch et al., "Optical properties of diamonds with an unusually high hydrogen content," in R. Messier et al., Eds., *Materials Research Society International Conference Proceedings*, 2nd International Conference on New Diamond Science and Technology, Washington, DC, Sept. 23–27, 1991, Materials Research Society, Pittsburgh, PA, pp. 671–676; E.

Fritsch and K. Scarratt, "Gemmological properties of type Ia diamonds with an unusually high hydrogen content," *Journal of Gemmology*, Vol. 23, No. 8, 1993, pp. 15–24). The brownish yellow color is well within the range described by the family name, and the color of such stones extends all the way to brown (B. M. Laurs, "Gem News International: International Geological Congress," *Gems & Gemology*, Vol. 41, No. 1, 2005, pp. 67–69).

Nevertheless, I was delighted to learn that this category is so prominent among yellow diamonds (the second most common after "cape" stones, representing about 4% of submitted diamonds). This demonstrates that what might be perceived as a curiosity when first described may later turn out to be of larger significance.

Emmanuel Fritsch
IMN, University of Nantes, France

IN MEMORIAM: ALFRED A. LEVINSON (1927–2005)

Gems & Gemology mourns the loss of Dr. Alfred A. Levinson, professor emeritus of geology at the University of Calgary. A longtime contributor, reviewer, and editor for *G&G*, Dr. Levinson passed away December 12 at the age of 78.

Al Levinson was born and raised in Staten Island, New York, and became interested in geology at a young age. He attended college for a year before enlisting in the Navy in 1945. After the war, he used his G.I. Bill benefits to attend the University of Michigan, where he received a Ph.D. in mineralogy in 1952.

After working as an assistant professor of mineralogy at Ohio State University in the mid-1950s, Dr. Levinson spent the next 10 years in private industry, conducting mineral exploration with Dow Chemical Co. and petroleum studies for Gulf Research and Development Co. In 1966, he proposed a system of mineral nomenclature for rare-earth elements that was accepted by the International Mineralogical Association in 1971 and to this day is widely known as the Levinson system. In 2002, the mineral species levinsonite-(Y) was named in his honor.

Eager to return to academia, Dr. Levinson accepted a professorship at the University of Calgary in 1967. From 1967 to 1970, he also served as executive editor of *Geochimica et Cosmochimica Acta*, even as he was preparing the *Proceedings of the Apollo 11 Lunar Science Conference*

(1970) and the *Proceedings of the Second Lunar Science Conference* (1971). During the 1970s and 1980s, he published two textbooks on geochemistry.

Dr. Levinson turned to gemology late in his career, and was particularly active after becoming a professor emeritus in 1994. He was an acknowledged expert on the occurrence, exploration, recovery, and economics of diamonds. Among the 10 feature articles he coauthored for *Gems & Gemology* were some of the most important diamond papers in the journal's history. Three received Most Valuable Article awards: "Age, origin, and emplacement of diamonds: Scientific advances in the last decade" (Spring 1991); "Diamond sources and production: Past, present, and future" (Winter 1992); and "Diamonds in Canada" (Fall 2002). He also contributed a chapter on diamond sources to *The Nature of Diamonds* (1998), edited by Dr. George Harlow.

Al Levinson meant many things to *Gems & Gemology*. He was a mainstay of the editorial review board since 1995 and the editor of the Gemological Abstracts section since 1997. And for the past three years, he carefully reviewed the final set of page proofs for each issue before publication. Yet his importance to *G&G* went beyond his intellectual contributions. Above all, Al was a beloved friend and a constant source of support and encouragement for the entire staff. He will be greatly missed.

A GEMOLOGICAL PIONEER: DR. EDWARD J. GÜBELIN

Robert E. Kane, Edward W. Boehm, Stuart D. Overlin, Dona M. Dirlam,
John I. Koivula, and Christopher P. Smith

During a career that spanned more than 65 years, the eminent Swiss gemologist Dr. Edward J. Gübelin (1913–2005) built a monumental legacy. He is perhaps best known for his pioneering work on gemstone inclusions. He established the first systematic classification of inclusions in natural gem minerals, and his research demonstrated the importance of these internal features in determining a gem's identity as well as its country of origin. He wrote extensively on nearly all aspects of gemology, eloquently recording his observations in 13 major books and more than 250 articles. A widely traveled explorer, Dr. Gübelin also reported on some of the world's most important gem localities. In addition, he was an innovator in gem-testing instruments, an influential educator, a major gem collector, and one of gemology's most ardent and respected global ambassadors.

To those who are able to explore their secrets, precious stones relate a story as interesting as that of the huge pyramids erected by the Pharaohs at Memphis, and it would seem that their sublime internal spheres might best be called, "The Fingerprints of God."

Edward J. Gübelin
Inclusions as a Means of Gemstone Identification,
1953

The late Dr. Edward J. Gübelin (1913–2005; figure 1) will forever be linked to the study of inclusions in gemstones, an area of research he pioneered in the early 1940s. His lifelong studies yielded breakthroughs in determining a gem's identity and geographic origin based on these internal features, thus helping to establish the foundation of modern gemology. In many ways, he transformed the way we look at and study these very special minerals. Yet his acclaimed research on inclusions tells only part of the story. Dr. Gübelin was also an insightful and prolific writer whose works on nearly all aspects of gems and their study have been widely read and translated into several languages. He was an inventor of gem-testing instruments, an important gem collector, and an educator who influenced several generations of gemologists. In addition, he was an explorer who chronicled many of the world's major gem sources, both classic and new.

As a tribute to one of the most remarkable figures in the history of gemology, this article examines the many dimensions of Edward J. Gübelin's career, from his early academic training to the enduring legacy he has left behind.

THE EARLY YEARS

The story of Edward J. Gübelin begins with the founding of a family business. In 1854, Jakob Josef Mauritz Breitschmid opened a watchmaker's shop in the picturesque lakeside city of Lucerne, Switzerland. Breitschmid's apprentice, Eduard Jakob Gübelin, married his master's daughter in 1886 and purchased the company in 1899. Their son, Eduard Moritz Gübelin (1888–1945), took the reins in 1919 (*150 Years of Gübelin*, 2004).

Figure 1. The pioneering Swiss gemologist Edward J. Gübelin (1913–2005) looks at a set of gems from his personal collection, which contains more than 5,000 specimens. Best known for his landmark research on gemstone inclusions, Dr. Gübelin was a renowned author, photographer, educator, and explorer whose contributions to the field may never be surpassed.

Eduard Joseph Gübelin, the eldest son of Eduard M. and Maria (Schriber) Gübelin, was born March 16, 1913. Young Eduard (figure 2) attended grammar and high school in Lucerne, with a special focus on natural science and languages. He eventually became fluent in four languages—German, French, English, and Italian—in addition to his native Swiss German, and he could read and write Latin and Greek. Because Dr. Gübelin preferred the English spelling of his given name when publishing for an English-speaking audience, the balance of this article will refer to him as "Edward."

Edward J. Gübelin's lifelong passion for gems was sparked while walking home from grammar school one day, when he saw a brooch set with rubies and diamonds in a shop window. To nurture his son's budding interest, watchmaker Eduard M. Gübelin took the remarkable step of adding a jewelry division to the company:

> It must have been about 1922 or '23 when my father wanted me and my younger brother to decide which profession we wanted to take. And I told my father I'd like to become a jeweler. He said, "Okay, I like the idea. And under the circumstances, I shall add a jewelry section to the firm." However, he was a watchmaker and he didn't know much about gemstones and jewelry. So he took a gemological course with Prof. Michel, who—from Vienna—was the European pioneer in gemology. (Gübelin, 2001)

In 1923, the senior Gübelin also established a small gemological lab to support the fledgling jewelry side of the business. This facility would become the foundation for the Gübelin Gem Lab (*150 Years of Gübelin*, 2004).

THE ACADEMIC AND HIS THIRST FOR KNOWLEDGE

Academic Career. In 1932, at the age of 19, Edward J. Gübelin joined the family business. While working part-time, he majored in mineralogy at the University of Zurich, with additional studies in art history, literature, and ancient languages (Jaeger, 2005).

A crucial period in Dr. Gübelin's gemological education was the winter 1936–37 term, which he spent at the Institute of Precious Stones in Vienna. There he studied under Prof. Hermann Michel, his father's tutor a decade earlier. The professor was an early pioneer in practical gemology whose books included the English-language *Pocketbook for Jewelers, Lapidaries, Gem & Pearl Dealers* (1929). Prof. Michel taught his young protégé to "observe and distinguish inclusions within gemstones and to appreciate their diagnostic value" (Gübelin, 1953). Dr. Gübelin's detailed notes from this class reveal a systematic rigor and enthusiastic curiosity that would characterize his work over the next seven decades.

Another influential figure during these formative years was the renowned German gemologist and mineralogist Prof. Karl Schlossmacher, who had revised Dr. Max Bauer's classic book *Edelsteinkunde*

Figure 2. Edward J. Gübelin, second from the left, excelled from an early age in natural science and languages. Also shown, left to right, are his younger siblings Werner, Walter, Hans Ulrich, Robert, Maria, and Albert Gübelin. Courtesy of Gübelin AG.

[*Precious Stones*] in 1932. During his university time in Zurich, Dr. Gübelin attended a summer course taught by Prof. Schlossmacher, who remained a friend and guiding influence for many years (Gübelin, 2001).

Dr. Gübelin's doctoral dissertation, written in 1938, examined the minerals in dolomite from Campolungo, in the Tessin region of the Italian Swiss Alps (Gübelin, 1939). He was formally awarded his doctorate from the University of Zurich in 1941. His university studies completed,

Dr. Gübelin traveled by steamship to the United States in January 1939 to work in the Gübelin firm's New York office and improve his salesmanship and English skills. At this same time, he contacted Robert M. Shipley, founder of the Gemological Institute of America, and enrolled in the Institute's correspondence classes. Dr. Gübelin arrived at GIA in Los Angeles in July 1939 to complete the coursework and prepare for his examinations. He later recalled, "The deeper I delved [into the courses], the more enthusiastic I grew" (Shuster, 2003, p. 66). In August 1939, he received GIA's title of Certified Gemologist (the forerunner of today's Graduate Gemologist, or G.G., diploma; Certified Gemologist later became the title given by the American Gem Society).

After graduating from GIA, Dr. Gübelin returned to Lucerne, where he married Idda Niedermann and rejoined the family business. During World War II, he served in the Swiss Army as an intelligence officer while continuing to pursue gemological studies and independent research when his military duties allowed (figure 3). In 1945, he earned his Diamond Certificate from the Swiss Gemmological Society. He continued his studies with the Gemmological Association of Great Britain and became a Fellow of the Gemmological Association of Great Britain (FGA) with distinction in 1946. This was followed by a gemological certificate from the German Gemmological Society and the Institute of Gemstone Research, both in Idar-Oberstein, in 1954. The next year, Dr. Gübelin was awarded the Gemstone Expert Diploma of the Swiss Gemmological Society.

When Dr. Gübelin was asked recently what

1854	1913	1923	1936–1937	1938	1939	1940

March 16, 1913 Edward J. Gübelin born in Lucerne

1936–1937 Edward J. Gübelin is introduced to the study of inclusions under Prof. Hermann Michel in Vienna

1938 Completes doctorate in mineralogy at the University of Zurich (diploma awarded in 1941)

1939 Earns Certified Gemologist diploma at GIA

1940 Returns to the family business in Lucerne and marries Idda Niedermann

Publishes his first *Gems & Gemology* article, "Differences between Burma and Siam rubies"

The Gübelin company begins issuing diamond and colored stone certificates signed by Edward J. Gübelin

Joins the Swiss Army, serves until 1945

1854 Jakob Breitschmid opens watchmaking shop in Lucerne, forerunner of the Gübelin group of companies

1923 Jewelry division added to the watch company, as well as the precursor to the Gübelin Gem Lab

Figure 3. Dr. Gübelin began publishing on gemstone inclusions in 1940. Here he is using the darkfield Gemmoscope, which he developed in 1942 using the latest in Zeiss optics. Inset: One of Dr. Gübelin's early photomicrographs, of curved striae and elongated gas bubbles in a flame-fusion (Verneuil) synthetic ruby.

other people, but remain curious to find out everything you can about gemstones" (Gübelin, 2001).

Lifelong Thirst for Knowledge. Throughout his life, Dr. Gübelin's yearning for gemological knowledge never diminished. Into the 21st century, he rigorously read gemological journals in at least four languages and frequently wrote letters to the authors of these articles to compliment, critique, comment on, or politely question their findings and conclusions.

Perhaps one reason Dr. Gübelin stayed so productive for so long was that his vocation was also his hobby, and as such he did not make any distinction between work and pleasure. In 1991, at the age of 78, he commented on his retirement from business 15 years earlier. "Gemology has become a necessity to me, something that I have to do," he said (Berenblatt, 1991, p. 30). "I'm still studying gemological literature. I'm still receiving gems from all over the world. I enjoy analyzing the nature of the gems."

UNLOCKING THE MYSTERIES OF GEMSTONE INCLUSIONS

Inclusions in gemstones speak eloquently of the geological origins and subsequent history of their costly host. All we need to do is open our eyes and explore.
Photoatlas of Inclusions in Gemstones, 1986
(p. 518)

advice he would give a young gemology student today, he responded, "The best advice I can give him is to be curious. Ask questions [of] yourself, [of]

No one in the history of gemology has had as profound an impact on the research and appreciation of inclusions as Edward J. Gübelin. When he first

1942	1945	1946	1950	1952	1953	1962	1963

1945 Takes over the Gübelin company with brother Walter after the death of their father

1946 Receives FGA with distinction from the Gemmological Association of Great Britain

1952 Helps found the International Gemmological Conference (IGC)

1954 Receives gemological certificate from the German Gemmological Society

1962 First trip to Burma (now Myanmar)

1953 Publishes the classic *Inclusions as a Means of Gemstone Identification*

1963 Produces the film "Mogok, Valley of Rubies" with daughter Marie-Helen. He is the last Western gemologist to visit Mogok for nearly 30 years.

1942 Develops the Gemmoscope, a darkfield-illuminator-equipped microscope, and creates a diamond cut gauge

1950 Develops the first desk-model gemological spectroscope

Founding member of the Swiss Gemmological Society

gazed into a microscope in the 1920s, inclusions were considered little more than undesirable flaws and imperfections. As a direct result of his pioneering research and photomicrography, inclusions are now recognized as valuable indicators of a gem's identity, geographic origin, and natural or treated condition, as well as—in many cases—conclusive proof of whether a gem is natural or synthetic. They are also appreciated as objects of natural beauty in their own right, in gems cut or carved to showcase their internal features.

Classifying Gemstone Inclusions. In his 1953 book *Inclusions as a Means of Gemstone Identification*, Dr. Gübelin proposed a classification of mineral inclusions based on when they formed in relation to the host gem crystal.

- **Protogenetic (preexisting) inclusions:** Protogenetic inclusions formed before the growth of the host. These inclusions are always minerals; preexisting gases and liquids are not considered protogenetic. Examples include actinolite and biotite in emerald, and pyrrhotite in diamond. Calcite and dolomite in ruby can be either protogenetic or syngenetic (figure 4, top).

- **Syngenetic (contemporaneous) inclusions:** Mineral inclusions, as well as fluids (liquids and gases), that formed and were "imprisoned" as the host crystal was growing are syngenetic. Classic examples of syngenetic inclusions are the well-known three-phase inclusions in Colombian emeralds, and pyrite in quartz or emerald (figure 4, middle).

- **Epigenetic (post-growth) inclusions:** Epigenetic inclusions formed after the host completed growing, anywhere from immediately to millions of years later. Perhaps the best-known examples are rutile needles in rubies and sapphires, as well as the "fingerprints" that occur in many gemstones, including rubies and sapphires. Rutile needles occur in corundum through exsolution of trace amounts of titanium forced out of the gem's crystal structure during cooling, while fingerprint-like inclusions result from the healing of internal surface-reaching fractures by growth fluids, sometimes long after the host crystal's formation (figure 4, bottom).

In addition to when they were created, Dr. Gübelin classified inclusions by their physical form. This allowed for better description of the inclusion, which has become increasingly important with the multitude of treatments that often alter the internal characteristics of a gemstone. Here he also broadened the definition of *inclusion* beyond internal solids, liquids, and gases within a host gem to encompass characteristics such as cracks and fissures and growth phenomena (e.g., twinning, color zoning, and textural growth structures).

Today, Dr. Gübelin's various inclusion classifications are widely accepted, and their usefulness only grows as new localities are discovered and new synthetics and treated materials continue to emerge. The just-released *Photoatlas of Inclusions in Gemstones, Volume 2* (Gübelin and Koivula, 2005) presents a new classification of gemstone inclusions based on specific diagnostic

1967 | **1968** | **1969** | **1974** | **1975** | **1976** | **1980** | **1982**

1967 Publishes *Burma, Land der Pagoden*

1968 Publishes *Die Edelsteine der Insel Ceylon*

1969 Publishes *Edelsteine,* translated in 1975 as *The Color Treasury of Gemstones*

1974 Publishes *Internal World of Gemstones*

1975 Writes groundbreaking articles on green grossular garnet (tsavorite) deposit in Kenya

Photo by Robert Weldon

1976 Officially retires from the Gübelin company

1980 Receives the Jewelers of America's International Award for Jewelry Leadership

Photo by Robert Weldon

Writes seminal article on cause of color in alexandrite and alexandrite-like gems in *Neues Jahrbuch für Mineralogie Abhandlungen*

1982 Named first honorary member of the American Gem Trade Association (AGTA)

Founding organizer of the International Colored Stone Association (ICA)
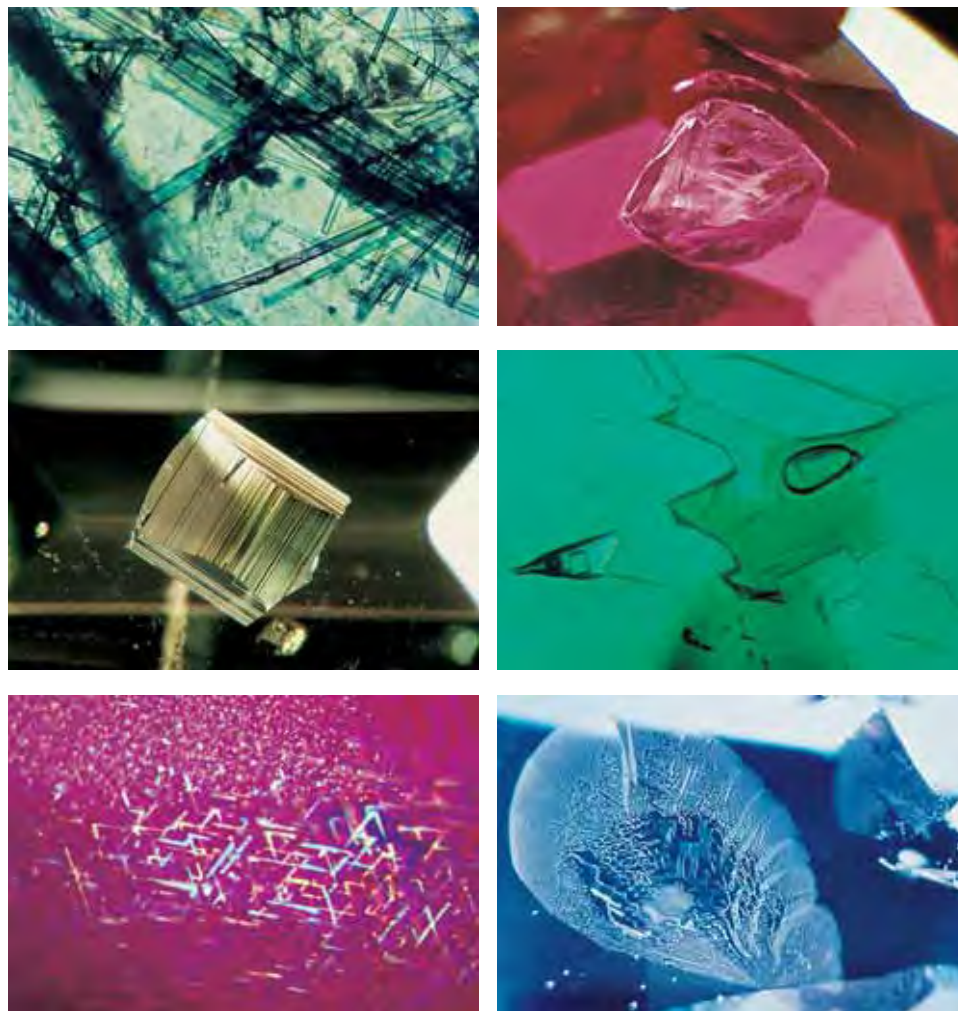
Figure 4. Dr. Gübelin classified mineral inclusions according to when they formed in relation to the host gem crystal. Top: These inclusions of actinolite in Austrian emerald (left, magnified 32×) and calcite in Burmese ruby (right, 32×) are protogenetic (formed before the growth of the host). Middle: This pyrite crystal in Brazilian quartz (left, 25×) and the three-phase inclusions in Colombian emerald (right, 50×) are syngenetic (formed and then "imprisoned" as the host crystal was growing). Bottom: These rutile needles in Burmese ruby (left, 50×) and "fingerprints" in Burmese sapphire (right, 20×) are epigenetic (formed after the host completed growing). Photomicrographs by Edward J. Gübelin, from the Photoatlas of Gemstone Inclusions *(1986); used with permission from Opinio Verlag, Basel, Switzerland.*

mineral species, colors, morphology, and fluid inclusions. It also makes correlations between the inclusions and their hosts on the basis of their geologic formation.

Inclusions as Diagnostic Tools. How did Dr. Gübelin use these microscopic features as diagnostic tools? His understanding of mineralogy and of how and where certain minerals formed in the

| 1986 | 1988 | 1991 | 1993 | 1994 | 1997 | 1999 | 2003 | 2005 | 2005–2006 |

1991
Receives the ICA Lifetime Achievement Award

1993
Presented with the coveted Medal of the City of Paris

1999
Publishes *Edelsteine: Symbole der Schönheit und der Macht* (with Franz-Xaver Erni), translated in 2000 as *Gemstones: Symbols of Beauty and Power*

March 15, 2005
Dies in Lucerne at the age of 91

2005–2006
Posthumous publication of *Photoatlas of Inclusions in Gemstones, Volumes 2 and 3* (with John I. Koivula)

1986 Publishes the classic *Photoatlas of Inclusions in Gemstones* (with John Koivula)

1994 Receives the American Gem Society's Robert M. Shipley Award

1988 Publishes the "World Map of Gem Deposits" (with the Swiss Gemmological Society)

1997 *Gems & Gemology's* Most Valuable Article Award is renamed in his honor

One of the first Westerners to return to the gem areas of Mogok

2003 Inducted into GIA's League of Honor

Figure 5. These amphibole fibers, which Dr. Gübelin believed were tremolite, are characteristic of emeralds from Sandawana, Zimbabwe. Photomicrograph by Edward J. Gübelin, magnified 20×, from the Photoatlas of Gemstone Inclusions *(1986); used with permission from Opinio Verlag, Basel, Switzerland.*

earth enabled him to surmise a great deal of information simply by looking at an inclusion with magnification. With polarized-light microscopy, for example, Dr. Gübelin could observe long, slender, fibrous clusters of highly birefringent transparent crystals in an emerald and conclude that they were amphibole inclusions, such as tremolite or actinolite. He knew that such inclusions, with their slightly rounded edges and lack of sharp crystal faces, indicated a protogenetic formation. Protogenetic amphibole inclusions in emerald are known to occur only in certain metasomatic geologic environments, such as those at the mines in Sandawana, Zimbabwe (see, e.g., Gübelin, 1958). Thus armed with a profound knowledge of the relationships between gem minerals, their host rocks, and their internal features, Dr. Gübelin could look through his microscope and ascertain within seconds that these protogenetic inclusions were amphiboles and, on the basis of their morphology, that the emerald in question grew in a geologic environment similar to that at Sandawana (figure 5). The shape, size, quantity, distribution, and fissure patterns of these amphibole inclusions differentiate Sandawana emeralds from those found at other sources, such as Habachtal in Austria or the Ural Mountains in Russia, which also contain amphibole crystals. It was remarkable that Dr. Gübelin could identify these amphibole inclusions without chemical analysis, and determine the

emerald's probable geographic origin using only a microscope.

Characteristics of Gem Species. In some cases, Dr. Gübelin stressed, an inclusion type alone will conclusively identify a particular gemstone species or variety. For instance, thread-like "trichites" indicate tourmaline, and "lily pads" are typical of peridot from most localities. Octahedral negative crystals filled with white dolomite identify spinel. "Heat-wave" or "roiled-effect" growth structures are characteristic of hessonite. When such internal features are present, no further tests are necessary to identify the gemstone host (Gübelin, 1999).

His research also revealed that the internal features of many gemstones are globally analogous, or even the same. A few examples of gems where the inclusions are the same from one locality to the next are beryl (other than emerald), kyanite, spodumene, and zircon.

Over the course of his long career, Dr. Gübelin identified hundreds of mineral species as inclusions in the tens of thousands of gems he examined. There is scarcely a gem material he did not report on, from the most common stones on the market to the rarest collector gems, such as ekanite, taaffeite, axinite, and cassiterite. If a gemstone had inclusions, he was intent on learning as much as he could about it. Dr. Gübelin was the first to observe many inclusion relationships, such as chromium-pyroxene in diamonds and apatite and calcite in hessonite. Also consider quartz, which Dr. Gübelin once said he regarded as the most interesting gem mineral. In an October 1995 International Gemmological Conference (IGC) lecture in Thailand, he reported that he had discovered 136 different inclusions in quartz, 40 of them in material from the Swiss Alps.

Genetic Conditions. In 2000, Dr. Gübelin (with Franz-Xaver Erni) wrote, "Just as fossils in rocks give paleontologists information about past geological periods in the earth's history, the inclusions in precious jewels bear witness to formation and growth conditions as well as to the gemstones' place of origin" (p. 218). Conclusions about the geologic conditions under which the original crystal grew can be drawn by studying the internal paragenesis (mineral association) of a gemstone. Dr. Gübelin published his initial observations on this in a 1943 *Gems & Gemology* article titled "Survey of the genesis of gem stones" (figure 6). Calcite and dolomite inclusions in a ruby are proof of the

Figure 6. This illustration from Dr. Gübelin's Winter 1943 Gems & Gemology *article, "Survey of the genesis of gem stones," shows a system for classifying primary and secondary gem deposits.*

metamorphic cycle that created the marble in which the original crystal grew, whereas pyrrhotite in ruby betrays its igneous (basaltic) origin. Some (igneous) peridot contains small black chromite crystals, which are remnants from the earth's mantle, just as they are in some (ultramafic) diamonds.

Dr. Gübelin (1999) pointed out that not only do certain inclusions indicate origin in a specific magmatic environment, but they also provide evidence of where within the earth their gemstone hosts formed. For example, chromium-rich diopside, enstatite, and pyrope indicate origin in metamorphic ultramafic rocks of the upper mantle, whereas actinolite, diopside, epidote, and ilmenite predominate in metamorphic rocks of the lithosphere, which extends to the earth's surface.

Diamonds contain a multitude of mineral inclusions (olivine, garnet, pyroxene, spinel, etc.), as well as diamond itself. Because diamonds formed deep in the mantle and were carried to the surface by a magma, inclusions in diamond do not serve as indicators of geographic origin and typically are similar from one locality to the next. They do, however, offer scientists great insights into "deciphering the

genesis of diamond and the composition of the earth's mantle at depths of approximately 200 km. These depths are far beyond man's capability to reach, and thus the information contained in these inclusions is of much scientific interest" (H. O. A. Meyer in Gübelin and Koivula, 1986, p. 271).

Natural versus Treated. In some gemstones, inclusions supply evidence of treatment or the absence thereof. With rubies and sapphires, for example, the unaltered or altered state of the inclusions may indicate whether or not the stone has been heat treated at moderate to high temperatures. In emeralds, the microscope reveals visual evidence of the oils and other foreign fillers that are commonly used to reduce the visibility of fractures. As gemstone treatments became prevalent in the trade, Dr. Gübelin began reporting on them (see, e.g., his 1964 *Gems & Gemology* article, "Black treated opals"), and the 1986 *Photoatlas* contains an entire chapter devoted to inclusions in treated corundum.

Natural or Synthetic Origin. Inclusions are essential to identifying the vast majority of synthetics available today. Dr. Gübelin's first report on a synthetic

gem material was "The synthetic emerald" (Gübelin and Shipley, 1941), which described the new products from German manufacturer IG Farben. This article detailed the gemological properties of the Farben synthetics and compared them to natural emeralds from Colombia, Brazil, Russia, and Africa, with several exceptional photomicrographs of the synthetic emeralds' characteristic inclusions. This was the first of many articles on the subject, and nearly every book Dr. Gübelin published featured a discussion accompanied by photomicrographs of inclusions showing the reader how to identify what he dubbed "usurpers from the factory" (Gübelin, 1974a, p. 197). The 1986 *Photoatlas* devoted an entire section, comprising 10 chapters, to synthetics and imitations.

Locality Characteristics (Country of Origin). Historically, certain gemstones with a legendary provenance—such as Burmese rubies, Kashmir sapphires, and Colombian emeralds—have commanded higher prices than comparable stones from other sources (figure 7). Dr. Gübelin learned this fact as early as the mid-1930s, even before his formal gemological training, when the Gübelin firm was dealing with a Colombian emerald:

> They sent the emerald to Prof. Michel, and [he] decided it was a genuine emerald from Colombia. I wondered, 'Why is it so important to know about Colombia?' My father gave me [the] rudimentary information he had, but it impressed me very much. And especially afterwards when I learned about Burmese rubies and the emphasis on Burmese rubies and Kashmir sapphires, I wanted to know why. . . . I started studying inclusions, and that's how I noticed that [there were] visible differences, so I started classifying inclusions. (Gübelin, 2001)

Dr. Gübelin systematically studied geographic origin during his 1936–37 term under Prof. Michel, who had a collection of gemstones that were classified according to localities and their typical inclusions. He learned that certain inclusions form only in specific geologic environments. Dr. Gübelin (1999) acknowledged the "almost incalculable" number of factors that contribute to the variation of inclusions from one gem deposit to another, but are frequently consistent at one particular geographic locality:

> [E]ven gems formed in identical parent rocks e.g. dolomitic marbles at Jagdalek (Afghanistan), Mogok and Mong Hsu (Myanmar), Chumar and

Figure 7. The two sapphires in this photo illustrate the commercial importance of determining a gem's geographic origin, which was one of Dr. Gübelin's specialties. Although the natural-color 8.92 ct loose sapphire on the right looks remarkably similar to a "classic" Kashmir sapphire—which many dealers argued that it was—the fact that it was actually from Madagascar resulted in its selling for less than one-fifth the price of a comparable gem from Kashmir. The price per carat of the 20.97 ct natural-color Burmese sapphire in the ring would fall between the prices for comparable Kashmir and Madagascar stones. The matched pair of heated Burmese rubies weighs a total of 4.02 ct. Photo © Erica & Harold Van Pelt and Robert E. Kane; courtesy of Fine Gems International.

Ruyil (Nepal), Hunza Valley (Pakistan), Morogoro (Tanzania) and Luc Yen (Vietnam) manifest specific local differences, by which the gems from these deposits may be ascribed to their particular place of origin. While pargasite may be an inmate of rubies from Mogok and the Hunza Valley, it has not been observed in rubies from other similar sources. Hunza rubies also usually boast margarite mica and pyrite inclusions, whereas calcite, scapolite, sphene, spinel, and sometimes pyrite as well, characterise rubies from Mogok. Rubies from Mong Hsu are devoid of this inclusion assembly—they excel rather in fluorite, which has not been encountered in rubies from any other locality. Rutile—usually with acicular habit and oriented along three . . . directions (forming so-called "silk")—is a regular inhabitant of rubies from most of those places. . . .

However, it is not merely the presence of a specific, single guest mineral which may indicate a particular mother rock, but more often the

internal association of various repeatedly occurring guest minerals is symptomatic of a specific source. . . . The guest mineral assembly such as apatite, rutile, zircon, etc., in sapphires from metamorphic rocks (e.g., from Sri Lanka) is completely different from that in sapphires from basaltic beds (volcanic origin: Australia, Cambodia, Laos, Thailand, Vietnam) encompassing columbite, plagioclase, uraniumpyrochlor [*sic*] (uranpyrochlore). On the other hand, allanite, pargasite, plagioclase, tourmaline and zircon specify sapphires of pegmatitic origin in Kashmir. (pp. 20–22)

Dr. Gübelin was particularly adept at recognizing combinations of features that were characteristic of a particular locality. A classic example he described was ruby from Mogok: "The combination of calcite- or dolomite- crystals (with their typical lamellar cleavage and poly-synthetic twins) with small 'gratings' of rutile needles in swirly surroundings, is the privilege of the sought-after Burma rubies" (Gübelin and Koivula, 1986, p. 48).

He observed that fibrous inclusions in some gemstones "emphatically hint to definite places of origin," such as almandine with fibrous sillimanite from Okkampitiya, Sri Lanka; andalusite with sillimanite fibers from Santa Teresa, Minas Gerais, Brazil; and quartz with fibrous, hair-fine sepiolite from Finland (Gübelin, 1999, p. 22).

Conversely, Dr. Gübelin reported, "the lack of a particular mineral inclusion may also exclude a particular origin and therefore indicate another source" (Gübelin, 1999, p. 22). A well-known example he cited, demantoid from Namibia, was found to be devoid of the "horsetail" chrysotile inclusions that are characteristic of its counterpart from Russia's Ural Mountains and Val Malenco, Italy.

Starting with the issuance of his first gemological report in the early 1940s, and propelled by his continuing research and the trade's widespread acceptance of geographic locality origin in the 1960s, Dr. Gübelin in effect began what is now a gemological "cottage industry." Using techniques pioneered by Dr. Gübelin, today many gemological laboratories around the world issue reports on a gem's probable country of origin by analyzing a combination of properties such as inclusions, trace-element chemistry, spectral characteristics, and internal growth structures. Because origin determination is not an exact science, in situations where ambiguity exists or properties overlap, most of these labs will not provide a report opinion on the geographic origin of that specific gemstone.

The Science and Art of Capturing Inclusions on Film. Dr. Gübelin's introduction to photographing inclusions through the microscope came during his 1936–37 gemological studies with Prof. Michel in Vienna. Learning to take photomicrographs, he recounted, "was a great experience . . . to put down on paper documents what I had seen with my eyes" (Gübelin, 2001). In the early 1940s, he began providing Gübelin jewelry store customers with a photomicrograph of a gem's inclusions along with a certificate (Peet, 1957). Over the decades, he took tens of thousands of photomicrographs, many of which he published or presented to captivated audiences during his lectures. Dr. Gübelin's enthusiasm for photographing inclusions never waned: He took his last photomicrographs on March 5, 2005, just 10 days before his passing.

In his 1974 *Internal World of Gemstones* (p. 28), Dr. Gübelin wrote, "For research and documentation the employment of microphotography is more or less mandatory. Only photomicrographs—if possible, in colour—allow comparison of objects, provide material for proof of gemstone identity, and at the same time preserve in permanent visual form the inner glories of the world of inclusions for everyone." Indeed, Dr. Gübelin's artistic photomicrography, particularly with the widespread use of color in his books and articles beginning in the 1960s, gave gemologists an entirely new appreciation of the natural beauty of inclusions. "I was always fascinated by looking at gemstones under the instruments," he once noted (Berenblatt, 1991, p. 30). "What has always motivated me to continue my work has been the beauty of gemstones and the beauty of inclusions."

Dr. Gübelin's photomicrographs were exceptional not only for their technical content, but also for their visual quality. He had an artistic eye and an intense curiosity, which he combined with an ability to build and adapt his equipment.

Dr. Gübelin began taking photomicrographs in the 1930s with a monocular microscope before turning to the binocular Gemmoscope he developed in 1942. He also modified Prof. Schlossmacher's horizontal immersion microscope to take many of the photomicrographs that appeared in his 1953 book *Inclusions as a Means of Gemstone Identification* (see "Development of Practical Gem-Testing Instruments" section below). In recent years, his microscopes of choice were the Zeiss SV8 (with a custom adapter for a Nikon SLR camera; figure 8) and a Zeiss petrographic research microscope. With the Zeiss research microscope and its built-in camera, he

Figure 8. Throughout his career, Dr. Gübelin continuously refined his photomicrographic techniques. Here he is shown taking a photomicrograph with his Zeiss SV8 microscope with custom darkfield illumination.

could attain 600× magnification and capture highly detailed inclusion scenes. His last microscope was a Zeiss SV11 with an advanced camera attachment and special exposure timing device, which he used for the new *Photoatlas* volumes (2005 and 2006).

Dr. Gübelin constantly experimented with the best micro-optics available and continued to refine his techniques. He worked with different light sources from the early lamps through fiber optics in his later years. In *Internal World of Gemstones*, Dr. Gübelin describes how he combined darkfield and transmitted light (lightfield) illumination, as well as other techniques, to bring out the contrast between the host mineral and the inclusion (1974a, pp. 27–28). More recently, he used oblique fiber-optic illumination and shadowing techniques to better illuminate the desired inclusion. As he upgraded his microscopes and camera equipment, he also adopted new and better film. His recent favorite was Kodak Tungsten 64.

For his photomicrographs, Dr. Gübelin took detailed notes in shorthand that included the date, film type, magnification, exposure time, and description of the subject inclusion. As part of a larger acquisition, GIA obtained many of these log books along with the entire collection of more than 22,000 slides (see the "Gem Collection" section below). These slides actually represent less than half the number he developed, since he routinely disposed of duplicates or those that did not meet his high standards.

It is unlikely that there is a gemologist anywhere in the world who has not consulted one of Dr. Gübelin's invaluable photomicrographs. It is common practice for many gemologists to compare what they observe in their microscopes to photomicrographs in Dr. Gübelin's many published works. This started with his landmark articles in the 1940s, and continued with his many books such as *Inclusions as a Means of Gemstone Identification* (1953), *Internal World of Gemstones* (1974a), and the original *Photoatlas of Gemstone Inclusions* (1986). His recently published *Volume 2* (2005) and the forthcoming *Volume 3* (in preparation for 2006) of the *Photoatlas* will continue to provide gemologists with the most current inclusions in gemstones for many years to come. Without a doubt, his brilliant execution of photomicrography helped bring the science of gemology to where it is today.

PROLIFIC AUTHOR

Since his early years, when he was one of only a few gemological researchers, Dr. Gübelin sought to inform jewelers and gemologists of new developments in synthetics, treatments, and localities, as well as inclusions. Although he achieved this through his frequent lectures and classes around the world (figure 9), Dr. Gübelin's greatest impact was in his numerous landmark articles and books. He was a

Figure 9. Dr. Gübelin began lecturing and teaching gemological classes in the early 1940s. In this photo, he is giving a lecture in Sweden (Swenska Dagbladet, August 20, 1946). Courtesy of the Edward J. Gübelin family.

Figure 10. This 1987 photo shows Edward and Idda Gübelin and their five daughters. Standing (left to right): Birgitta Burkart, Franziska Greising, Mrs. Gübelin, Dr. Gübelin, Marie-Helen Boehm. Seated: Isabelle Morelli and Daniela Strub. Courtesy of the Edward J. Gübelin family.

gifted writer, with the ability not only to present his ideas in an informative manner, but also to poetically stimulate the reader's interest in the science and beauty of gemstones. This excerpt from *Internal World of Gemstones* (1974a, p. 137) offers a glimpse:

> The saturated green crystal-clear calm mountain lake is the image of the most beautiful emeralds. Such a peaceful mountain lake magnetizes our gaze into its depths. As we sink into it we attain a world where, in the shimmer of a distant greenish light, fronds of weed cast shadows, rigid growths stretch their limbs like chandeliers, vistas open up in bizarre forests of plants motionless in the eternal tranquility of the deep. . . . This, too, is the scene in the depths of the loveliest emeralds, in whose clear interior we find again vegetation of the deeps and the green foliage; floating between them, we dream our way into it, marvelling, as we admire them under the microscope.

Dr. Gübelin was a dominant force in 20th century gemological literature, with many books and more than 250 articles. His output is all the more astonish-

ing when one considers that he accomplished this as co-director of the Gübelin group of companies, head of its gemological laboratory, a devoted family man with a wife and five daughters (figure 10), and an international traveler. To assist in his prolific output of gemological research, Dr. Gübelin always maintained two sets of fully equipped gemological laboratories—one at the company, and another at his home—so that he could work in the evenings and on the weekends (figure 11). Even after his retirement in 1976, Dr. Gübelin dedicated more hours to his gemological pursuits than many do during their most productive working years.

Books. During his career, Dr. Gübelin wrote 13 major books (see Box A for an annotated bibliography). Many of these were subsequently revised or published in various languages, for a total of at least 34 volumes. In addition, he wrote more than a dozen promotional gem and jewelry booklets for the Gübelin company. Each new book marked a unique contribution to the gemological literature.

"My favorite book is the *Internal World of Gemstones*, because it is the most beautiful. I prefer it, to a certain extent, to the *Photoatlas* because it is

Figure 11. Dr. Gübelin's tremendous research output was aided by his having access to two fully equipped gemological laboratories—one at the company and another at his home. This photo shows his private laboratory as it appeared between 1942 and 1947. Courtesy of the Edward J. Gübelin family.

Box A: BOOKS BY EDWARD J. GÜBELIN

Between 1940 and 1957, Dr. Gübelin wrote more than a dozen promotional booklets for the Gübelin jewelry stores, covering a wide range of gem-related topics. These handsome booklets were written for the gem and jewelry buying public, both to educate and to generate excitement about precious gems. Most were in German, and the topics included diamonds, color grading of diamonds, precious stones, rubies and sapphires, emeralds, pearls, gems and jewelry, inclusions, and birthstones.

Edelsteine [*Gemstones*] (1952): This small but comprehensive book was intended for the layperson, with 18 beautiful watercolors of rough and faceted gemstones. First published in German in 1952, it was translated into French (*Pierres Précieuses*), with 1953 and 1955 editions. An English version (*Precious Stones*) was published in 1963, followed by a second edition and a third in 1973.

Inclusions as a Means of Gemstone Identification (1953): This is the first book in gemology to provide a comprehensive classification of gemstone inclusions and explain their usefulness in identification. Detailed text and 256 black-and-white photomicrographs describe the internal features in diamond as well as ruby, sapphire, emerald, and other major colored stones. This book is a compilation of Dr. Gübelin's popular series of *Gems & Gemology* articles on inclusions in gemstones, which were published between 1940 and 1946.

Schmuck- und Edelsteinkundliches Taschenbuch [*Jewelry and Gemology Pocketbook*] (with Karl F. Chudoba, 1953): In the introduction, the authors suggest that this is the first German-language pocket reference on precious stones. It contains brief characterizations of the major gems, plus information on inclusions, synthetics and imitations, and instruments.

Echt oder Synthetisch? [*Natural or Synthetic?*] (with Karl F. Chudoba, 1956): This succinct volume on the differences between natural and synthetic gems provides a brief history of the development of synthetics and describes how they can be identified by growth marks, inclusions, and other features. It contains exceptional black-and-white photomicrographs of inclusions in synthetic and natural gemstones.

Edelsteinkundliches Handbuch [*Gemology Handbook*] (with Karl F. Chudoba, 1966): This retitled and significantly revised second edition of the 1953 *Schmuck- und Edelsteinkundliches Taschenbuch* had considerable text and photographs added. A third edition, with an expanded dictionary and important new material on synthetics, followed in 1974.

Burma, Land der Pagoden [*Burma, Land of Pagodas*] (1967): Researched in various parts of Burma in 1963, this volume is illustrated with extraordinary photos by Dr. Gübelin's eldest daughter, Marie-Helen Gübelin Boehm. This German-language text is a general-interest book on Burma with a section on Mogok and ruby mining. It was an important commentary on this country, published just as a military regime took power and foreign entry became severely limited for the next several decades. A French version was later issued.

Die Edelsteine der Insel Ceylon [*The Gemstones from the Island of Ceylon*] (1968): Based on Dr. Gübelin's numerous travels to Sri Lanka (formerly Ceylon), it provides information on the geology, mining, and production of the island's gem wealth. It also contains many of Dr. Gübelin's exceptional locality photos and inclusion photomicrographs. Aside from descriptions of individual gemstones, sources, and inclusions throughout various chapters, the gemological properties and data are summarized in a tabular format in the last part of the book.
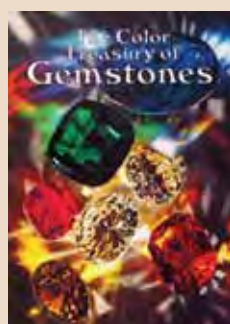
Edelsteine [*Gemstones*] (1969): This all-new work with the same German title as his 1952 book was also written in a nontechnical style that emphasizes the beauty of gems. In addition to profiles of the major gemstones, it touches on subjects such as rarity, cause of color, lapidary arts, phenomenal gems, and ornamental stones. It is accompanied by superb color photographs, many of which were taken by Dr. Gübelin. The German version sold 50,000 copies; it was also published in Italian as *Pietre Preziose*, in French as *Pierres Précieuses*, and rereleased in German as *Schmuck- und Edelsteine aus aller Welt* in 1977. The English edition was published in 1975 as *The Color Treasury of Gemstones*.

Innenwelt der Edelsteine: Urkunde aus Raum und Zeit [*Internal World of Gemstones: Documents from Space and Time*] (1973, followed by the English translation in 1974): This successor to Dr. Gübelin's 1953 book on inclusions contains 350 color photomicrographs and additional text on the genesis of these internal features. Sinkankas (1993) wrote of this work, "The photographs of superb quality and sharpness of detail are expected to provide ready reference as the student examines inclusions in the microscope." This book was ideally suited for the gem expert as well. Second and third English editions appeared in 1979 and 1983.
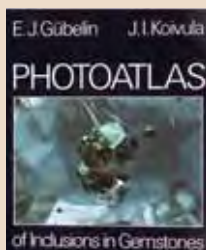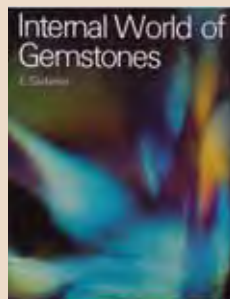
Photoatlas of Inclusions in Gemstones (with John I. Koivula, 1986): The *Photoatlas* is considered one of the most important gemological texts of the 20th century, and is the "crown" of Dr. Gübelin's 50 years of intensive research on gemstone inclusions. It contains some 1,400 color photomicrographs of inclusions in diamond, ruby, sapphire, emerald, quartz, and many other gems, as well as in the synthetic and treated gems introduced up to that time. First published in both German and English in 1986, a second revised English edition came out in 1992, followed by a third revised edition in 1997, and a fourth edition in 2004. A Chinese version was released in 1991.

Gemstones: Symbols of Beauty and Power (with Franz-Xaver Erni, 2000): This book, which followed a 1999 German edition, and preceded a 2001 Polish edition, is intended for a broad audience. It is lavishly illustrated with several hundred color photos, many by celebrated gem and mineral photographers Harold and Erica Van Pelt, with exceptional gem mining photos by Dr. Gübelin.
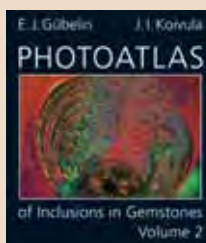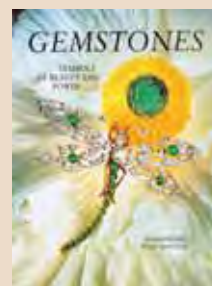
Photoatlas of Inclusions in Gemstones, Volumes 2 [2005] *and 3* [scheduled for late 2006] (with John I. Koivula): These two new volumes add to the already comprehensive work contained in the *Photoatlas of Gemstone Inclusions* (1986). They cover the many new localities for natural gems, the latest synthetics, and all the treatments that the authors encountered in the 20 years since the publication of the first *Photoatlas*. Thousands of original photomicrographs have been included, along with an expanded inclusion classification system and a chapter focusing on geologic correlations in origin determinations. A first draft for this work as a single volume was prepared shortly before Dr. Gübelin's passing. Due to its length, however, the manuscript was divided into two separate volumes.

Figure 12. The 1988 "World Map of Gem Deposits," with more than 750 localities and color-coded designations for the type of gem as well as its geologic environment, remains the most comprehensive map of its kind. On the back are 40 photos of gem localities with descriptions of the mines and mining operations, as well as 24 photos of gems from Dr. Gübelin's collection. Inset: One of the locality photos, taken by Dr. Gübelin, which shows the alluvial mining of gems in Southeast Asia.

more of a pictorial, while the *Photoatlas* is more of a study book," he recalled (Berenblatt, 1991, p. 30). "But I am most proud of the *Photoatlas*, which I co-authored with John Koivula. I would call it the crown of my work of investigation of inclusions in gemstones."

Dr. Gübelin also contributed entire chapters to other authors' books. A few examples include: *The Great Book of Jewels* (Heiniger and Heiniger, 1974); *Diamonds: Myth, Magic, and Reality* (Legrand, 1980); *Edelsteine und ihre Mineralieneinschlüsse* (Weibel, 1985); and *Emeralds of Pakistan* (Kazmi and Snee, 1989).

World Map of Gem Deposits. In 1988, Dr. Gübelin published a remarkable reference guide, the "World Map of Gem Deposits" (figure 12). The map, which took two years to produce, was designed to commemorate the 50th anniversary of the Swiss Gemmological Society in 1992. It shows more than

750 deposits worldwide, with color-coded designations for the type of gem as well as its geologic environment. The text was presented in English, French, German, Italian, Spanish, and Portuguese. The reverse side of the map contains 65 photos of gems and gem localities, with descriptions of the mines, mining operations, and the gems themselves.

This world map was one of Dr. Gübelin's proudest achievements. "It's the work that gave me the greatest pleasure to accomplish," he recalled (Berenblatt, 1991, p. 30). "It was just like traveling around the world, though I never left my desk in my living room. Traveling and visiting these deposits always gave me great pleasure."

It remains the most complete gem deposit map ever produced, and can be seen in jewelry stores and gemological laboratories around the world.

Articles. During his career, Dr. Gübelin published more than 250 scholarly articles (visit www.gia.edu/

gemsandgemology and click on "*G&G* Data Depository" for a complete list). He was a frequent contributor to a host of gemological journals from Australia, Austria, France, Germany, Great Britain, India, Switzerland, and the U.S.

Dr. Gübelin's longest affiliation, however, was with *Gems & Gemology*. From 1940 to 2003, he contributed 54 articles to the journal. Dr. Gübelin's first report, "Differences between Burma and Siam rubies," featured inclusion photomicrographs and engaging, descriptive text. This began a popular six-year series in *Gems & Gemology* on inclusions in gemstones, which in 1953 was compiled into the book *Inclusions as a Means of Gemstone Identification*. His last contribution to *Gems & Gemology*, which he co-authored with six other researchers, was "Poudretteite: A rare gem species from the Mogok Valley" (Smith et al., 2003). The article was published in the Spring 2003 edition, a special issue celebrating Dr. Gübelin's 90th birthday.

The Dr. Edward J. Gübelin Most Valuable Article Award. Dr. Gübelin also exerted a lasting influence on the gemological literature with his support of *Gems & Gemology*'s annual Most Valuable Article Award. The award was established in 1982 to recognize outstanding contributions, as voted by the journal's readers. (Dr. Gübelin himself received an award for his 1982 article "The gemstones of Pakistan: Emerald, ruby, and spinel.") In 1996, GIA officials approached the eminent gemologist about renaming the award in his honor. Dr. Gübelin accepted, and 1997 marked the first Dr. Edward J. Gübelin Most Valuable Article Award.

Dr. Gübelin's generosity went beyond just lending his name and prestige to the award. Each year, he insisted on writing a check that would cover the prize money. In 2003, he established a fund that would be used in perpetuity to provide a financial award for the winning authors and thus promote continuing excellence in gemological writing.

INTERNATIONAL EDUCATOR AND MENTOR

Dr. Gübelin's charm, elegance and intellect combined with an artist's eye, a poet's heart and a philosopher's approach to life has instilled in him a unique talent to convey complex topics in a manner which is readily understood and the ability to inject others with his infectious adoration of gemstones.

Gübelin Gem Lab, 2005

Over the years, Dr. Gübelin delivered hundreds of lectures on various aspects of gemstones for both scientific and popular audiences (figure 13). Some were at regularly occurring events, such as the annual meetings of the Swiss Gemmological Society and the biennial International Gemmological Conference. Other speaking venues included the American Gem Society Conclaves in North America, the CISGEM Gemmologia Europa in Milan, the Gemmological Association of Great Britain meetings, the 1981 International Gemological Symposium in Los Angeles (figure 14), and assemblies of gemological associations and trade shows worldwide. His "superabundance of enthusiasm" (Ruff, 1948, p. 125) was infectious for the many thousands who attended his lectures and courses over the decades.

Dr. Gübelin took pains to combine scientific reasoning with ethics to protect consumer confidence and promote the economic vitality of the gem and jewelry trade. He invariably stressed that "the consequence of applied gemology should culminate

Figure 13. In this photo from a 1967 Swiss Gemmological Society meeting, Dr. Gübelin uses a pair of models to demonstrate crystal structure. His diagrams on the blackboard illustrate refractive indices of various gem materials. Photo by Jürg H. Meyer.

Figure 14. In addition to speaking on inclusions at the 1981 International Gemological Symposium hosted by GIA in Los Angeles, Dr. Gübelin also participated in this panel with other prominent gemologists. From right to left: Richard T. Liddicoat, Edward J. Gübelin, Edward Tiffany, Bert Krashes, and G. Robert Crowningshield. Photo © GIA.

in ethical behavior for the benefit of the clientele" (Hays, 1989, p. 20).

As far as gemology was concerned, Dr. Gübelin had no competitors, only colleagues. His work with the Swiss Gemmological Society illustrates his dedication to training other gemologists. Each summer he would devote one or (in later years) two weeks to teaching gemology at the national meeting. Then he would travel to each of the regional chapters and lecture on a specific gem or other gem-related topic. He could conduct the courses equally well in English, French, German, or Italian.

His friend and colleague from the Swiss Gemmological Society, Daniel Gallopin, recently marveled that Dr. Gübelin could give an hour-long lecture (in perfect French) illustrated with 100 inclusion slides and accurately identify all the obscure mineral inclusions without any notes or script. "Dr. Gübelin exemplified the 'Universal Spirit,'" said Mr. Gallopin (pers. comm., 2005). "It was not enough that he knew and could state the scientific details accurately, but he could also say it and write it in the proper manner."

Even as he limited his appearances in later years, Dr. Gübelin still maintained an avid correspondence with fellow gemologists around the world. Colleagues, including many of the authors of this article, have retained those letters, which are unique in their professional wisdom, kindness, and encouragement. Just as the legendary Profs. Michel and Schlossmacher helped guide his own professional development as a gemological re-

searcher, Dr. Gübelin served as an inspiration and mentor to countless gemologists for more than six decades.

INTREPID EXPLORER

His academic pursuits made Edward J. Gübelin a scholar, but his travels to hundreds of gem localities and trading centers across the globe for nearly 50 years gave him rare practical experience (figure 15). Dr. Gübelin relished these extensive, often rugged expeditions to remote locales. Indeed, he was as comfortable at a gem mine in mud-splashed khakis as he was in a freshly pressed tuxedo at a symphony. He and his wife, Idda, also journeyed the world as tourists interested in art and culture, to places such as Afghanistan, Egypt, Greece, and South Africa. Sometimes they were accompanied by one of their five daughters, all of whom became world travelers themselves.

Dr. Gübelin was often one of the first gemologists to write a detailed study about a major gem locality. Many were classic sources, such as Mogok and the jadeite mines of Upper Burma (see, e.g., Gübelin, 1964–1965, 1965, 1966c, 1978); the ancient turquoise mines of Iran (see, e.g., Gübelin, 1966a,b); the gem-rich island of Ceylon (Gübelin, 1968); and Zabargad, the ancient peridot island in the Red Sea (Gübelin, 1981). Among the newer localities he documented were the emerald and alexandrite deposits at Lake Manyara in Tanzania (Gübelin, 1974b, 1976), and later the Merelani tanzanite mines in that same country (Gübelin and Weibel, 1976); the tsavorite mines in Kenya (Gübelin, 1975; Gübelin and Weibel, 1975); the emerald, ruby, spinel, and topaz areas of Pakistan (Gübelin, 1982; Gübelin et al., 1986); and the sapphires of Andranondambo, Madagascar (Gübelin, 1996; Gübelin and Peretti, 1997).

For nearly 50 years, he repeatedly visited the most important gem sources on five continents, examining the inclusions in gemstones and field-collecting or purchasing material for subsequent investigations back in his Lucerne laboratory. The knowledge he acquired from his many journeys to gem deposits in Asia, Africa, North and South America, and Australia appeared in his books, articles, lectures, and films.

Not only did Edward Gübelin have a passion for the photomicrography of gemstone inclusions, but he also mastered landscape, still life, and action photography, as well as motion picture
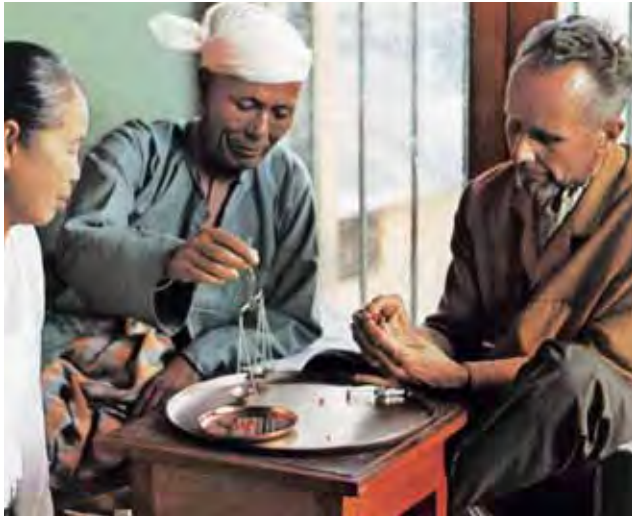
Figure 15. Over the course of more than 50 years, Dr. Gübelin's travels took him to hundreds of gem localities and trading centers across the globe. Upper left: Purchasing rubies in Mogok, Burma, 1963 (photo by Marie-Helen Gübelin Boehm). Upper right: Buying gems in Bangkok with C. Supanya, 1970 (photo by Daniela Gübelin Strub). Lower left: Sailing in 1980 to the oldest known source of peridot, the Red Sea island of Zabargad (photo by Peter Bancroft).

filming (see the "Filmmaker" section below). During these trips, he excelled at capturing on film the occurrence, mining, and recovery of gems at their source (figure 16). What comes through most vividly in Dr. Gübelin's travel photography, however, is his fondness for people and their unique cultures.

As a gem collector and, for more than 30 years, the co-owner and president of the Gübelin group of jewelry stores, Dr. Gübelin was also a major buyer of fine gemstones for nearly five decades—a unique situation for a research gemologist. One notable incident occurred during a single 24-hour visit to Rangoon, Burma, in 1964. Dr. Gübelin later recounted, "They showed me their goods . . . Burmese rubies and sapphires and spinels, and whatever the heart could ask for, and I just purchased like that. . . . I purchased for $2 million that day between 11:00 a.m. and 6:00 p.m." (Gübelin, 2001).

Figure 16. After washing of the illam (gem-bearing gravels), miners in Sri Lanka examine them for gem rough. Today, these time-honored recovery methods are still used by many gem miners in Sri Lanka and elsewhere. Photo by Edward J. Gübelin, from the early 1960s.

DEVELOPMENT OF PRACTICAL GEM-TESTING INSTRUMENTS

Edward J. Gübelin's accomplishments in instrument development, though typically overshadowed by his famed inclusion research and literary works, stand alone as monuments to his innovative genius. Much of Dr. Gübelin's early research was performed using instruments he invented or improved on during the 1940s and '50s. Gem-testing equipment was not readily available in those days, and Dr. Gübelin often recognized a need and filled it by developing a particular instrument. This impulse, he later recounted, grew out of his student days at GIA:

> I never had [seen] any of these instruments. I'd never seen a Diamondscope or other instruments [GIA] had developed. And that was a great experience for me. So these were my first activities when I returned to Switzerland, to improve instruments. (Gübelin, 2001)

Back in Lucerne, Dr. Gübelin was "full of enthusiasm," and soon gemological instruments began to emerge from his workshop. Many of the following instrument descriptions were from a January 20, 1983, letter to one of the authors (REK) from Dr. Gübelin, while others mentioned in the last paragraph of this section were cited in a curriculum vitae written by Dr. Gübelin in the early 1980s; copies of both documents are archived at GIA's Richard T. Liddicoat Library and Information Center.

The Horizontal Immersion Microscope. One of the existing instruments Dr. Gübelin modified and improved was the horizontal immersion microscope (figure 17A), which he later used to take many of the more than 250 photomicrographs that appeared in his 1953 classic *Inclusions as a Means of Gemstone Identification*. The main body of this instrument had been invented by his friend and colleague, Prof. Karl Schlossmacher. "With the help of a few changes and additional accessories," Dr. Gübelin later wrote in his 1983 letter to REK, "it became a very efficient photomicroscope."

The Koloriskop. The first instrument Dr. Gübelin designed and had built was the Koloriskop, a self-contained device that provided a controlled light source for color grading diamonds (figure 17B). His design was directly inspired by GIA's Diamolite (an early version of the modern DiamondLite). Dr. Gübelin had first used the Diamolite as a student at

the Institute, and Robert Shipley granted him permission to develop a similar instrument. The GIA unit used an incandescent bulb (producing "yellowish" light) that was covered by a blue filter to simulate natural daylight. To improve the accuracy of diamond color grading, Dr. Gübelin utilized a daylight-equivalent fluorescent tube and created a trough with slots in which ring-mounted diamonds could be inserted in the proper position for color grading. Like most of the instruments he designed, the Koloriskop incorporated elements of practicality and ease of use.

The Detectoscope. Dr. Gübelin also made improvements to the Detectoscope (figure 17C), an instrument first created by Prof. Michel and Gustav Riedl in the mid-1920s (Eppler and Eppler, 1934) to examine the absorption of light in a gemstone when placed over filters of different colors or a luminescence filter. A magnifying lens and a dichroscope could also be inserted into a special holder in the original Detectoscope (Michel, 1929). Dr. Gübelin added a Chelsea color filter, a daylight filter, and to further improve the instrument's use in combination with a dichroscope, a "milk glass" diffuser (Pough, 1949).

The Gemmoscope. This darkfield illuminator–equipped binocular microscope (figure 17D) was devised by Dr. Gübelin in 1942. He drew upon newly developed Zeiss optics and improved the darkfield illumination from a GIA Diamondscope. Not only was this microscope useful for the observation and photography of inclusions, but it was also compatible with Prof. Michel's pearl-testing device, enabling the visual examination of half- or fully drilled pearls to determine whether they were natural or cultured. The Gemmoscope even featured an ergonomically designed base for resting the hands and forearms during use. It is interesting to note that the logo at the top of Dr. Gübelin's personal stationery was a stylized depiction of the microscope objectives on the Gemmoscope positioned over a round brilliant–cut gemstone.

The Cut-Measuring Device. That same year, Dr. Gübelin created the Schliffmessgerät für Edelsteine (gemstone cut measuring) diamond gauge (figure 17E). This innovative handheld device was designed to measure the facet angles and proportions of faceted diamonds. A mere 6.5 cm (2½ in.) in diameter, with a thickness of only 5 mm (³⁄₁₆ in.),

Figure 17. Dr. Gübelin developed a number of diagnostic gem-testing instruments during the 1940s and '50s, including: (A) the horizontal immersion photomicroscope, (B) the Koloriskop, (C) the Detectoscope, (D) the Gemmoscope, (E) the cut measuring device, (F) the Jewelers' Spectroscope, and (G) an innovative device that allowed the user to magnify and then photograph a gem's spectrum. With the exception of photo E, which was taken by Harold & Erica Van Pelt, all the other photos were commissioned or taken by Dr. Gübelin shortly after the development of the instrument.

it could be used to measure crown angles and pavilion angles, as well as the girdle thickness, table diameter, crown height, pavilion height, and total height of a cut gem. The back of the gauge listed two separate sets of proportions—both the Tolkowsky and Eppler cut calculations—for handy reference. Along with his Swiss Army knife, Dr. Gübelin carried this instrument with him almost everywhere he went.

The Gemmolux. In 1945, Dr. Gübelin designed the Gemmolux (Gübelin, 1945), a small, portable light source for examining gemstones. This instrument had built-in darkfield illumination and could be fitted with a removable loupe or dichroscope. The Gemmolux was especially handy when the user was buying gems away from the office.

The Jewelers' Spectroscope. One of Dr. Gübelin's influential mentors and teachers was B. W. Anderson, the "father of gem spectroscopy," whom the young Edward Gübelin met on his return from the U.S. in 1939. Anderson inspired in Dr. Gübelin a great appreciation for the diagnostic value of spectra in gem identification. In 1950, Dr. Gübelin invented the world's first desk-model spectroscope unit (figure 17F) designed solely for use with rough and cut gemstones (Bruton, 1951; E.J. Gübelin, pers. comm., 1983). Prior to the introduction of this instrument, gemologists had to rely on handheld spectroscopes that were designed for use in other fields.

Dr. Gübelin's spectroscope unit featured a clip to hold the stone and a light built into the base of the instrument, which enabled the gemologist to position the gem and adjust the light intensity (with a rheostat knob on the side of the instrument) so as to bring out the clearest spectrum possible. The spectroscope tube could be raised to permit observation by reflected light. The design also allowed delicate opening and closing of the slit. In addition, the unit sat on a work surface and was inclined at such an angle that the gemologist could sit comfortably for long periods of time while examining spectra and still have both hands free to take notes or draw the spectrum being observed. Dr. Gübelin even added a forward-thinking ergonomic touch: special eyepiece lenses that could be used to lengthen the blue end of the spectrum and accommodate an observer who wore eyeglasses.

Dr. Gübelin debuted his Jewelers' Spectroscope unit during the 1951 Gemmological Exhibition in London. On the second day of the exhibition, Dr. Gübelin and Dr. G. F. Herbert Smith of the Gemmological Association of Great Britain personally gave Queen Mary a special tour through the event (Bruton, 1951).

Photographing Absorption Spectra. In addition to the Jewelers' Spectroscope, Dr. Gübelin designed another innovative device that allowed him to magnify and then photograph a gem's spectrum (figure 17G). Dr. Gübelin was keen on being able to photograph spectra, and since such instruments were not available, he developed his own.

Zeiss Spectrometer Optical Bench. Working with the German optical company Zeiss, Dr. Gübelin developed an ingenious optical bench spectrometer setup, whereby two spectra could be observed simultaneously, one above the other. This was accomplished by using a comparison prism. This instrument was particularly useful for checking the spectrum of an unknown gem against those of standard reference stones (Pough, 1949). Not only could the spectra be observed through an eyepiece lens apparatus, but at the same time a 35 mm camera mounted perpendicular to the eyepiece could take photographs of the spectra.

Other Instruments. Dr. Gübelin also developed a custom-made polariscope, suspension equipment for specific gravity determination using heavy liquids, an electrical conductivity meter to differentiate treated blue diamonds from natural-color type IIb blue diamonds, a fluoroscope for measuring fluorescence emission lines, and an apparatus for examining the absorption spectra of gemstones while they were exposed to long-wave ultraviolet radiation. In addition, he was particularly adept at getting the most out of commercially available instruments. One example was his own Erb & Gray refractometer, which he mounted on a specially designed stand that had a compact sodium light source, providing sharper refractive index readings (Pough, 1949).

Some of Dr. Gübelin's state-of-the-art instruments, including the Koloriskop and Jewelers' Spectroscope, became important tools for gemologists around the world. Yet the place where these devices made their greatest contribution was in Lucerne, both at his personal home laboratory and at the Gübelin Gem Lab.

ROLE IN DEVELOPING
THE GÜBELIN GEM LAB

In 1923, not long after young Edward J. Gübelin expressed his desire to become a jeweler, his father established a small but well-equipped gem-testing laboratory. This facility was staffed by Charles Salquin, whom the senior Gübelin also had sent to study with Prof. Michel. Having opened two years before the London Laboratory, it is credited with being one of the world's first privately owned gemological laboratories (Gübelin, 2001). The lab was added on to the firm's Lucerne headquarters (figure 18) to ensure consumer confidence in the authenticity of gems purchased from the Gübelin jewelry stores, at a time when the undisclosed sale of cultured pearls and synthetic rubies posed a major threat to the international jewelry industry.

In late 1939, after completing his studies at GIA, Dr. Gübelin assumed leadership of the laboratory. He immediately began acquiring more gem-testing instruments, and for many years it was considered the best-equipped gemological laboratory in the world (figure 19):

> The main laboratory . . . is probably without peer. Certainly, the GIA laboratories and the fine London Laboratory do not have the full variety of equipment that the Gübelin Laboratory boasts. Here Dr. Gübelin maintains X-ray diffraction and radiographic equipment; a quartz spectrograph; a variety of spectroscopes and spectroscope light sources, including a versatile light and spectroscope mount of his own design; a variety of ultraviolet light sources; separate balances for weighing and S.G. determinations; petrographic and binocular microscopes of recent vintage (and the only darkfield-illuminator-equipped binocular microscopes we saw in European laboratories); and many other instruments. Each of the three refractometers, including one of [only] three Rayner has made with a diamond hemisphere, is equipped with its individual monochromatic sodium light source. (Liddicoat, 1961, p. 138)

After taking over the laboratory, Dr. Gübelin began issuing written gemological reports for the customers of the Gübelin jewelry stores and gem dealers (Gübelin, 2001). These included diamond grading reports (figure 20), based on the system he had learned while studying at GIA, as well as locality-of-origin reports for colored stones.

By the early 1960s, demand for the Gübelin lab's locality-of-origin services was growing, and a number of auction houses, insurance companies, collec-

Figure 18. This photo provides a glimpse of the early Gübelin Gemological Laboratory, circa 1930s. Note the gemological property tables, which were handwritten by Dr. Gübelin when he was a 19-year-old student at the University of Zurich. Courtesy of the Edward J. Gübelin family.

tors, and museums were sending their gems to Lucerne for reports (*150 Years of Gübelin*, 2004). Today the Gübelin Gem Lab is a leader in ruby, sapphire, and emerald locality-of-origin determinations.

Figure 19. This represents only some of the gem-testing equipment at the Gübelin Gemological Laboratory from 1946 to 1952. For many decades, it was the regarded as the world's best-equipped gem-testing lab. Courtesy of the Edward J. Gübelin family.

Figure 20. By 1940, Dr. Gübelin's expertise enabled the family firm to issue diamond grading reports. This certificate, signed by him, is dated May 28, 1940.

While Dr. Gübelin's early inclusion investigations relied primarily on the microscope, he later championed the application of advanced technologies in his laboratory's inclusion analyses and locality-of-origin determinations. As early as the mid-1960s, he began having lapidaries grind down rough and faceted research samples to expose mineral inclusions in order to have them analyzed by university scientists with an electron microprobe or by X-ray diffraction, methods that allowed definitive identification. He also had microthermal analyses performed on fluid inclusions (Gübelin and Koivula, 1986). UV-visible spectroscopy has been used in the Gübelin lab for origin determinations (particularly of sapphires) since the 1960s (see, e.g., Hänni, 1990; Schwieger, 1990). As technology advanced, lab gemologists were able to use features in the ultraviolet region of the spectrum and later in the near- and mid-infrared regions. Origin-of-color determination in fancy-color diamonds using spectral analyses was also an interest and a specialty of Dr. Gübelin's.

After his official retirement in 1976 until his passing in 2005, Dr. Gübelin remained a forceful advocate of integrating advanced technologies into gemological research. These included energy-dispersive X-ray fluorescence (EDXRF) analysis, Raman spectroscopy, and even laser ablation–inductively coupled plasma–mass spectroscopy (LA-ICP-MS). Once a particular analysis had been conducted on an inclusion or the host gem, Dr. Gübelin would incorporate the data into his ongoing research.

Through his publications, lectures, and extensive correspondence, he broadcast the importance of these advanced analytical tools to the international gemological community.

LEADER OF THE GÜBELIN GROUP OF JEWELRY STORES

The Gübelin watch and jewelry company thrived during the 1920s and early '30s, opening stores in New York, St. Moritz, and Zurich, successively (*The House of Gübelin 1854–1954*, 1954). Under the senior Eduard Gübelin's leadership, the firm weathered the Great Depression and World War II. When the patriarch died suddenly in 1945, Dr. Gübelin and his younger brother Walter took over the family business. Walter was the watchmaker, while Dr. Gübelin was the driving force in the gem and jewelry realm. He led the company's gem purchasing activities, buying millions of dollars worth of fine stones from various sources (figure 21). He also combined his gem expertise and literary flair to pen Gübelin company promotional books and jewelry catalogs. During these years, the firm's reputation benefited from articles about Dr. Gübelin's gemological work and expertise that appeared in many popular magazines and newspapers (see, e.g., figure 22). In the words of the late Richard T. Liddicoat (1961, p. 138), "Dr. Gübelin's enthusiastic appreciation of the beauty of gemstones and fine jewelry craftsmanship, as well as his knowledge of both, permitted him to increase jewelry sales rapidly."

With the two brothers at the helm, the postwar years saw continued growth of the Gübelin company, which boasted nine retail stores by the time Dr. Gübelin retired from the business. Under the leadership of his nephew, Thomas Gübelin, the Gübelin group of watch and jewelry stores, the gem laboratory, and associated companies continue to flourish.

THE DR. EDWARD J. GÜBELIN GEM COLLECTION

Dr. Gübelin was a world-class collector of many objects, including books; antiques; paintings; Russian icons; stamps; Greek, Egyptian, Roman, Burmese, and Nepalese artifacts; and—not surprisingly—gemstones. His main gem collection, acquired over a period of more than 70 years from gem dealers and on-site at gem localities around the world, comprises approximately 2,700 gemstones, at a total weight of some 24,000 carats, representing

Figure 21. This circa 1963 Gübelin Atelier bracelet features exceptional natural-color Mogok rubies purchased in Burma by Dr. Gübelin in the early 1960s. Courtesy of JOEB Enterprises; photo © Harold & Erica Van Pelt.

more than 250 different gem varieties and mineral species (Boehm and Morelli, 2005).

When viewing any of the four main collections (see, e.g., figure 23), one is immediately impressed with the fact that there are as many as seven examples of each gemstone type. The vast majority of these gems are faceted. He arranged the main collection into four separate categories:

Figure 22. This 1956 photo of Dr. Gübelin sorting gemstones prior to setting into jewelry at the Gübelin company appeared in the weekly Swiss newspaper insert, Wochenblätter *(Zurich).*

1. *The Geographic Collection.* This is the largest of the four major collections, with more than 1,000 gemstones from Brazil, India, Kenya, Madagascar, Mexico, Mozambique, Myanmar (figure 24), Namibia, Nepal, Sri Lanka, Switzerland, Tanzania, Thailand, the United States, and Zimbabwe. The total weight is more than 10,000 carats.

2. *The Species Collection.* This includes varieties of beryl, corundum, feldspar, fluorite, garnet, opal, quartz, sapphirine, spinel, topaz, tourmaline, and zircon. The total weight of the more

Figure 23. Dr. Gübelin arranged his main gemstone collection into four categories (geographic, species, rare, and collector gems), comprising approximately 2,700 stones, at a total weight of some 24,000 carats. Shown here are a few of the more than 70 boxes in the main collection. Photo by Robert E. Kane.

Figure 24. Included in this 1993 photo are some of the many fine Burmese gemstones in Dr. Gübelin's collection. By vertical columns, from top to bottom: Column 1 (far left)—16.55 ct danburite, 14.18 ct kornerupine, 5.13 ct tourmaline, 6.23 ct citrine, and 3.15 ct amblygonite. Column 2—8.08 ct scapolite, 15.39 ct tourmaline, 8.98 ct aquamarine, 10.13 ct zircon, and 4.62 ct apatite. Column 3—25.30 ct danburite, 10.77 ct chrysoberyl, 11.31 ct apatite, 8.38 ct topaz, 4.84 ct zircon, and 1.69 ct chrysoberyl. Column 4 (far right)—11.79 ct sillimanite, 6.78 ct amethyst, 5.51 ct fluorite, 9.09 ct zircon, and 4.02 ct taaffeite. Note that the 15.39 ct tourmaline, 10.77 ct chrysoberyl, 5.13 ct tourmaline, and 1.69 ct chrysoberyl are part of the permanent collection at the British Museum (Natural History) London, and were part of a study Dr. Gübelin and one of the authors undertook (Kane, 1993). Photo by Shane F. McClure, © Robert E. Kane.

than 750 gems in this collection is approximately 7,800 carats.

3. *The Rare Gemstone Collection.* This consists of just under 500 gems, representing more than 38 different mineral species, from apatite to zoisite. The total weight is approximately 3,500 carats.

4. *The Collector Items Collection.* Many of the gem species in the Rare Gemstone Collection are also represented in this fourth collection, with more than 95 additional species; samples range from anglesite to zincite. It contains just over 300 gems for a total weight of over 2,000 carats.

Among the highlights of the Edward J. Gübelin Gem Collection are:

- 420 pieces from Sri Lanka, including a 6.22 ct ruby, an 18.86 ct sillimanite, and a 13.23 ct violet taaffeite

- 290 pieces from Brazil, including a 16.88 ct deep-red tourmaline and six different colors of Paraíba tourmaline

- 215 pieces from Myanmar (Burma), including a 3.16 ct Mogok ruby, a 9.98 ct red spinel, and a 4.02 ct violet taaffeite (see figure 24, bottom right)

- The largest gemstone in the collection, a 100.99 ct morganite from Minas Novas, Brazil

In addition to the main collections, there are several important specialty collections, comprising several thousand gems, which are organized under the headings of Ornamental, Synthetics, Treated Stones, Imitations, Opals, Organics, Testing, and Inclusion Research. These study and display collections contain virtually all materials ever cut for use as gemstones in the above categories. They contain at least one sample of each type of gem, and nearly all treated gems, synthetics, and imitations (in many cases, there are several to dozens of each).

Aside from the sheer beauty and rarity of the gems, this is one of the most important gemological research collections ever assembled. Much of its research value stems from its completeness and the known provenances, but it is also remarkable for the thoroughness of the documentation. Many gemstones in the various collections were used for research reported in Dr. Gübelin's various publications, as well as in his teaching seminars over the last six decades. In addition, among his records are much unpublished data collected from many of these gems. The fact that he personally obtained

many of these specimens at their sources—in large part before modern treatment techniques existed—greatly enhances our understanding of gems from the various localities.

The main gem collection and significant portions of the specialty collections are now part of the GIA Museum, where they will be used for public display, research, education, and as a source of inspiration for future generations of gemologists and other scientists. As part of the overall purchase, GIA also acquired Dr. Gübelin's vast collection of color slides and literature reference files, as well as a number of important early gemological instruments.

ESTABLISHMENT OF TRADE AND GEMOLOGICAL ORGANIZATIONS

An active member of virtually every gemological association in the world, Dr. Gübelin also founded or co-founded several professional and trade organizations, with the vision of fostering professional education in gemology, as well as the ethical promotion and sale of gemstones. He contributed his vast energy and intellect to these associations, which continue to thrive.

Swiss Gemmological Society. This organization, of which Edward Gübelin was a co-founder, emerged over a controversy. When the Gübelin company began issuing grading reports on diamonds in 1940,

a practice then unheard of in Switzerland, many of the firm's Swiss competitors bitterly objected and began planning legal action. Learning of this, the senior Gübelin persuaded the jewelers to join him instead. He convinced them that forming an association and studying diamond grading and gem testing, in seminars taught by his eldest son, would actually benefit their businesses (Gübelin, 2001). The new organization, established in 1942 and modeled after the American Gem Society, was named the Swiss Gemmological Society.

The one condition Eduard M. Gübelin imposed was that his son could never be president of the organization, only an adviser. And so for the first 40 years, until 1982, Dr. Gübelin served as scientific counselor to the Swiss Gemmological Society. Beginning in the early 1940s, the new Society held annual five-day educational meetings, during which Dr. Gübelin gave lectures and taught hands-on practical diamond grading and gem testing (figure 25), generously sharing gemstones from his extraordinary collection and presenting his latest inclusion research (Pough, 1949). He would dazzle the audience with his colorful and didactic inclusion slides. As the decades passed, and gemology became increasingly complex, the annual teaching sessions were expanded to two weeks. Even after retiring from the post of scientific counselor in 1982, until October 2004, he continued to give lectures and courses at the Society's annual meetings.

Figure 25. Dr. Gübelin served as scientific counselor to the Swiss Gemmological Society from 1942 to 1982. In this 1940s photo, he is seen standing at the back of the classroom giving personal instruction to one of the attendees of the organization's annual five-day educational meetings, which were held in various Swiss cities.

International Gemmological Conference. Dr. Gübelin also helped found the International Gemmological Conference (IGC), one of the longest running academic gatherings in the field today. The conference was an outgrowth of the early Bureau International pour la Bijouterie, Orfèvrerie, Argenterie (BIBOA), which eventually became the present-day CIBJO, the World Jewellery Confederation. At a 1951 nomenclature meeting, Dr. Gübelin and fellow BIBOA members such as Prof. Schlossmacher and B. W. Anderson agreed to gather regularly to share their latest gemological research, thereby establishing the framework of the IGC (figure 26).

The first International Gemmological Conference took place in October 1952 in Locarno, Switzerland. At this inaugural assembly, Dr. Gübelin was joined by seven other leading European researchers. Initially an annual event, the IGC became biennial after 1958, held in a different country alternating between Europe and the rest of the world.

Dr. Gübelin regularly attended the IGC conferences for nearly 50 years. He remained a member of the executive committee through the 29th IGC, held in September 2004 in Wuhan, China, which was attended by delegates invited from 33 countries on six continents.

Figure 26. Dr. Gübelin and B. W. Anderson, seen in a lighthearted exchange at the 1951 BIBOA Congress in London, were two of the founders of the International Gemmological Conference the following year.

International Colored Gemstone Association. Dr. Gübelin was also a founding organizer of the non-profit International Colored Gemstone Association (ICA), established in 1984. Headquartered in New York City with bureaus in Idar-Oberstein and Israel, ICA is a trade association that has more than 500 members in 45 countries worldwide.

Dr. Eduard Gübelin Association for Research and Identification of Precious Stones. In 2003, Dr. Gübelin co-founded, with other members of the Swiss gem trade and scientific community, what is now known as the Dr. Eduard Gübelin Association for Research and Identification of Precious Stones. This nonprofit organization, based in Lucerne, was established to initiate, promote, and support gemological research projects.

FILMMAKER

An accomplished filmmaker (figure 27), Dr. Gübelin narrated and produced a number of high-quality 16 mm films, which were shown to lecture groups around the world and in public theaters in Lucerne and elsewhere. One of them, "Mogok, Valley of Rubies," (1963) appeared in German, French, and English and was sold internationally as a videotape.

His other films include:

- "Ceylon, Fairyland of Gemstones" (German, English, and French versions)
- "Ceylon, Island of the Lion Folk" (German)
- "Jade: Prehistoric Tool Material, Present-Day Gem Material" (German and French versions)
- "Sri Lanka: Pearl of the Tropics, Island of Gems" (German and French versions)
- "Ruby Mining in Burma" (German and French versions)

In addition to the films he produced, Dr. Gübelin shot hundreds of hours of raw footage during worldwide travels to gem deposits. Occasionally, he would film other aspects of a country that interested him. One entire reel of film captures a traditional Burmese folk dance accompanied by native music. Part of this footage is featured in "Mogok, Valley of Rubies."

HONORS AND AWARDS

In recognition of his achievements, Dr. Gübelin received many awards, honorary memberships, and commendations. Among the most prestigious are:

- Honorary memberships in the gemological associations of many different countries, including Australia, Germany, Great Britain, Japan, Poland, South Africa, Sweden, his native Switzerland, and the United States
- First Research Member of GIA (1943)
- Research Diploma of the Gemmological Association of Great Britain (1957)
- Honorary Professor at the University of Stellenbosch in South Africa (1973)
- Jewelers of America International Award for Jewelry Leadership (1980; figure 28)
- First honorary member of the American Gem Trade Association (1982)
- ICA Lifetime Achievement Award (1991)
- The Medal of the City of Paris (1993)
- The American Gem Society Robert M. Shipley Award (1994)
- GIA League of Honor (2003)

ENDURING LEGACY

Long after he had revolutionized gemology, Edward J. Gübelin was voted one of *JCK* magazine's "Gemstone People of the Century" (Roskin, 1999). Yet even into the 21st century, until his passing on March 15, 2005, one day shy of his 92nd birthday, Dr. Gübelin remained closely involved in the science he had helped pioneer (figure 29). He still exuded palpable enthusiasm when discussing his gem collection, a recent trip, a fine gemstone, or a new discovery. Dr. Gübelin's abiding passion for gemology was captured in these words, which hung on the wall in his home laboratory for many years:

> *The job of a laboratory trade gemologist is an interesting occupation—we seldom see the same thing twice and feel constantly the challenge or possibility of something new, unusual or demanding.*

Dr. Gübelin will be remembered not only for his monumental contributions to gemology over more than seven decades, but also for his extraordinary humanity. Despite the often solitary nature of his research, he touched the lives of thousands around the world. Whether you were his colleague, his friend, his student, or simply one of the thousands of people around the globe who once met him, you would undoubtedly remember his courteous way, his warmth and quick wit, and how he

Figure 27. Dr. Gübelin, shown filming in Mogok in 1963, shot hundreds of hours of footage from his travels and produced several gem-related films. This photo was taken by his daughter Marie-Helen Gübelin Boehm, with whom he published the 1967 book Burma, Land der Pagoden.

Figure 28. Among his many honors, Dr. Gübelin received the Jewelers of America International Award for Jewelry Leadership in 1980. (Harry Winston also received this award, posthumously, that same year.) Presenting the award is former JA president Michael Roman.

Figure 29. Dr. Edward J. Gübelin had an enthusiasm that never diminished, as evident in this 1997 photo of him riding along the Ngorongoro Crater, Tanzania, at the age of 84. This gem and animal safari trip was organized by the Gemmological Association of Great Britain. Photo by Eric Van Valkenburg.

treated even the youngest colleague with respect. Gem dealer David Atkinson said it well: "He was a 19th century gentleman, with 20th century mobility."

Dr. Gübelin and his wife of 51 years, Idda, had five daughters and many grandchildren and great-grandchildren. He instilled in them an appreciation of nature, including gems and minerals. In fact, two of his grandchildren have followed in his footsteps, one as a goldsmith and the other as a gemologist.

Edward J. Gübelin has left behind an indelible legacy through his writings and photomicrographs, his laboratory, his gem collection, the instruments he developed, the organizations he helped establish, and the future generations of gemologists he will inspire.

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CHARACTERIZATION OF THE NEW MALOSSI HYDROTHERMAL SYNTHETIC EMERALD

Ilaria Adamo, Alessandro Pavese, Loredana Prosperi, Valeria Diella, Marco Merlini,
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A new production of hydrothermal synthetic emeralds, grown in the Czech Republic with Italian technology, has been marketed since December 2004 with the trade name Malossi synthetic emerald. Several samples were investigated by standard gemological methods, combined with chemical analyses and UV-Vis-NIR and IR spectroscopy. A comparison of this material with natural and other synthetic emeralds (the latter grown by the flux and hydrothermal techniques) reveals that Malossi hydrothermal synthetic emerald can be identified on the basis of microscopic features and chemical composition, along with the mid-infrared spectrum.

Because of emerald's commercial value, a remarkable number of synthetic emeralds, grown by flux and hydrothermal processes, have entered the market over the past five decades. The hydrothermal synthetic emeralds are particularly notable in terms of the quantity produced and their availability (see, e.g., Kane and Liddicoat, 1985; Koivula et al., 1996; Schmetzer et al., 1997; Koivula et al., 2000; Chen et al., 2001; Mashkovtsev and Smirnov, 2004).

The present study focuses on a new hydrothermally grown synthetic emerald manufactured since 2003 in Prague, Czech Republic. This new gem material, called Malossi synthetic emerald (figure 1), has been marketed since December 2004 in Italy by Arsaurea Gems (Milan) and in the U.S. by Malossi Inc., the U.S. subsidiary of Malossi Created Gems (Raleigh, North Carolina). Currently, about 5,000–6,000 carats of the faceted synthetic emeralds are produced per year, and this rate is expected to increase (A. Malossi, pers. comm., 2005). The crystals produced so far range from 25 to 150 ct, with a mean weight of about 77 ct, and the largest faceted stone obtained weighs about 15 ct (A. Malossi, pers. comm., 2005). In this article, we report those fea-

tures of Malossi synthetic emeralds that can be used to distinguish this material from natural and other synthetic (hydrothermal and flux) emeralds.

GROWTH TECHNIQUE

Malossi synthetic emeralds are grown at about 450°C in a small rotating autoclave that is lined with gold and carefully sealed. A seed of natural yellow beryl, suspended by a platinum wire, is used to help initiate growth. Concentrated hydrochloric acid is usually used to prevent Cr (the only chromophore used) from precipitating. Large crystals of the synthetic emerald can be grown in 40–60 days (A. Malossi, pers. comm., 2005).

MATERIALS AND METHODS

For this study, we examined 30 emerald-cut gems and 5 rough samples of the new synthetic emerald,

Figure 1. Malossi synthetic emeralds are grown by a hydrothermal technique in the Czech Republic, using Italian technology. These crystals (28.40–141.65 ct and 7.1–69.9 mm) and emerald cuts (1.34–7.89 ct) are some of the samples examined for this study. Photo by Alberto Malossi.

which were provided by A. Malossi (see, e.g., figure 1). The faceted samples weighed 1.34–7.89 ct, and the rough specimens ranged from 28.40 to 141.65 ct (30.0–69.9 × 10.8–22.5 × 7.1–14.8 mm). Representative faceted samples of hydrothermal synthetic emeralds from other commercial sources (all from the collection of the Italian Gemological Institute) were studied for comparison: Russian (5), Biron (5), and Linde-Regency (1). In addition, literature comparisons were made to other synthetic emeralds produced by the hydrothermal technique (Chinese, Lechleitner), as well as to flux synthetics and natural emeralds.

All the faceted samples were examined by standard gemological methods to determine their optical properties (refractive indices, birefringence, and pleochroism), specific gravity, UV fluorescence, and microscopic features.

Preliminary qualitative and semiquantitative chemical analyses of 11 faceted synthetic specimens (8 Malossi, 1 Russian, 1 Biron, and 1 Linde-Regency) were obtained by a Cambridge Stereoscan 360 scanning electron microscope, equipped with an Oxford Isis 300 energy-dispersive X-ray spectrometer, for the following elements: Si, Al, V, Cr, Fe, Ni, Cu, Na, Mg, and Cl. Quantitative chemical data (for the same elements) were obtained from these same 11 samples using an Applied Research Laboratories electron microprobe fitted with five wavelength-dispersive spectrometers and a Tracor Northern energy-dispersive spectrometer.

Room-temperature nonpolarized spectroscopy in the visible (460–750 nm), near-infrared (13000–4000 cm^{-1}), and mid-infrared (4000–400 cm^{-1}) regions was carried out on all Malossi, Russian, Biron, and Linde-Regency samples. We used a Nicolet NEXUS FTIR-Vis spectrometer, equipped with a diffuse reflectance accessory (DRIFT), which had a resolution of 4 and 8 cm^{-1} in the infrared and visible ranges, respectively.

Mid-infrared spectroscopy (4000–400 cm^{-1}) was also carried out in transmission mode using KBr compressed pellets with a 1:100 ratio of sample:KBr. Since this is a destructive technique, we restricted these IR measurements to portions of two rough specimens only.

Additional UV-Vis-NIR reflectance spectra were recorded by an Avantes BV (Eerbeek, the Netherlands) apparatus equipped with halogen and deuterium lamps and a CCD spectrometer with four gratings (200–400 nm, 400–700 nm, 700–900 nm, and 900–1100 nm), a 10 μm slit, and a spectral resolution of 0.5 nm. A polytetrafluoroethylene disk (reflectance about 98% in the 400–1500 nm range) was used as a reference sample.

X-ray powder diffraction was also used to investigate an incrustation on the surface of one Malossi synthetic emerald crystal. Measurements were performed at room temperature, by means of a Bragg-Brentano parafocusing X-ray powder diffractometer Philips X'Pert, in the θ–θ mode, with CuKα radiation (λ = 1.5418 Å), over the range of 5° to 75° 2θ.

RESULTS AND DISCUSSION

Gemological Testing. The standard gemological properties obtained on the 30 faceted Malossi samples are summarized in table 1. All the samples were transparent, with a bluish green color. They exhibited strong dichroism in yellowish green and bluish green.

Their R.I. and S.G. values: (1) overlapped those of their natural counterparts, especially low-alkali emeralds from various geographic localities (such as Colombia and Brazil; Schrader, 1983); (2) were similar to those we measured in Biron and Linde-Regency synthetics, and to those reported for Lechleitner and Chinese synthetic emeralds (Flanigen et al., 1967; Kane and Liddicoat, 1985; Schmetzer, 1990; Webster, 1994; Schmetzer et al., 1997; Sechos, 1997; Chen at al., 2001); but (3) were lower than those of our Russian synthetic samples (in agreement with Schmetzer, 1988; Webster, 1994; Koivula et al., 1996; Sechos, 1997). Most flux-grown synthetic emeralds from various manufacturers have R.I., birefringence, and S.G. values that are lower than those observed in the Malossi samples (for comparison, see Flanigen et al., 1967; Schrader, 1983; Kennedy, 1986; Graziani et al., 1987). The pleochroism and Chelsea filter reaction of the Malossi samples were not diagnostic of synthetic origin.

The various synthetics showed significant differences in their fluorescence to UV radiation: Malossi synthetic emeralds belonged to a group exhibiting red UV fluorescence that includes Linde-Regency and Chinese products, whereas Russian and Biron synthetic emeralds are inert to long- and short-wave
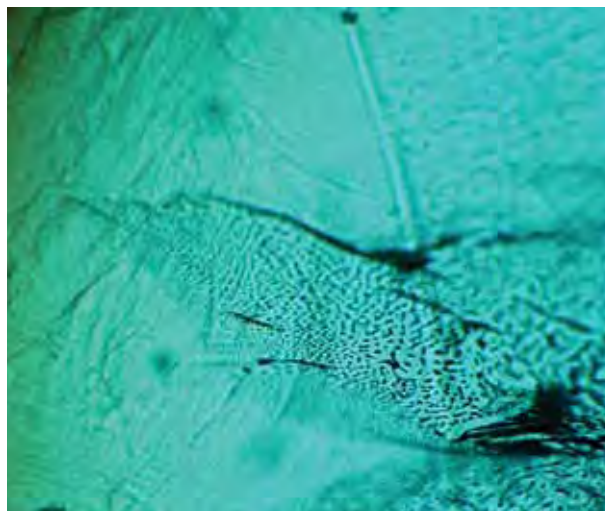

Figure 2. Straight, parallel growth bands, which also may be present in natural emeralds, are seen in this faceted Malossi synthetic emerald. Photomicrograph by Renata Marcon; magnified 30×.

UV radiation. The fluorescence of Malossi synthetic emeralds might hint at a synthetic origin, although a few high-Cr and low-Fe Colombian emeralds also have red UV fluorescence (Graziani et al., 1987).

The Malossi synthetic emeralds showed a variety of internal features when viewed with a gemological microscope. Growth patterns of various forms (straight, parallel, uniform, angular, and intersecting), often associated with color zoning, were widespread in some of the crystals and cut stones (e.g., figure 2). Irregular growth structures (figure 3), similar to those observed in other hydrothermal synthetic emeralds, were seen in almost all the samples, providing evidence of hydrothermal synthesis. Six of the faceted Malossi synthetic emeralds contained seed plates (fig-

Figure 3. Irregular growth structures are also seen in Malossi synthetic emeralds. Such features provide evidence of a hydrothermal synthetic origin. Note also the natural-appearing "fingerprints" in this sample. Photomicrograph by Renata Marcon; magnified 35×.

TABLE 1. Gemological properties of Malossi hydrothermal synthetic emeralds.

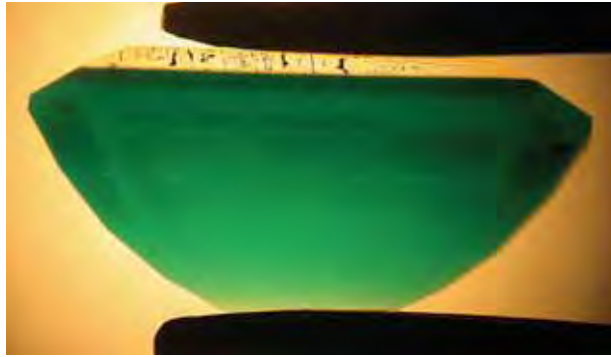|	
Color	Bluish green
Diaphaneity	Transparent
Optic character	Uniaxial negative
Refractive indices	n_o = 1.573–1.578 n_e = 1.568–1.570
Birefringence	0.005–0.008
Specific gravity	2.67–2.69
Pleochroism	Strong dichroism: o-ray = yellowish green e-ray = bluish green
Chelsea filter reaction	Strong red
UV fluorescence	Short-wave: moderate red Long-wave: weak red
Internal features	Crystals (probably synthetic phenakite), "fingerprints," two-phase inclusions, growth tubes, fractures, various forms of growth structures, color zoning, seed plates, irregular growth zoning

Figure 4. A seed plate (with obvious fluid inclusions) forms the table of this faceted Malossi synthetic emerald (3.92 ct). Photomicrograph by Renata Marcon.

ure 4; this seed plate had n_e = 1.568, n_o = 1.573, and a birefringence of 0.005). In some cases, irregular growth zoning was seen in the synthetic overgrowth adjacent to the seed plates. The presence of a seed plate is proof of synthetic origin.

"Fingerprints" and two-phase (liquid and gas) inclusions were observed in most of the Malossi samples (again, see figure 3 and figure 5). In some cases, these inclusions were similar to those observed in natural emeralds, in contrast to flux-grown synthetics, in which any fingerprint-like inclusions consist of fractures that are healed by flux filling. Fractures were also common in the Malossi synthetic emeralds, but they do not provide any evidence of synthetic origin. Two Malossi samples contained small cone-shaped growth tubes, filled with a fluid, similar to those that were recently documented in a natural emerald (Choudhary, 2005). Prismatic, transparent,

and colorless crystals—alone or in aggregates—were observed in four Malossi samples (figure 6). On the basis of their morphology, birefringence, and refractive index (higher than that of emerald), such crystalline inclusions are probably phenakite (Be_2SiO_4), which is somewhat common in hydrothermal synthetic emeralds (Flanigen et al., 1967) and also may provide evidence that the host emerald is synthetic (Kane and Liddicoat, 1985).

X-ray powder diffraction of an incrustation on the surface of one Malossi synthetic emerald crystal revealed the presence of phenakite and beryl, hinting at the occurrence of an incongruent precipitation of beryl (Nassau, 1980; Sinkankas, 1981). We did not observe the lamellar metallic inclusions that are sometimes present in other synthetic emeralds (e.g., gold, which is frequently found in Biron samples; Kane and Liddicoat, 1985).

Chemical Composition. Quantitative chemical analyses of eight Malossi synthetic emeralds (samples A to H) and three other hydrothermal synthetic emeralds (one each from Russian, Biron, and Linde-Regency production) are summarized in table 2.

Chromium was the only chromophore found in the Malossi samples. The following elements were below the detection limits of the electron microprobe: Na, Mg, V, Fe (in all but one sample), Ni, and Cu. Cl, probably from the growth solution (Nassau, 1980; Stockton, 1984; Kane and Liddicoat, 1985; see also Growth Technique section), was inhomogeneously distributed within the samples and between

Figure 5. This faceted Malossi synthetic emerald contains conspicuous "fingerprints" (left) that are composed of tiny two-phase (liquid/gas) inclusions (right). Photomicrographs by Renata Marcon; magnified 8× (left) and 60× (right, in darkfield illumination).
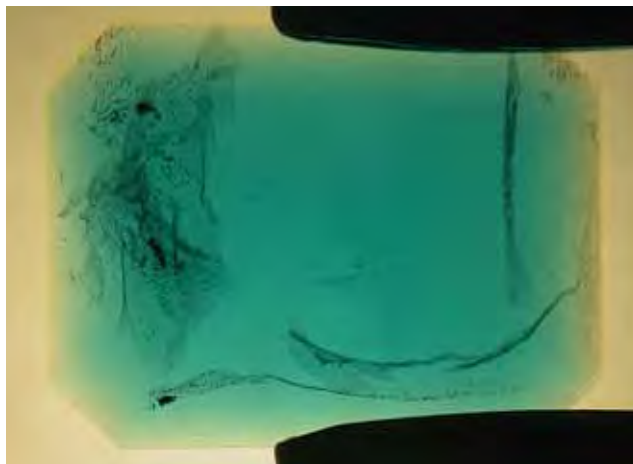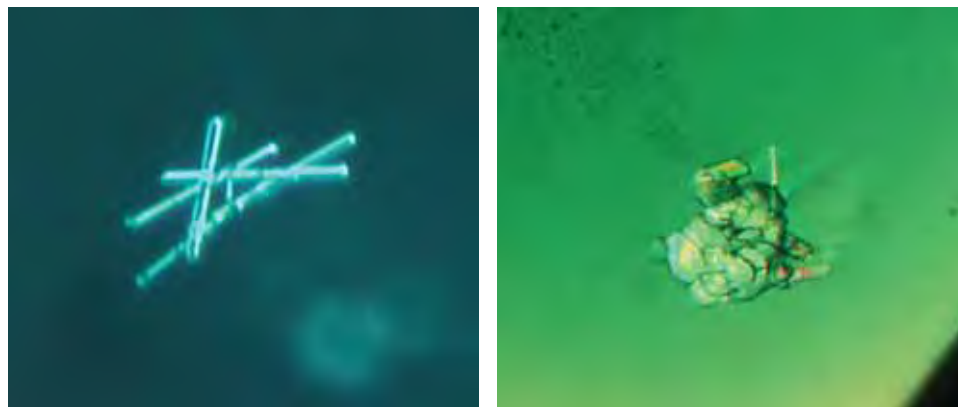
Figure 6. These images show examples of inclusion aggregates formed by transparent colorless prismatic crystals in Malossi synthetic emeralds. Their optical characteristics and occurrence in hydrothermal synthetic emerald suggest they are phenakite. Photomicrographs by Renata Marcon, in darkfield illumination (left, magnified 100×) and with crossed polarizers (right, magnified 50×).

different specimens, as shown in figure 7. The Cl content ranged up to 0.93 wt.%, with a mean value of 0.10 wt.%.

Figure 8 and table 2 compare the chemical properties of Malossi synthetic emeralds to those of representative samples from other hydrothermal producers. The chemical composition of Malossi synthetic emeralds is distinctively different from Russian and Biron synthetics. In agreement with the results of Schmetzer (1988), Mashkovtsev and Solntsev (2002), and Mashkovtsev and Smirnov (2004), our Russian synthetic sample contained Cr, Fe, Ni, and Cu, but neither Cl nor V was detected. Although not tested for this study, Lechleitner synthetic emeralds report-

TABLE 2. Averaged electron-microprobe analyses of Malossi and other hydrothermal synthetic emeralds.[a]

Chemical composition	Malossi samples								Russian	Biron	Linde-Regency
	A	B	C	D	E	F	G	H			
No. analyses	8	6	13	4	9	5	6	5	9	5	7
Oxides (wt.%)											
SiO_2	66.21	66.00	66.01	65.81	65.34	65.72	64.50	66.02	64.33	64.09	65.83
Al_2O_3	18.96	19.01	19.69	19.42	18.81	18.14	18.28	19.35	16.77	18.56	19.05
V_2O_3	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.75	bdl
Cr_2O_3	0.36	0.43	0.51	0.60	0.82	1.96	1.01	0.66	0.34	0.75	0.78
Fe_2O_3[b]	bdl	0.06	bdl	bdl	bdl	bdl	bdl	bdl	3.31	bdl	bdl
NiO	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.24	bdl	bdl
CuO	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.18	bdl	bdl
Cl	0.21[c]	0.09[c]	0.14[c]	0.03[c]	0.05	0.06	0.06	0.09	bdl	0.31	0.18
BeO[d]	13.79	13.74	13.74	13.70	13.60	13.68	13.43	13.74	13.39	13.35	13.70
Total	99.53	99.33	100.09	99.56	98.62	99.56	97.28	99.86	98.56	97.81	99.54
Cl range	0.07–0.93	0.04–0.14	0.03–0.87	bdl–0.06	0.03–0.11	0.02–0.11	bdl–0.14	bdl–0.25	bdl–0.05	0.28–0.36	0.12–0.34
Cr_2O_3 range	0.18–1.17	0.36–0.51	0.42–0.59	0.58–0.63	0.76–0.87	1.37–3.53	0.96–1.07	0.63–0.71	0.25–0.40	0.74–0.79	0.49–0.94
Ions per 6 Si atoms											
Si	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000	6.000
Al	2.025	2.037	2.109	2.087	2.036	1.952	2.004	2.072	1.843	2.048	2.046
V	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.083	bdl
Cr	0.026	0.031	0.037	0.043	0.060	0.141	0.074	0.047	0.025	0.056	0.056
Fe	bdl	0.004	bdl	bdl	bdl	bdl	bdl	bdl	0.232	bdl	bdl
Ni	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.018	bdl	bdl
Cu	bdl	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.013	bdl	bdl
Cl	0.032	0.014	0.022	0.005	0.008	0.009	0.009	0.014	bdl	0.049	0.028

[a] *Instrument operating conditions: accelerating voltage = 15 kV, sample current = 15 nA, count time = 20 seconds on peaks and 5 seconds on background, beam spot size = 15 μm. Standards: natural omphacite (for Si, Fe, Al, Na, Mg) and sodalite (for Cl); pure V, Cr, Ni, and Cu were used for those elements. Abbreviation: bdl = below detection limit (in wt.%): 0.05 V_2O_3, 0.04 Fe_2O_3, 0.11 NiO, 0.10 CuO, 0.02 Cl. Sodium and magnesium were below the detection limits in all analyses (0.01 wt.% Na_2O and 0.03 wt.% MgO).*
[b] *Total iron is calculated as Fe_2O_3.*
[c] *Average Cl content was calculated for 6, 4, 12, and 3 points, respectively, for samples A, B, C, and D.*
[d] *Calculated assuming Be/Si=0.5.*

edly have a similar composition (Hänni, 1982; Schmetzer, 1990). In our Biron sample, V and Cr (acting as chromophores) were found along with Cl, which is consistent with previously published results (Stockton, 1984; Kane and Liddicoat, 1985; Mashkovtsev and Solntsev, 2002; and Mashkovtsev and Smirnov, 2004). The Linde-Regency synthetic emerald was characterized by the presence of Cr and Cl (see also Hänni, 1982; Stockton, 1984), similar to the Malossi material. However, the Cl content in the Malossi samples was generally less than 0.12 wt.%, as shown in figure 7, whereas the Cl in our Linde-Regency sample was never below 0.12 wt.%, in keeping with the results of Hänni (1982), who found a Cl content of 0.3–0.4 wt.% in Linde synthetic emeralds. Cr and Cl also were recorded in the two different generations of Chinese hydrothermal synthetic emeralds examined by Schmetzer et al. (1997) and Chen et al. (2001). Schmetzer et al. (1997) indicated an average Cl content of ≈0.68 wt.%, in an earlier Chinese synthetic production, whereas Chen et al. (2001) reported Cl ≈0.15 wt.%, in the later generation, in addition to a significant Na_2O content (>1 wt.%). The earlier Chinese production contains more Cl than the

Figure 8. The average contents of Cl, Cr, V, Fe, Ni, and Cu are shown here for Malossi synthetic emeralds compared to representative samples of Russian, Biron, and Linde-Regency hydrothermal synthetics examined as part of this study. The Malossi and Linde-Regency samples have similar chemical features, which are distinctively different from the Russian and Biron synthetics.

Malossi material; the later Chinese synthetic emerald is distinguishable from Malossi synthetics by the presence of Na.

As previously reported by Hänni (1982), Schrader (1983), and Stockton (1984), chemical composition can be of great importance in separating synthetic and natural emeralds. In the case of Malossi synthetic emerald, the presence of chlorine—which typically is not found in significant amounts in natural emerald—can be an important indicator. Yu et al. (2000) reported Cl in some natural emeralds, typically at low concentrations, although some Colombian and Zambian samples contained up to 0.19 wt.% Cl. Thus, a Cl content above 0.2 wt.% provides a strong indication of hydrothermal synthetic origin. The Fe-free Malossi synthetic emeralds (except sample B, with a trace of Fe) were similar in composition to some Fe-poor natural emeralds from certain localities (such as Colombia), but they are easily distinguishable from Fe-rich natural emeralds (such as Brazilian, Zambian, and Austrian stones: see Hänni, 1982; Schrader, 1983; Stockton, 1984; Yu et al., 2000). The absence of any significant Na and Mg in Malossi synthetic emeralds (≤0.01 and ≤0.03 wt.% oxide, respectively) can be used to separate these stones from alkali-rich natural emeralds (Hänni, 1982; Schrader, 1983).

Electron-microprobe analyses of a seed plate in a Malossi sample (again, see figure 4) revealed an appreciable iron content (0.40 wt.% Fe_2O_3), whereas Cr, V, and Cl were below the detection limits. This

Figure 7. The Cl contents measured in eight Malossi synthetic emeralds (each represented by a different color) are shown here. Most of the analyses contain less than 0.12 wt.% Cl (detection limit of Cl is 0.02 wt.%). For average Cl data, see table 2. Enriched contents of Cl were recorded in a few of the analyses, which illustrates the compositional inhomogeneity of the samples.

composition, combined with the R.I. values of the seed plate, is consistent with the producer's claim that natural yellow beryl is used for the seed material (compare to Sinkankas, 1981; Aliprandi and Guidi, 1987; Webster, 1994).

Spectroscopy. The results of UV-Vis-NIR and IR spectroscopy are summarized in table 3, including a comparison to natural and other synthetic emeralds.

Mid-infrared spectra (4000–2000 cm^{-1}) in diffuse reflectance mode are shown in figure 9. A series of intense peaks between 4000 and 3400 cm^{-1} in all the

synthetic emeralds we studied is related to their high water contents (Stockton, 1987; Schmetzer et al., 1997). Such features are characteristic of both natural and hydrothermal synthetic emeralds, but they are not found in flux synthetic samples (Stockton, 1987).

Bands in the range 3100–2500 cm^{-1}, commonly used to identify hydrothermal synthetic emeralds (Schmetzer et al., 1997; Mashkovtsev and Smirnov, 2004), were observed in our Malossi samples, as well as in those from Biron and Linde-Regency (see also Stockton, 1987; Mashkovtsev and Solntsev, 2002; Mashkovtsev and Smirnov, 2004). Schmetzer

TABLE 3. Main spectroscopic features of Malossi and other synthetic as well as natural emeralds.

Spectral region	Hydrothermal synthetic emeralds[a]				Flux synthetic emeralds[b]	Natural emeralds[b,c]
	Malossi	Russian	Biron	Linde-Regency		
Mid-IR (4000–2000 cm^{-1})	Intense absorption between 4000 and 3400 cm^{-1}, associated with high water content	Intense absorption between 4000 and 3400 cm^{-1}, associated with high water content	Intense absorption between 4000 and 3400 cm^{-1}, associated with high water content	Intense absorption between 4000 and 3400 cm^{-1}, associated with high water content	(none reported)	Intense absorption between 4000 and 3400 cm^{-1}, associated with high water content
	Band at 3295 cm^{-1}, with shoulder at 3232 cm^{-1}, probably related to vibration of N-H bonds			Band at 3295 cm^{-1}, with shoulder at 3232 cm^{-1}, probably related to vibration of N-H bonds		
	Group of bands in the 3100–2500 cm^{-1} range, associated with Cl		Group of bands in the 3100–2500 cm^{-1} range, associated with Cl	Group of bands in the 3100–2500 cm^{-1} range, associated with Cl		
Near-IR (9000–4000 cm^{-1})	Combination bands and overtones of water molecules	Combination bands and overtones of water molecules	Combination bands and overtones of water molecules	Combination bands and overtones of water molecules	(none reported)	Combination bands and overtones of water molecules
		Broad band at 8475 cm^{-1}, related to Cu^{2+}				
UV-Vis-NIR (300–1000 nm)	Cr^{3+} absorption features at 430, 476, 600, 637, 646, 662, 681, and 684 nm	Cr^{3+} absorption features at 430, 476, 600, 637, 646, 662, 681, and 684 nm	Cr^{3+} absorption features at 430, 476, 600, 637, 646, 662, 681, and 684 nm	Cr^{3+} absorption features at 430, 476, 600, 637, 646, 662, 681, and 684 nm	Cr^{3+} absorption features at 430, 476–477, 600, 637, 646, 660-662, 680, and 683 nm	Cr^{3+} absorption features at (420), 430–431, 476, 600–602, (629), 637, 645, 662, 680, and 683–685 nm
		Band at 373 nm, associated with Fe^{3+}				(Bands at 370 and 423 nm, associated with Fe^{3+})
		Band at 760 nm, related to Cu^{2+}				(Bands at 820 and 833 nm, related to Fe^{2+})
						(Fe^{2+}/Fe^{3+} intervalence charge transfer absorption band between 599 and 752 nm)

[a] Based on results from the present study.
[b] Data from the gemological literature (Wickersheim and Buchanan, 1959; Wood and Nassau, 1967, 1968; Farmer, 1974; Kennedy, 1986; Graziani et al., 1987; Stockton, 1987; Schmetzer, 1988).
[c] Features in parentheses are not seen in all natural emeralds.
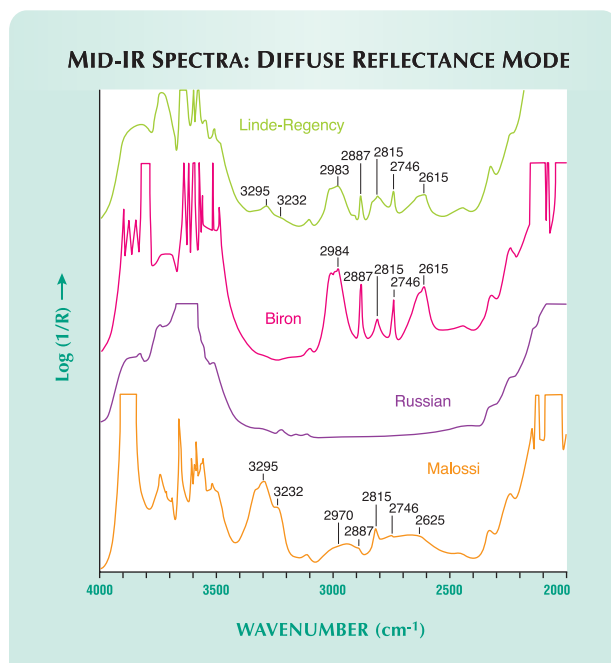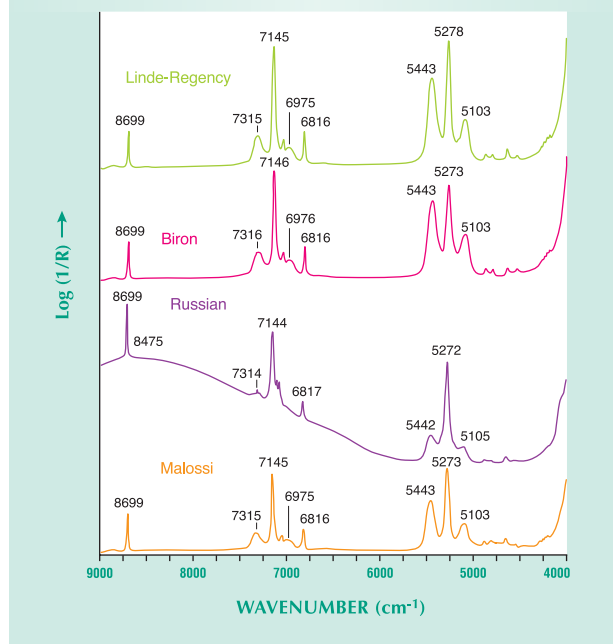
MID-IR SPECTRA: DIFFUSE REFLECTANCE MODE

Figure 9. Mid-infrared spectra (4000–2000 cm^{-1}) in diffuse reflectance mode are shown for the Malossi, Russian, Biron, and Linde-Regency hydrothermal synthetic emeralds tested for this study. The spectra exhibit several differences, particularly in the band at 3295 cm^{-1} with the associated shoulder at 3232 cm^{-1} that is so pronounced in the Malossi material. (The maxima above 3500 cm^{-1} and below 2200 cm^{-1} appear flat because of total absorption in these areas).

et al. (1997) found these bands in Chinese samples as well. However, Russian and Lechleitner synthetic emeralds are transparent over the same energy range (Stockton, 1987; Koivula et al., 1996; Mashkovtsev and Solntsev, 2002; Mashkovtsev and Smirnov, 2004; see also figure 9). Schmetzer et al. (1997) attributed these bands to Cl, in agreement with more recent results by Mashkovtsev and Solntsev (2002) and Mashkovtsev and Smirnov (2004), who specifically cited HCl molecules in the hexagonal channels of the beryl structure. This interpretation is consistent with the chemical compositions we determined for Malossi, Biron, and Linde-Regency synthetics and with the producer's statement that Malossi synthetic emeralds are grown in a solution of HCl.

An additional band at 3295 cm^{-1}, with a shoulder at 3232 cm^{-1}, occurred in both the Malossi and Linde-Regency products (Stockton, 1987; Mashkovtsev and Solntsev, 2002; Mashkovtsev and Smirnov, 2004; see also figure 9). Mashkovtsev and Solntsev (2002) and Mashkovtsev and Smirnov (2004) attributed this feature to the vibrational

stretching mode of the N-H bond (for details, see also references cited in these two articles), which is consistent with the known use of ammonium halides in the solutions employed for emerald synthesis (Nassau, 1980).

The "type" of water molecules in Malossi synthetic emeralds can be determined by (destructive) mid-infrared spectroscopy in transmission mode (see box A in Schmetzer et al., 1997, for the advantages of transmission IR spectroscopy). In the diagnostic range of 3800–3500 cm^{-1}, we recorded a single sharp absorption band at 3700 cm^{-1} (figure 10), which indicates that H_2O molecules in Malossi stones are type I (i.e., their H–H vector is parallel to the c-axis in alkali-free beryl samples; Wood and Nassau, 1967, 1968; Charoy et al., 1996; Kolesov and Geiger, 2000; Gatta et al., in press). All this is in keeping with the absence of any significant alkali content in Malossi material, which agrees with results reported by Kolesov and Geiger (2000), who observed the same single mode at 3700 cm^{-1} in other hydrous synthetic beryl crystals. However, relatively recent spectroscopic and neutron diffraction studies (Artioli et al., 1995; Charoy et al., 1996; Kolesov and Geiger, 2000; Gatta et al., in press) suggest that there are some uncertainties about the vibrational behavior and orientation of H_2O molecules in various beryl samples.

Nonpolarized near-infrared spectra (9000–4000 cm^{-1}) in diffuse reflectance mode of our Malossi,

Figure 10. The mid-infrared spectrum (3800–3500 cm^{-1}) in transmission mode of a pressed pellet containing powdered Malossi synthetic emerald shows a peak at 3700 cm^{-1} that is related to the presence of type I water molecules.

MID-IR SPECTRUM: TRANSMISSION MODE
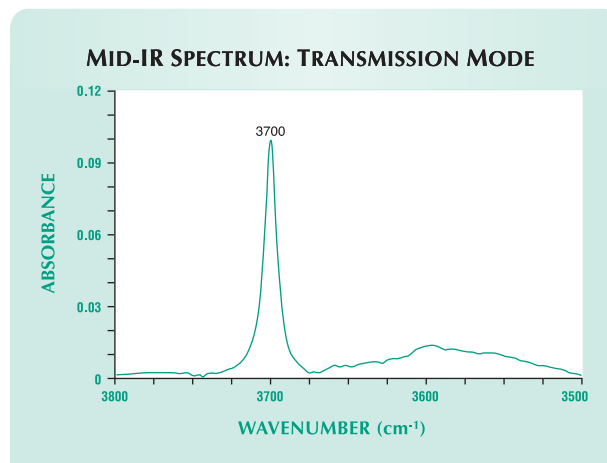
NEAR-IR SPECTRA: DIFFUSE REFLECTANCE MODE

Figure 11. Near-infrared spectra (9000–4000 cm^{-1}) in diffuse reflectance mode are shown for the Malossi, Russian, Biron, and Linde-Regency hydrothermal synthetic emeralds studied. The spectra of all samples exhibit combination bands and overtones of water molecules, which are typical features of both hydrothermal synthetic and natural emeralds.

Russian, Biron, and Linde-Regency synthetic emeralds are displayed in figure 11. All samples show combination bands and overtones of water molecules (Wickersheim and Buchanan, 1959; Wood and Nassau, 1967, 1968; Farmer, 1974). These features are also typical of natural emeralds (see references above), whereas they are always lacking in flux synthetic emeralds. Russian hydrothermal synthetic emeralds exhibit a broad band at 8475 cm^{-1} (see also Koivula et al., 1996; Mashkovtsev and Smirnov, 2004) related to an optical transition involving Cu^{2+} ions (Mashkovtsev and Smirnov, 2004) that is commonly absent in hydrothermal specimens from other producers.

Nonpolarized UV-Vis-NIR absorption spectra of our Malossi, Russian, Biron, and Linde-Regency hydrothermal synthetic emeralds (figure 12) confirm the presence of Cr^{3+} through the occurrence of two broad bands at 430 and 600 nm; peaks at 476, 637, 646, and 662 nm; and a doublet at 681–684 nm (see Wood and Nassau, 1968; Rossman, 1988; Schmetzer, 1988, 1990), similar to natural and flux

synthetic emeralds. Given that the absorption peaks of Cr^{3+} and V^{3+} are very close to one another (see references above and Burns, 1993), it is not possible to reliably discriminate the patterns of Malossi and Linde-Regency synthetic stones (Cr-bearing only) from those of Biron synthetic samples (Cr- and V-bearing). However, Russian synthetic emeralds show differences from the other hydrothermal synthetics: a broad band at about 750 nm, which Schmetzer (1988, 1990) related to Cu^{2+}, as well as an absorption at 373 nm, which he associated with Fe^{3+}. In natural iron-bearing emeralds, absorption bands for Fe^{3+}, Fe^{2+}, and Fe^{2+}/Fe^{3+} may also be present (Schmetzer, 1988; again, see table 3).

IDENTIFICATION

Separation from Natural Emeralds. Malossi synthetic emeralds have a number of characteristics that, in combination, allow them to be separated from natural emeralds:

1. *Microscopic features:* Irregular growth structures (observed in almost all Malossi synthetic emeralds), natural seed plates (used to initiate growth), and phenakite-like crystals (hinting at the occurrence of an incongruent beryl precipitation) provide evidence of hydrothermal synthesis.

Figure 12. The nonpolarized UV-Vis-NIR (300–900 nm) absorption spectra of the Malossi, Russian, Biron, and Linde-Regency hydrothermal synthetic emeralds tested all show Cr^{3+} absorption bands. Only the Russian sample exhibits other significant features, such as a peak at 373 nm (related to Fe^{3+}) and a broad band at about 750 nm (associated with Cu^{2+}).

UV-VIS-NIR ABSORPTION SPECTRA
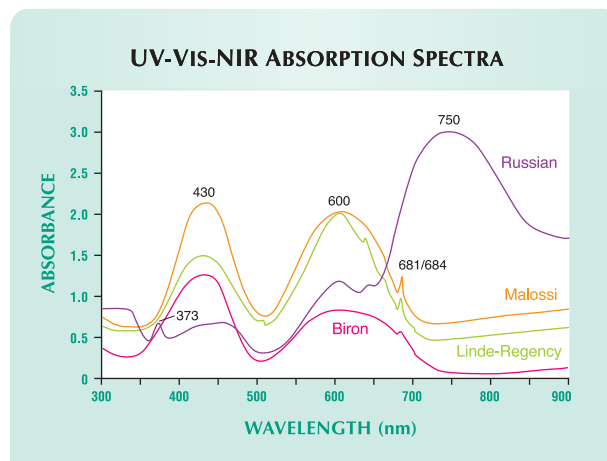
2. *Chemical composition:* The presence of Cl, combined with the absence of any significant amounts of Fe, Na, and Mg, provides a useful tool for the separation from Fe-alkali-bearing natural emeralds. In the case of Fe-Na-Mg–poor natural samples (such as Colombian stones), a Cl content >0.2 wt.% can be used to identify the Malossi synthetics, although due to possible compositional overlap, chemical analysis alone is not a reliable proof of synthesis.

3. *Spectroscopic measurements:* Mid-infrared bands in the 3100–2500 cm^{-1} range (related to Cl) and a band at 3295 cm^{-1} with an associated shoulder at 3232 cm^{-1}, are further diagnostic features of synthetic origin.

In summary, Malossi synthetic emeralds are readily separated from most natural Fe- and/or alkali-bearing emeralds, whereas a combination of the diagnostic features discussed above is required to distinguish them from Fe- and alkali-poor natural emeralds.

Separation from Other Synthetic Emeralds. Malossi, like all other hydrothermal synthetic emeralds, are readily separated from flux synthetic emeralds because the latter (1) have lower refractive index (from 1.556), birefringence (from 0.003), and specific gravity (from 2.64) values; (2) contain typical flux inclusions; and (3) do not exhibit water-related bands in the mid- (between 4000 and 3400 cm^{-1}) and near- (9000–5000 cm^{-1}) IR spectra.

Malossi synthetic emeralds, which are Cr- and Cl-bearing, differ from the Russian, Lechleitner, and Biron hydrothermal synthetic emeralds studied to date on the basis of chemical composition. Russian and Lechleitner synthetics have Cr, Fe, Cu, and Ni, while Biron has V in addition to Cr and Cl. These differences can be seen in their gemological and spectroscopic properties. The separation of Malossi from Chinese synthetic emeralds may be possible based on either a larger amount of Cl in the earlier-generation Chinese material or the presence of Na in the later-generation Chinese synthetics. Also, according to information given by Chinese gemologists at the Fall 2004 International Gemological Congress in Wuhan (China), the production of Chinese hydrothermal synthetic emeralds has been discontinued (K. Schmetzer, pers. comm., 2005). The chemical separation of Malossi from Linde-

Figure 13. Faceted Malossi synthetic emeralds have been commercially available in Italy and in the U.S. since December 2004. These emerald cuts (4.00 ct, left, and 2.20 ct, right) are set in rings together with synthetic moissanite. Composite photo by Alberto Malossi.

Regency hydrothermal synthetic emeralds is less straightforward and further research is needed.

CONCLUSIONS

A new type of hydrothermal synthetic emerald is now being produced in the Czech Republic with Italian technology. These Malossi synthetic emeralds have been commercially available since December 2004 (figure 13). This material belongs to the group of Cl-bearing, alkali-free hydrothermal synthetic emeralds, with Cr^{3+} as the only chromophore. Water is present as type I molecules.

Malossi synthetic emerald can be distinguished from its natural counterpart on the basis of microscopic features (in particular, irregular growth structures, seed plates, and/or phenakite-like crystals), as well as by the presence of Cl combined with the absence of significant Fe, Na, or Mg. In addition, mid-infrared spectroscopy reveals diagnostic bands in the 3100–2500 cm^{-1} range and at 3295 cm^{-1} (with a shoulder at 3232 cm^{-1}).

Malossi hydrothermal synthetic emerald can be easily discriminated from its flux synthetic counterparts, primarily on the basis of the absence of water molecules in the latter. The separation from Russian, Lechleitner, Chinese, and Biron hydrothermal synthetic emeralds can be made on the basis of chemical composition. The discrimination from Linde-Regency hydrothermal synthetic emeralds is more ambiguous, and further research is needed.

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LAB NOTES

Yellow CUBIC ZIRCONIA
Imitating Cape Diamonds

Two yellow kite-shaped step cuts (1.77 and 1.70 ct; figure 1) were submitted to the West Coast laboratory by Mitchell Swerdlow Inc. of Miami, Florida, for diamond color origin determination. Initial observation in the laboratory weights and measures department indicated specific gravity values that were close to 6 for both, requiring additional testing by the Identification staff. Subsequent observation of the spectra seen with the desk-model spectroscope appeared to reveal a cape spectrum in both samples, with the addition of a line at 595 nm, which is often indicative of irradiation and annealing in a yellow diamond. However, due to the high density of the specimens, it was obvious that they were in fact not diamonds at all, and further testing was clearly required.

No inclusions were seen in either sample when examined with magnification, and there was no visible strain. Lack of doubling in the microscope suggested that the kite shapes were singly refractive, and they were over the limits of the refractometer. In addition, they fluoresced weak orange red to long-wave ultraviolet radiation and medium to strong orangy red to short-wave UV, which is also not consistent with yellow diamonds.

When the visible absorption spectra were examined more closely, it became apparent that although they did closely resemble the spectrum of a treated cape diamond, the 415 nm band was missing, and the positions of some of the main bands were shifted slightly on the scale. The spectra of cape diamonds contain bands in the violet-to-blue region, with lines at approximately 415, 435, 452, 465, and 478 nm; the 415 and 478 nm bands are the strongest. When a diamond is artificially irradiated and annealed to produce a yellow color, the cape lines are usually fairly weak, and there are often additional lines at 496 and 503 nm and a weak line at about 594 nm. Figure 2 compares the spectrum of the yellow samples we received for identification with a representative spectrum from a cape diamond. Due to the close proximity of lines on the scale, at first glance the 485 nm band in the samples could have been confused with the comparatively strong 478 nm band in a cape diamond, although the two samples also had an even closer but weaker line around 473 nm. The samples also had a fine weak line around 594 nm, which could have been confused with the same line in an irradiated and annealed diamond, but the more prominent band at 585 nm in the samples is really the culprit in a potentially mistaken comparison.

To further characterize the spectra of the two samples, research scientist

Figure 1. These two yellow samples of cubic zirconia (11.30 × 5.50 × 3.72 and 10.54 × 5.57 × 3.71 mm) could be mistaken for irradiated and annealed cape diamonds if a gemologist relied on their visible spectra to identify them.
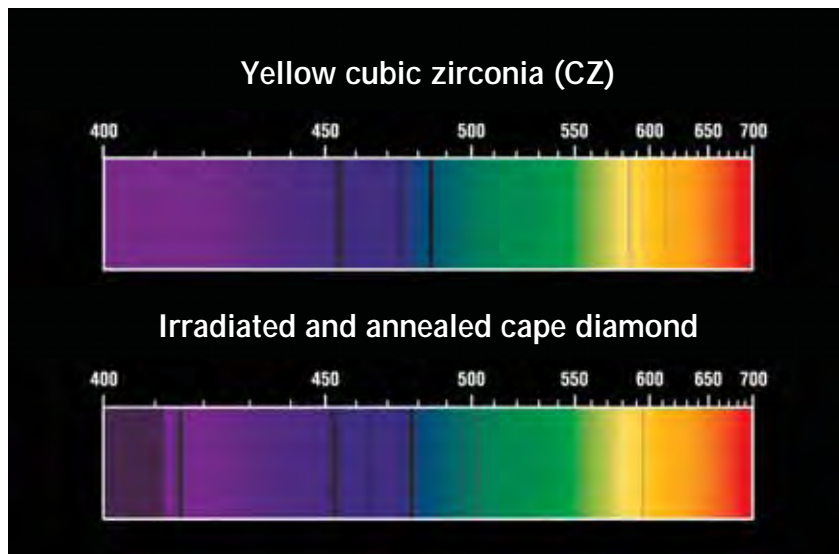
Figure 2. As seen from these approximate representations, the visible absorption spectra of the two yellow CZs in figure 1 (top) and an irradiated and annealed cape diamond (bottom) are similar enough to lead to confusion in a quick examination with a desk-model spectroscope.

Andy H. Shen collected UV-visible spectra. The absorption features presented themselves generally as small broad bands, and for the most part they corresponded to the lines observed in the desk-model spectro-

Figure 3. The UV-visible spectra of the two yellow CZs (top) and an irradiated and annealed cape diamond (bottom spectrum) support the bands detected with the desk-model spectroscope (figure 2), and also show differences in the absorption features more distinctly. (All spectra were collected at room temperature.)
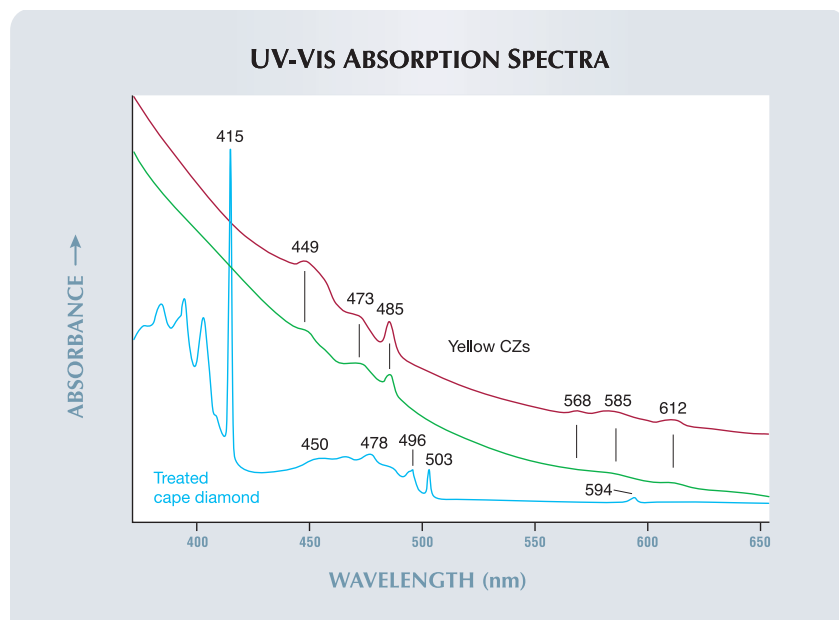
scope. However, the weak feature at about 594 nm was not visible. A comparison of the UV-visible spectra of the two yellow samples and an irradiated and annealed cape diamond is shown in figure 3.

Energy-dispersive X-ray fluorescence (EDXRF) analysis performed by senior research associate Sam Muhlmeister revealed Zr as the major chemical component, along with a trace of Y and Hf. These findings were consistent with cubic zirconia. As this note illustrates, if one is using a desk-model spectroscope to quickly confirm the identification of a "yellow diamond," one must be aware that the spectrum of a yellow CZ can be mistaken for that of a cape or treated cape diamond. The lines should be studied closely to avoid a potentially embarrassing error.

CYW

DIAMOND
Orange, Treated by
Multiple Processes

Two major laboratory treatment techniques have been applied to alter the apparent bodycolor of diamond. One is irradiation with or without annealing at a relatively low temperature; the other is annealing under high pressure and high temperature (HPHT). Though these two processes were first used in isolation, some treaters have begun combining them (see, e.g., W. Wang et al., "Treated-color pink-to-red diamonds from Lucent Diamonds Inc.," Spring 2005 *Gems & Gemology*, pp. 6–19). The diamonds in the Wang et al. article were type Ia with very high concentrations of nitrogen; however, in the East Coast laboratory, we recently examined two diamonds treated in a similar way to introduce an attractive orange color, and these had extremely *low* nitrogen contents (i.e., they were virtually type IIa).

The 5.89 ct round brilliant was color graded Fancy pinkish orange; the 4.31 ct emerald cut was color graded Fancy orange (figure 4). The
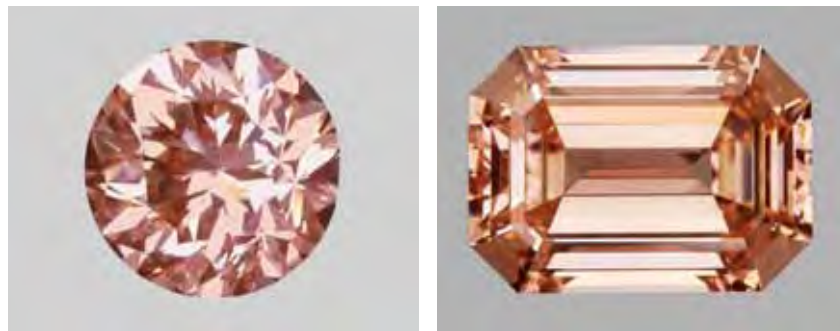
Figure 4. These 5.89 ct Fancy pinkish orange (left) and 4.31 ct Fancy orange (right) diamonds proved to have been treated by multiple processes. The most likely scenario is HPHT annealing followed by irradiation and then annealing at relatively low temperatures.

two diamonds had no unusual internal characteristics, either inclusions or fractures. When exposed to long-wave UV radiation, the round brilliant displayed a moderately strong yellow fluorescence, while the emerald cut showed a moderate-to-strong yellow-green fluorescence; both displayed moderate-to-strong orange fluorescence to short-wave UV. No phosphorescence was observed.

A notable feature in both diamonds was that the orange color was concentrated in their culets, though this was more obvious in the round brilliant (figure 5). It is well-known that this feature can be created by irradiation and annealing (see, e.g., E. Fritsch and J. E. Shigley, "Contribution to the identification of treated colored diamonds: Diamonds with peculiar color-zoned pavilions," Summer 1989 *Gems & Gemology*, pp. 95–101).

In their infrared absorption spectra, both diamonds appeared to be nearly type IIa, with extremely weak absorption from both B-form nitrogen ($0.012–0.014$ cm^{-1} in absorption coefficient at 1282 cm^{-1}, about 1 ppm each) and isolated nitrogen ($0.004–0.005$ cm^{-1} in absorption coefficient at 1344 cm^{-1}, about 0.1 ppm each). The coexistence of isolated nitrogen and highly aggregated B-form nitrogen has not been reported in a natural-color diamond, and such a combination is contrary to the natural aggregation process. Thus, it was very likely the result of HPHT annealing. (Under HPHT conditions, part of the highly aggregated nitrogen will decompose and form isolated nitrogen.) This conclusion was supported by the presence of small frosted surfaces near the girdle of the round brilliant, a tell-tale trace of the annealing process that is not always

completely removed by re-polishing after treatment (T. M. Moses et al., "Observations on GE-processed diamonds: A photographic record," Fall 1999 *Gems & Gemology*, pp. 14–22; Wang et al., 2005).

UV-visible spectra collected at cryogenic temperatures from the two diamonds showed very similar absorption features (figure 6). Relatively strong absorptions at 574.9 nm [(N-V)^0] and 637.0 nm [(N-V)$^-$] and their side bands were responsible for the orange hues. These two centers can be easily introduced by radiation/annealing of a diamond that contains isolated nitrogen. Other absorptions known to be due to irradiation and annealing at relatively low temperatures were also detected, including those at 393.4 (ND1), 495.9 (H4), 594.2, and 741.0 nm (GR1).

While we do not know the original colors of these two diamonds, all observations lead to the conclusion that they were treated by at least two processes to introduce an attractive orange hue. The most likely scenario is HPHT annealing followed by irradiation and then annealing at relatively low temperatures; this treatment method is known to produce a pink hue (also caused by N-V centers) in some type IIa diamonds. The use of multiple processes to enhance the bodycolor of natural diamonds presents a new identification challenge for gem laboratories.

Wuyi Wang, TMM,
and Carol Pearce

Figure 5. The orange color was concentrated in the culets of both stones, a feature often induced by irradiation. This feature is more evident in the round brilliant (left) than in the emerald cut (right).

Pink Diamonds with a Temporary Color Change

Diamonds that change color for a brief period in certain environments occupy a special niche in the diamond world. Most reported "color-change" diamonds temporarily change from a greenish to a yellowish hue when heated or when placed in darkness for long periods of time; these stones are known in the trade as "chameleon" diamonds. Even rarer are diamonds that temporarily change color when

UV-VISIBLE ABSORPTION SPECTRA

Round brilliant

Emerald cut

268.3
271.6
393.4 ND1
415.2
424.5
495.9 H4
505.0
574.9 (N-V)⁰
594.2
637.0 (N-V)⁻
741.0 GR1

ABSORBANCE

WAVELENGTH (nm)
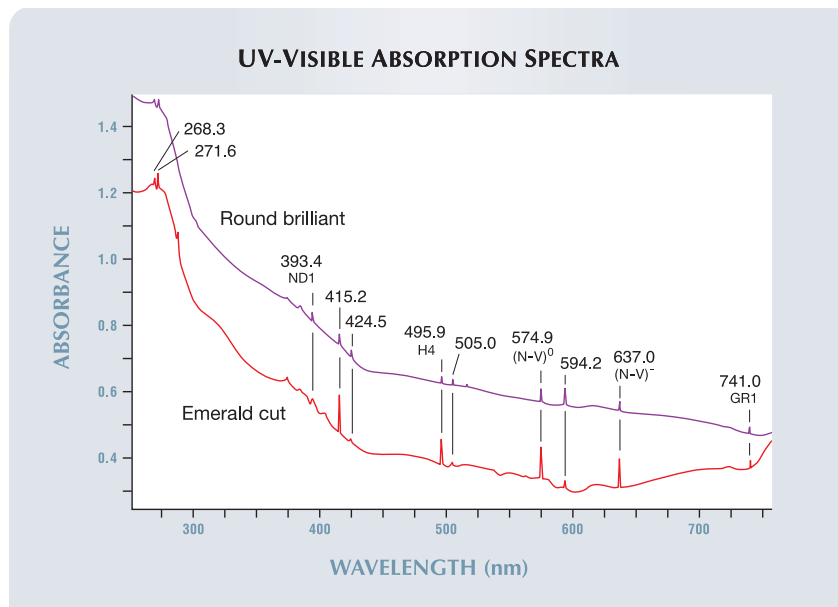
Figure 6. Absorption spectra in the UV-visible region showed relatively strong absorptions at 574.9 nm and 637.0 nm, which are responsible for the orange hues. Absorptions at 393.4, 495.9, 594.2, and 741.0 nm are introduced by irradiation and annealing at relatively low temperatures.

cooled or exposed to UV radiation (e.g., Summer 1975 Lab Notes, pp. 57–59; E. Fritsch, "The nature of color in diamonds," in G. E. Harlow, Ed., *The Nature of Diamonds*, Cambridge University Press, Cambridge, U.K., 1997, pp. 23–47; M. Van Bockstael, "Chameleon diamonds," *Antwerp Facets*, 1997, pp. 40–41; Summer 2002 Lab Notes, pp. 165–166; Hainschwang et al., "A gemological study of a collection of chameleon diamonds," Spring 2005 *Gems & Gemology*, pp. 20–34).

Earlier this year in the West Coast laboratory, we examined two pink diamonds (2.01 and 2.17 ct) that temporarily changed color after exposure to high-energy short-wave (<230 nm) UV radiation in the DiamondView. The 2.01 ct stone changed from Fancy Light pink-brown to Fancy Light brownish yellow (figure 7); the 2.17 ct stone changed from Fancy Light pink to light brown (L color). Over a period of several hours in normal lighting conditions, both stones returned to their original pink colors.

Both diamonds were type IIa with no detectable impurities in the mid-infrared spectrum, and both showed distinctive cross-hatched strain patterns when viewed between crossed polarizers. The 2.01 ct stone had a moderate yellow reaction to long- and short-wave UV, whereas the larger diamond fluoresced a weak blue to both. These two diamonds did not change color after exposure to typical long- or short-wave handheld UV lamps (which emit UV radiation at wavelengths of ~366 nm and ~254 nm, respectively). When examined with diffused white light, the color distribution in the 2.17 ct diamond appeared uniform; subtle brown and pink graining was present in the smaller stone.

Visible-range absorption spectra were collected at cryogenic temperatures from the 2.01 ct diamond in both the pink and yellow color states to assess the mechanism behind the color change. In both states, the diamond displayed a distinct H3 defect (503.2 nm; see figure 8), which was responsible for the small amount of green luminescence seen when the diamond was viewed with magnification. The H3 band is extremely rare in natural type IIa diamonds, and the reason for its occurrence in this diamond is unclear.

In the stable pink color state, a general increase in absorption toward the blue end of the spectrum and a broad band at ~550 nm were responsible for the pink color. After exposure to high-energy UV radiation, the baseline absorbance increased and the 550 nm band decreased substantially, leaving a transmission window in the yellow

Figure 7. This 2.01 ct diamond experienced a notable change in color after exposure to high-energy short-wave UV radiation. At left, before exposure, the stone was Fancy Light pink-brown; afterward, it changed to Fancy Light brownish yellow. The stone returned to its original color after several hours in normal light.

VISIBLE ABSORPTION SPECTRA

503.2
(H3)

After exposure to high-energy UV
(yellow color state)

503.2
(H3)

550

Before exposure to high-energy UV
(pink color state)

ABSORBANCE

WAVELENGTH (nm)

Figure 8. Low-temperature visible absorption spectra from the 2.01 ct diamond in its pink-brown and brownish yellow states show that the presence of the 550 nm band produces a pink color before UV exposure, whereas the absence of this band after exposure results in a transmission window in the yellow region.

interactions involving the band seem to occur in some pink diamonds.

This type of color change is a rare and interesting phenomenon that may provide more insight into the nature of the 550 nm absorption band that is common in natural pink diamonds.

Christopher M. Breeding
and Andy Shen

Unusually Large Novelty Cut

From time to time, diamonds cut into the shapes of animals or objects such as stars are submitted to the laboratory for grading (see, e.g., Spring 1983 Lab Notes, p. 43; Spring 1993 Gem News, p. 52; Fall 2001 Lab Notes, p. 214). Though the practice of carving diamonds into unusual shapes has a long history, most of these novelty cuts became possible only after the development of laser cutting and shaping techniques. Such novelty cuts tend to be relatively small and to be cut from oddly shaped, near-colorless rough that

part of the spectrum. The change in the 550 nm band is particularly interesting, because it is commonly associated with the graining features that cause the bodycolor of most natural pink diamonds.

Our results suggest that, in some diamonds, the 550 nm band may be temporarily removed (or "bleached") by exposure to high-energy UV radiation. Although the baseline absorbance increased after exposure, it did so evenly across the visible spectral range, suggesting that it was most likely not responsible for the noticeable decrease in the 550 nm band.

Over the years, we have examined a large number of pink diamonds in the laboratory and observed that not all that have a 550 nm band will change color in this manner. The change in intensity of the 550 nm band in response to UV energy suggests that some sort of electronic structure or charge transfer may be associated with this feature. While the 550 nm band is most likely due to plastic deformation, more complex electronic

Figure 9. This 21.42 ct novelty-cut diamond, which resembles an eagle's head, is unusual for its large size and fancy color.
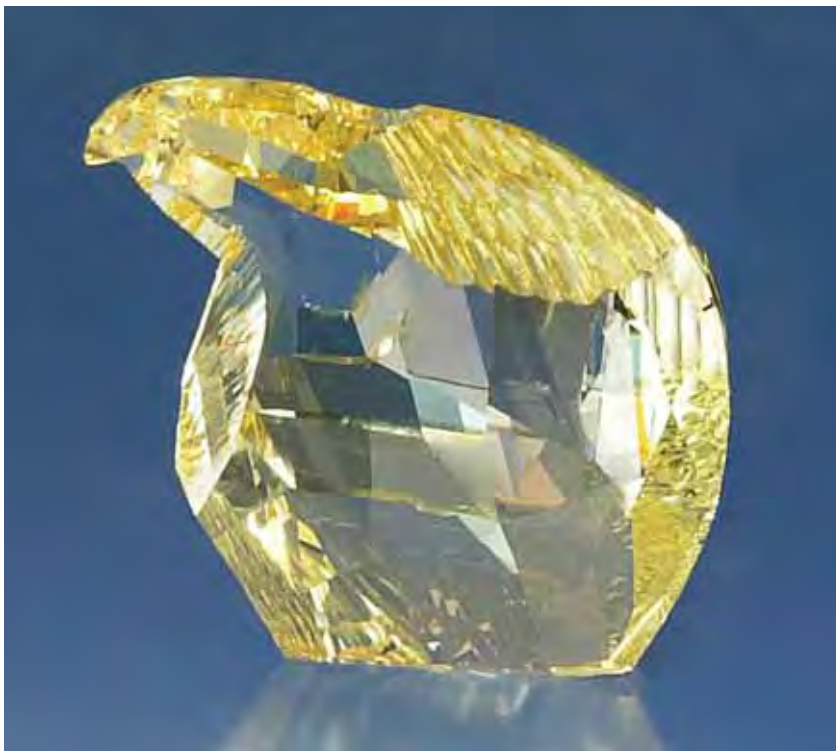
Figure 10. These facets, intended to represent the eagle's feathers, were cut by hand with a tool made expressly for this diamond. Magnified 8×.

Figure 11. Many naturals were left along the girdle edge of the eagle's head to emphasize that the original rough had a shape similar to that of the finished stone. Magnified 38×.

is not suitable for traditional shapes and proportions. Thus, we at the East Coast laboratory were very interested to encounter a novelty cut that was relatively large and in a fancy color.

This 21.42 ct yellow diamond (figure 9) was fashioned into the form of an eagle's head. In addition to its notable size and color, the diamond had curiously shaped facets in certain areas that gave the appearance of feathers (figure 10). In conversation with the manufacturer, we learned that—far from being the product of a laser cutting operation—these facets were cut by hand using a rather primitive tool that was created specifically for this purpose. The manufacturer also mentioned that the shape of the original rough evoked the outline of an eagle, which fueled his desire to fashion the diamond into this image. Some small remnants of the diamond's natural surface were left unpolished around the girdle edge to demonstrate how much weight and shape was retained from the original rough (figure 11).

We were also told that the rough from which this eagle's head was cut was relatively flat. When colored diamonds are faceted from flat rough, it is not uncommon for the color in the finished stone to concentrate near the edges, with a somewhat "colorless" window in the center. When color grading such a diamond, the grader concentrates on those areas where color is observed. However, if that color does not represent the majority of the face-up appearance (i.e., the window predominates), the color distribution entry on the grading report would state "uneven." Such was the case with this diamond (again, see figure 9), which was graded Fancy Intense yellow with uneven color distribution.

Thomas H. Gelb and John M. King

Small SYNTHETIC DIAMONDS

Several months ago, the West Coast laboratory received three melee-size (0.11, 0.12, and 0.16 ct; figure 12) bright orange-yellow gems of varying shapes for colored diamond identification and origin reports. Observation with a gemological microscope at approximately 10× magnification revealed that all three were fairly clean, which is not unusual for such small stones. At higher magnification, we could see that they contained only diffuse clouds and had no obviously natural inclusions. The particles making up the clouds were fairly regularly spaced and uniform in size. The clouds seen in most natural diamonds tend to be more irregular, so this led us to suspect that these samples might be of synthetic origin.

All three specimens were inert to long-wave UV radiation. One fluoresced a weak, zoned chalky orange—and the other two displayed a very weak green reaction—to short-wave UV radiation. Yet none of them displayed the diagnostic cross-shaped pattern of chalky fluorescence often seen in synthetic diamonds of this color. Examination with high magnification while they were immersed in methylene iodide did reveal at least one sharp, elongated, near-colorless zone in each specimen, but these zones were difficult to view due to the small size of the samples. However, examination with the DTC

Figure 12. Due to their small size and lack of obvious synthetic characteristics, these three melee-size synthetic diamonds (0.11–0.16 ct) could be a challenge to identify outside a laboratory.
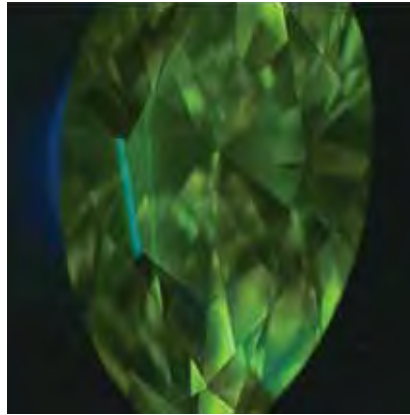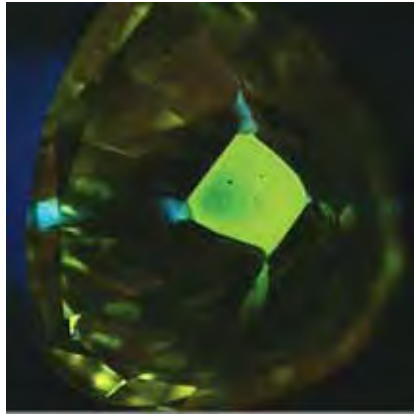
Figure 13. The fluorescence patterns in these DiamondView images of two of the small synthetic stones are diagnostic of synthetic diamond.

DiamondView, which uses higher-energy short-wave UV radiation, revealed fluorescent patterns characteristic of synthetic diamonds (figure 13) in each of the samples. Therefore, we concluded that all were indeed synthetic.

In recent months, we have seen a greater number of small synthetic diamonds of this color coming through the laboratory. Many of these do display the characteristic yellow-green chalky cross-shaped fluorescent pattern when exposed to UV radiation. As these three samples illustrate, though, some small synthetic diamonds cannot be readily identified with standard gemological techniques alone.

Elizabeth P. Quinn

DIASPORE "Vein" in Sapphire

Diaspore, orthorhombic aluminum hydroxide, is best known as a form of the aluminum ore bauxite, and is only rarely used as a gem material. However, it may be associated with corundum and can sometimes be seen as an inclusion in ruby and sapphire. *G&G* has previously reported on the presence of diaspore as irregular "veins" in Nepalese ruby (C. P. Smith et al., "Rubies and fancy-color sapphires from Nepal," Spring 1997 *Gems & Gemology*, pp. 24–41), and as the solid phase in three-phase inclusions in Sri Lankan sapphire (K. Schmetzer and O. Medenbach, "Examination of three-phase inclusions in colorless, yellow, and blue sapphires from Sri Lanka," Summer 1988 *Gems & Gemology*, pp. 107–111).

Recently, a 3.96 ct blue cushion-cut stone was submitted to the West Coast laboratory for identification. Standard gemological testing proved it to be natural sapphire. During the microscopic examination, we noticed that a distinctive circular fracture breaking the surface of the pavilion was filled with a material that had a

lower surface luster than the surrounding corundum (figure 14). Though such a feature is typically associated with the glass-like residues found in fractures and cavities of some rubies that have been exposed to high-temperature heat treatment, it is seldom seen in blue sapphires. Further, the filler material contained numerous irregular thread-like voids that did not resemble the patterns and inclusions we would expect to see in glassy residues (figure 15). For this reason, we decided to test the "filler" further.

Because the material broke the pavilion surface in a relatively wide "vein," we were able to use Raman spectroscopy for analysis. Even so, the spectral peaks representing the surrounding corundum needed to be "subtracted" from the spectrum of the sample. The resulting spectrum (figure 16) was an excellent match for diaspore. Diaspore is known to be unstable at temperatures over 600°C (again, see Schmetzer and Medenbach, 1988), so its presence was an excellent indicator that the stone had not undergone high-temperature heat treatment. Conversely, if we had found the material to be a glassy residue, its presence would be proof of heat treatment.

The similarity in appearance between this material and glass serves as an excellent reminder that careful scrutiny and testing are neces-

Figure 14. This 3.96 ct sapphire contained a circular fracture that in reflected light showed a lower luster than the surrounding sapphire, resembling the glass-like material commonly seen in heat-treated corundum. Magnified 40×.

Figure 15. The inclusions in the material filling the fracture in the sapphire in figure 14 did not resemble those one would expect to see in a glassy residue from heating. Magnified 37×.

RAMAN SPECTRA

Original sample spectrum for "vein" in blue sapphire

Blue sapphire

Subtraction result for "vein material"

Diaspore reference

INTENSITY →

RAMAN SHIFT (cm⁻¹)

2000   1600   1200   800   400
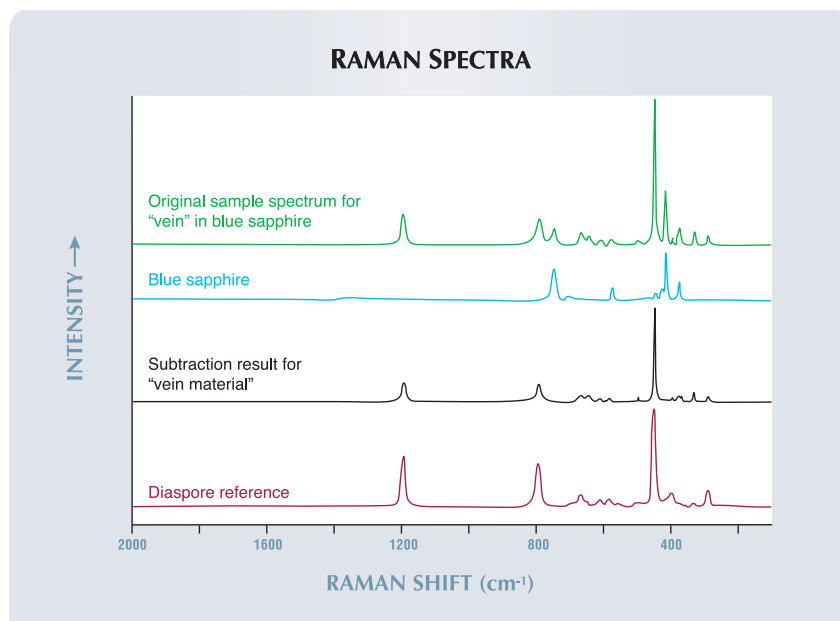
Figure 16. The Raman spectrum of the "vein" material with the primary corundum peaks removed, or "subtracted," shows a very close match to the GIA lab's library sample of diaspore.

sary to accurately interpret observations and, in this case, prevent mistaking evidence of *no* treatment for evidence of treatment.

Kimberly Rockwell

Unusual PEARL from South America

The natural oyster pearls that we see from south of the U.S. border usually originate from *Pinctada mazatlanica* or *Pteria sterna* along the Pacific coast of Mexico or within the Gulf of California. Typically, these pearls occur in colors that include blacks to grays, various shades of brown, and deep purples. Many have iridescent overtones (orient) of pink, purple, green, blue, yellow, and/or orange. Although a verbal description of these pearls might not distinguish them from those of French Polynesia, there are visual subtleties in color, as well as in shape and size, that can provide clues as to the origin of some of these gems. Recently, the West Coast laboratory received an interesting 9.51 ct pearl (figure 17) whose size and unusual grayish

greenish yellow color made it difficult to discern whether it might have originated from Tahiti or Central/South America.

The long-wave UV luminescence was very weak brown to reddish brown with a very weak to weak chalky yellow-green surface cast. This

Figure 17. This natural pearl from the Pacific coast of South America (11.15–11.60 × 10.10 mm), presumed to be from a P. mazatlanica *oyster, exhibits a rare color for pearls from this oyster.*

subtle fluorescence ruled out *P. sterna* as the source oyster due to a lack of the characteristic stronger chalky reddish fluorescence that would be observed in that type of pearl (see, e.g., L. Keifert et al., "Cultured pearls from the Gulf of California, Mexico," Spring 2004 *Gems & Gemology*, pp. 26–38). However, it matched that of a similarly colored outer nacreous band of a *P. mazatlanica* shell in our research collection. It also matched that of the non-nacreous outer lip of a *Pinctada margaritifera* shell (the famed black-lipped oyster from French Polynesia), but this was an area of the oyster where the pearl could not have formed.

The UV-visible absorption spectra of pearls from *P. mazatlanica* are similar to those from *P. margaritifera*; as with some dark pearls from both oysters, there was increased absorption around 700 nm in this pearl. Although the West Coast laboratory has not had the opportunity to observe this 700 nm absorption in *P. mazatlanica* pearls, it has been recorded in the past (K. Scarratt, pers. comm., 2005).

The client reported that the pearl originated from an undisclosed location along the Pacific coast of South America, which is good circumstantial evidence that the producing oyster was *P. mazatlanica* rather than *P. margaritifera*. The client also said that, in his considerable experience, the color of this *P. mazatlanica* pearl was quite rare.

CYW and Shane Elen

Unusually Small Natural-Color Black CULTURED PEARLS

The black cultured pearls from French Polynesia we see in the laboratory are typically at least 9 mm in diameter, but occasionally we see them between 8 and 9 mm. So when a very dark strand consisting mostly of cultured pearls under 9 mm (with several 8 mm or slightly less; figure 18) came into the West Coast laboratory, we were suspicious that they might be dyed. However, visual

Figure 18. Several of the very dark cultured pearls (11.00 mm to 8.00 × 7.80 mm) in this strand were smaller and had thinner nacre than is typical for Tahitian exports.

observation of the nacre did not reveal any evidence of dye. The cultured pearls were highly polished, and some had thin, transparent nacre through which the bead nucleus could be seen when viewed with transmitted light from a fiber-optic source.

The long-wave UV luminescence of such dark cultured pearls is often inert to faint or occasionally very weak, so we were somewhat surprised to see very weak to weak reddish brown fluorescence that is more typical of slightly lighter Tahitian cultured pearls. Senior research associate Sam Muhlmeister performed EDXRF analysis to check for the presence of metals such as Ag, which would be proof of color treatment. The results were consistent with naturally colored pearls and revealed no evidence of dye. Using UV-visible spectroscopy, research gemologist Shane Elen then characterized 18 cultured pearls from the center of the strand; the spectra were consistent with naturally colored dark pearls from the

Pinctada margaritifera, with increased absorption around 700 nm.

These results established that the black cultured pearls were of natural color. Observation of the bead nuclei on an X-radiograph revealed that the smallest nucleus seen in one two-dimensional view measured approximately 6.2 mm in diameter, with numerous others ranging from 6.3 to 7.0 mm. In this same X-radiograph, the nacre varied from 0.3 to 1.7 mm, with quite a few having nacre in the 0.4–0.6 mm range. It is interesting to note, as G.I.E. Perles de Tahiti kindly informed us, that the French Polynesian government requires a nacre thickness of at least 0.8 mm on cultured pearls for export.

Also according to G.I.E. Perles de Tahiti, there could be a number of explanations for the pearls' relatively thin nacre. One is that the procedure responsible for their high polish subsequently removed nacre to well below the minimum thickness required for their export. Another is

that the geographic source may not be French Polynesia.

CYW

Identification of TURQUOISE With Diffuse Reflectance Infrared Spectroscopy

Turquoise has been treated by plastic impregnation since the late 1960s (see, e.g., T. Lind et al., "The identification of turquoise by infrared spectroscopy and X-ray powder diffraction," Fall 1983 *Gems & Gemology*, pp. 164–168). This treatment not only improves color, luster, and durability, but it can also protect the turquoise from penetration by foreign substances such as dirt and skin oils. Traditionally, IR spectroscopy has been the most common method for detecting polymer impregnation of gem materials (see, e.g., Lind et al., 1983; E. Fritsch et al., "Identification of bleached and polymer-impregnated jadeite," Fall 1992 *Gems & Gemology*, pp. 176–187; M. L. Johnson et al., "On the identification of various emerald filling substances," Summer 1999 *Gems & Gemology*, pp. 82–107). This test is normally performed in transmission mode for opaque gems; however,

Figure 19. Although the appearance and low specific gravity of this turquoise tablet led to suspicions of treatment, no known polymer impregnation was detected.

IR REFLECTANCE SPECTRA
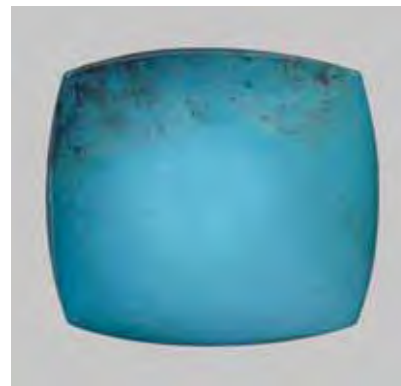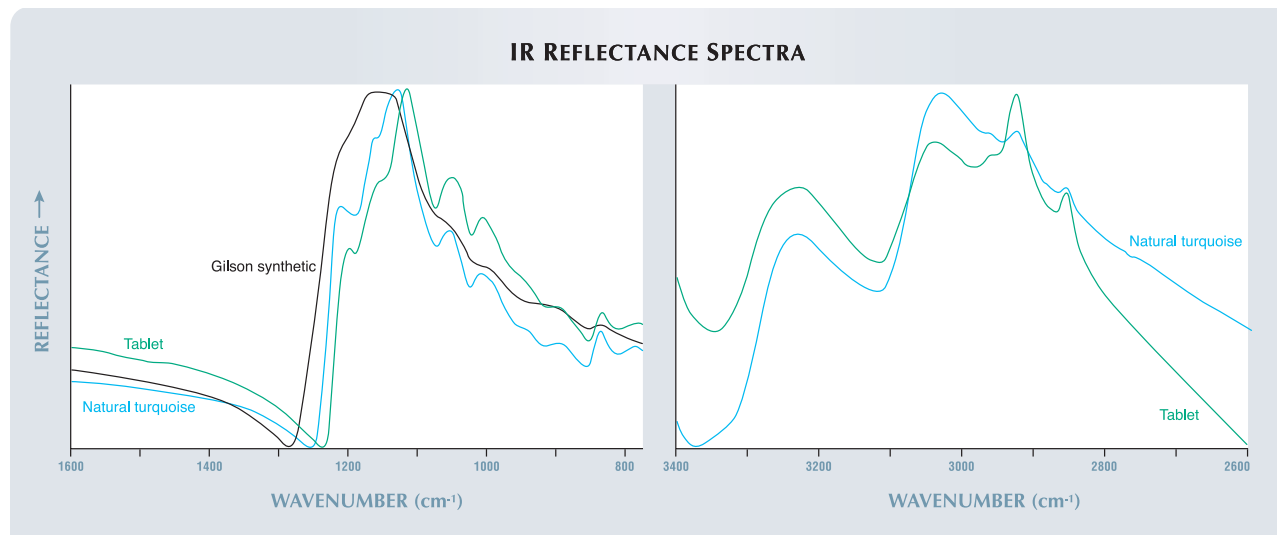
Figure 20. Comparing the diffuse infrared reflectance spectra of a natural turquoise, a Gilson synthetic turquoise, and the tablet in figure 19 indicated that the tablet is natural turquoise (left). No known polymer-related absorption bands, such as at 2965, 2930, and 2875 cm^{-1} were detected (right).

preparing an opaque sample for IR transmission spectroscopy requires scraping off a tiny amount of material and combining it with potassium bromide (KBr) into a small compressed pellet. Thus, it is both slightly destructive and somewhat time-consuming.

Recently, a bluish green turquoise tablet (22.44 × 20.24 × 5.68 mm) was submitted to the East Coast laboratory for identification (figure 19). It contained white veins and copper inclusions, and its spot refractive index was 1.60. Although the specific gravity of natural, untreated turquoise ranges from 2.60 to 2.90 (R. Webster, *Gems*, 5th ed., rev. by P. G. Read, Butterworth-Heinemann, Oxford, England, 1994), the S.G. of this tablet was only 2.47. This suggested that there might be some treatment, possibly plastic impregnation, causing a lower result. We considered whether this piece might have been subjected to the so-called Zachery treatment, but the S.G. of Zachery-treated turquoise is typically 2.61–2.74, with-

in the normal range (E. Fritsch et al., "The identification of Zachery-treated turquoise," Spring 1999 *Gems & Gemology*, pp. 4–16).

We then decided to test the tablet with diffuse reflectance infrared spectroscopy, rather than transmission spectroscopy. In this method, which requires no preparation or damage to the sample, the IR radiation penetrates the surface of an opaque gem only slightly, bounces off, and is collected by a curved mirror above it before passing to the detector.

The major peaks detected were at approximately 1125, 1050, and 1000 cm^{-1} (figure 20, left), indicating that it was natural (not synthetic) turquoise (again, see Fritsch et al., 1999). Additionally, no bands that could be attributed to any known polymers (such as Opticon or Pathalate) were detected (figure 20, right).

However, a strong absorption band was seen at 1746 cm^{-1}. To ensure that this band was not caused by mineral inclusions, we covered the turquoise

with a metal plate that had a 6 mm hole in the center, and tested the tablet again. The spectra obtained for both the blue area with white veins at the top and the pure blue area at the base showed the band at 1746 cm^{-1} (the spectrum for the metal plate was subtracted out). We do not know the assignment of this band.

This example shows that diffuse reflectance infrared spectroscopy is a simple, fast, and nondestructive method to help with the separation of natural and synthetic turquoise. It may also be used to help identify plastic (polymer) impregnation.

Kyaw Soe Moe, Paul Johnson, and Carol Pearce

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COLORED STONES AND ORGANIC MATERIALS

Ornamental blueschist from northern Italy. During the late 1990s, blueschist from a small number of localities in the lower Aosta Valley of the western Italian Alps was recognized as an ornamental material and polished into cabochons, beads, and other objects (see, e.g., figure 1). Since

Figure 1. Blueschist from Italy's Aosta Valley, with its combination of blue glaucophane, green omphacite, red garnet, and white calcite, has been polished into attractive objects, such as this 263 ct disk (80 × 4 mm). The material also shows a sparkly sheen when cut parallel to the foliation of the schist. Photo by A. Stucki.

then, its attractive and distinctive appearance has led to increased demand from Swiss and Italian lapidaries and local jewelers. It is estimated that a few hundred pieces (mostly cabochons) have been polished from this blueschist to date. In recent years, the annual production of rough blueschist has been in the range of a few hundred kilograms.

Blueschist is formed by the relatively high-pressure and low-temperature metamorphism of mafic rocks such as basalt. The overall blue color is due to the predominance of glaucophane (a sodic amphibole) in the rock. Outcrops of blueschist in the Aosta Valley are usually accompanied by eclogite and phengite schist (figure 2). Although blueschist is locally abundant and may form masses up to several meters wide, lapidary-grade material is quite rare, occurring as layers and lenses up to 30 cm thick. Such blueschist has a compact texture and is glaucophane-rich and mica-poor. These outcrops are found at elevations from 300 to 2,500 m, mostly in very steep, rugged terrain. Because of this, access is possible only by foot in most cases, and mining is commonly done by local collectors using simple hand tools.

Figure 2. This outcrop shows a tightly folded area of dark blueschist and adjacent light-colored phengite-rich layers. The hammer (provided for scale) is approximately 38 cm (15 inches) long. Photo by Daniela Rubatto.

The ornamental blueschist is dominated by millimeter-size prismatic crystals of glaucophane, ideally $NaMg_3Al_2(Si_8O_{22})(OH)_2$. Electron-microprobe analyses performed by this contributor and Dr. Barbara Kuhn at the Institute of Mineralogy and Petrography, ETH Zurich, determined that the glaucophane contains 7–8 wt.% FeO, which corresponds approximately to a composition of $glaucophane_{0.66}ferroglaucophane_{0.33}$ (a minor riebeckite component is also present). While glaucophane from

Figure 3. When viewed in thin section with a petrographic microscope, the blueschist is seen to consist of glaucophane with distinct blue-purple/near-colorless pleochroism, green omphacite, high-relief garnet that appears colorless, and interstitial colorless calcite. Photomicrograph by A. Stucki; field of view is approximately 5 × 4 mm.
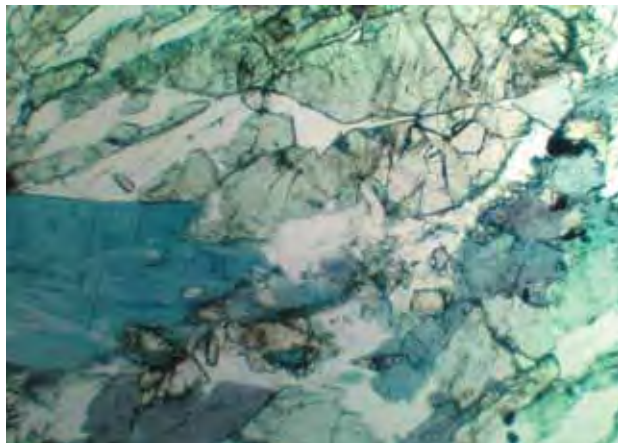
other localities (e.g., the Coast Range in California) is generally dark gray rather than blue and not very appealing as an ornamental stone, material from the Aosta Valley is characterized by an attractive, pure blue color without gray overtones. In thin section, the crystals show a distinct blue-purple/near-colorless pleochroism that is typical for iron-bearing glaucophane (figure 3). Also present in this ornamental material are green omphacite (with the composition $diopside_{0.3}hedenbergite_{0.1}jadeite_{0.5}aegirine_{0.1}$), brownish red garnet ($almandine_{0.6}grossular_{0.2}pyrope_{0.2}$), and varying amounts of pale yellow clinozoisite, white calcite, pyrite, and rutile.

This combination of blue, green, and red constituents with minor white and/or reflective spots results in a unique, striking appearance when properly fashioned. A schiller-like phenomenon is shown by polished surfaces cut parallel to the foliation of the schist; if cut perpendicular to this plane, the glaucophane will appear much darker and duller.

Because of its compact, interlocking microtexture, even thin pieces of blueschist from the Aosta Valley can be polished, some into fairly sizable objects. The main challenge for gem cutters is the large difference in Mohs hardness between the constituent minerals, notably garnet (7–7.5) and calcite (3).

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Emerald phantom crystal. At the July 2005 Jewelers of America Show in New York, Ray Zajicek of Equatorian Imports, Dallas, Texas, submitted an interesting emerald crystal from Colombia's Muzo mine to the AGTA laboratory for examination and research. This well-formed crystal (3.38 ct and 9.6 × 7.1 × 5.7 mm) had six hexagonal prism faces, and was terminated at one end by a basal pinacoid with six small rhombohedral faces.

Inside the crystal, we observed numerous growth tubes and densely concentrated primary fluid inclusions that had accumulated in the center. Collectively, these inclusions formed a translucent phantom that appeared a much lighter green in comparison to the deeper color of the transparent outer zone (figure 4).

The shape of the phantom corresponded almost exactly to the form of the outer parent crystal. The outer portion contained far fewer inclusions. These were primarily three-phase inclusions of brine, a vapor bubble, and a cubic crystal of salt—which are typical of, and well-known as, inclusions in Colombian emeralds.

Growth phantoms in emerald are not at all common. This was one of the best examples these contributors have encountered.

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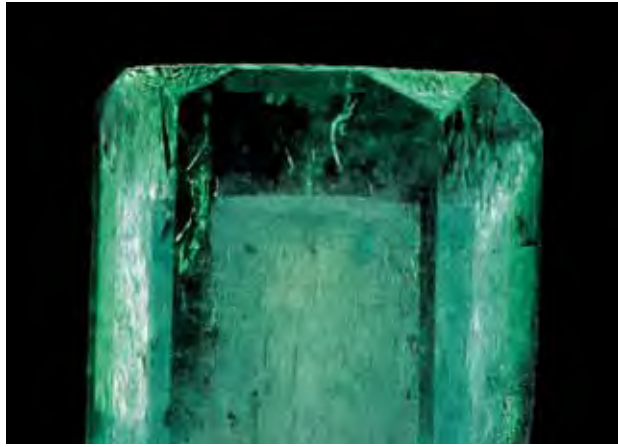
Figure 4. The phantom in this 3.38 ct emerald crystal from the Muzo mine in Colombia is an unusual growth feature. Photomicrograph by John I. Koivula; courtesy of microWorld of Gems.

Figure 5. These "Nectar of Life" earrings incorporate two unusual trapiche emeralds (19.40 and 19.69 ct). Courtesy of Sandra Müller; photo © Harold & Erica Van Pelt.

Unusual trapiche emerald earrings. The gem world is filled with remarkable oddities. However, the very qualities that make these gems notable often make them unsuitable for use in conventional jewelry, leaving them confined to the realm of "collectors' stones." It is therefore fairly rare to encounter jewelry featuring stones that are truly distinctive in a gemological sense.

In late July 2005, the AGTA Gemological Testing Center reported on a pair of unusual trapiche emeralds (see www.agta-gtc.org/2005-07-26_trapiche_emerald.htm). Unlike most such emeralds, these two stones (19.40 and 19.69 ct) had a colorless outer zone that had been cut into the shape of a six-rayed star, with each arm of the star radiating from a hexagonal prism face of the emerald core. These gems have now been used to great advantage in a unique pair of earrings (figure 5) by jewelry designer Sandra Müller (Sandra Müller Fine Jewelry, Los Angeles).

Titled "Nectar of Life," the jewelry is intended to portray slices of star fruit descending from strips of lemon peel. The star fruit dangles contain the trapiche emeralds in gold settings with yellow diamonds. (Star fruit is actually five-rayed, but one can forgive this as artistic license.) The upper "lemon peels" are green gold set with green, yellow, and colorless diamonds. Because of their weight, the earrings are designed to hook inside the wearer's ears rather than on the ear lobes.

Clearly, even gemological oddities can make beautiful jewelry, given sufficient artistic vision and inspiration.

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A large greenish yellow grossular from Africa. The GIA Gem Tech Lab recently examined a 68.55 ct greenish yellow round brilliant (figure 6) that, according to the client, was a garnet from East Africa. This stone showed unusually intense greenish yellow coloration and exhibited very distinct roiled ("scotch in water"; figure 7) structure that is typical for the hessonite variety of grossular.

The sample was examined by standard gemological testing and various spectroscopic methods. The R.I. was 1.743, and the S.G. (measured hydrostatically) was 3.62. Viewed between crossed polarizing filters, the sample was isotropic but exhibited very distinct strain that followed the granular swirl-like structure seen with the microscope. These results, as well as the specular reflectance FTIR spectrum, provided a good match with hessonite. EDXRF chemical analysis was consistent with a calcium-aluminum garnet ($Ca_3Al_2[SiO_4]$), which confirms grossular, with a significant amount of Mn and Fe present. These impurities are commonly found in hessonite, but the quantity of Mn detected was greater than is typically seen in this gem variety.

The UV-Vis-NIR absorption spectrum (figure 8) also was unusual for grossular, with three strong bands at 372, 409, and 430 nm, and two weaker bands at 418 and 455

Figure 6. This 68.55 ct grossular from East Africa shows an unusually bright greenish yellow color. Photo by T. Hainschwang.

Figure 7. With magnification, the grossular in figure 6 showed the distinct roiled "scotch in water" appearance that also is typically seen in hessonite. Photo by T. Hainschwang; magnified 8×.

nm. These absorptions can be attributed to Mn^{2+} (see Winter 1991 Gem News, p. 258). The intense manganese absorptions cause the steep slope starting at around 500 nm and cut off nearly all the blue in the spectrum. This feature, combined with high transmittance from 500 to 750 nm, is responsible for the unusually intense greenish yellow color in this garnet.

Manganese typically plays only a minor role in the coloration of grossular/hessonite. In the experience of these contributors, although Mn^{2+} bands are often present in this

material, they are very weak. In typical orange hessonite, the spectrum is a featureless broad band with greater transmittance in the orange and red parts of the spectrum. This broad band is attributed to $Fe^{2+} \rightarrow Ti^{4+}$ intervalence charge transfer, so the orange color in grossular is mainly due to this mechanism (E. Fritsch, pers. comm., 2005).

The client did not know precisely where in East Africa the material was found or whether more of this attractive garnet is available in the market.

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Figure 8. The UV-Vis-NIR absorption spectrum of the grossular showed very strong Mn^{2+}-related absorptions. These absorptions are responsible for the strong greenish yellow color, in contrast to the usual orange appearance of hessonite.

UV-VIS-NIR SPECTRUM
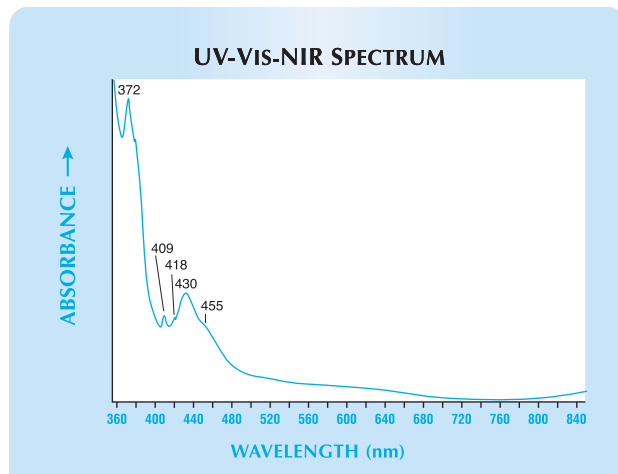
An opal triplet resembling an eye. Bill Hawes (Conifer, Colorado) recently brought to our attention a 9.75 ct (1.8 × 1.6 cm) opal triplet with an unusual pattern of play-of-color that resembled an eye (figure 9). He said that the opal was mined by Bob and Susan Thompson at their claim in eastern Idaho. Reportedly the Thompsons have also found one additional opal with a similar concentric pattern, which has been fashioned as a triplet and set into a pendant.

The triplet loaned by Mr. Hawes consisted of a very thin (0.1 mm) layer of opal that was glued to a black opaque backing with colorless cement, and covered by a colorless glass top. The opal showed strong play-of-color, with a near-round "pupil" surrounded by a multicolored "iris" that showed a radiating columnar structure. As seen in figure 9, the "pupil" appeared yellowish green in typical viewing environments. However, when illuminated with a fiber-optic source at an oblique angle, the "pupil" showed patchy violet and orange coloration. Although we could not measure the R.I. of the colorful layer (because it
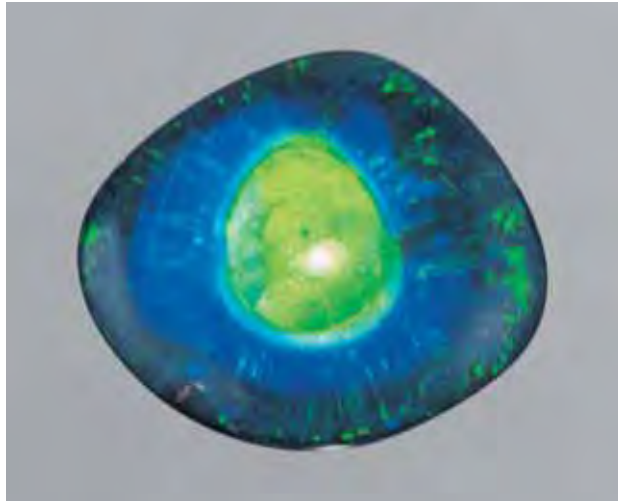
Figure 9. This unusual 1.8 × 1.6 cm opal triplet bears a striking resemblance to an eye. Courtesy of Bill Hawes; photo by Maha Calderon.

was so thin, and there was a risk of damaging the cement with the R.I. liquid), it was identified as opal by its diagnostic play-of-color. The natural or synthetic origin of the opal could not be ascertained due to its narrow thickness. However, the columnar structure more closely resembled that which is typical of synthetic opal. The GIA Laboratory has not previously encountered an opal (natural or synthetic) with this intriguing appearance.

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BML

Green orthoclase feldspar from Vietnam. In July 2005, these contributors received some interesting transparent "emerald" green samples that were reported to be amazonite from a new find in Vietnam. Five faceted stones were loaned and several pieces of rough were donated to GIA by Bill Larson (Pala International, Fallbrook, California). According to his supplier, Son T. Ta (I.T.C. International Trade Center, Ho Chi Minh City, Vietnam), they were mined from a pegmatite near Minh Tien, about 15 km south of Luc Yen in Yen Bai Province. This area is also known to produce transparent green fluorite, which when cobbed is similar in appearance to gem-quality orthoclase.

The following properties were obtained by GIA staff gemologist Eric Fritz on the five faceted feldspars (1.31–3.68 ct; see, e.g., figure 10): color—green; pleochroism—green and colorless; R.I.—1.521–1.529, with a birefringence of 0.008; and S.G.—2.58. They were inert to long-wave UV radiation, but displayed a moderate green fluorescence to short-wave UV (with no phosphorescence). When viewed with a desk-model spectroscope, no absorption features were seen. There was no reaction when they were observed with a Chelsea color filter.

Although the internal features were not recorded in these faceted samples, a subsequent examination of one piece of transparent rough revealed only fingerprint-like inclusions and a plane of minute transparent brown angular crystals. In addition, two-phase inclusions, apatite, and minute ruby crystals were reported in green Vietnamese orthoclase by J. Ponahlo et al. ("Transparent green orthoclase, a new ornamental stone from north Vietnam," *28th International Gemmological Conference, Extended Abstracts*, Madrid, Spain, 2001, pp. 71–75).

The green feldspar also was studied by one of us (GRR) using additional techniques. Infrared spectroscopy of a powdered sample in attenuated total reflectance (ATR) mode showed that it resembled orthoclase more closely than microcline (figure 11). Although X-ray diffraction analysis would be necessary to precisely establish the state of "order" of the feldspar (i.e., the distribution of Al and Si between tetrahedral sites)—and therefore its position within the orthoclase-microcline series—the IR spectrum did reveal diagnostic absorption features for orthoclase. The color of this feldspar is consistent with the observations of A. M. Hofmeister and G. R. Rossman, who found that lead-containing orthoclase turned green upon irradiation, microcline became blue, and intermediate feldspars turned blue-green ("A spectroscopic study of irradiation coloring of amazonite: Structurally hydrous, Pb-bearing feldspar," *American Mineralogist*, Vol. 70, No. 7/8, 1985, pp. 794–804). The green-to-blue color of such feldspars is due to color centers created by the exposure of the lead component in the feldspar to natural radiation from the surrounding rock and the potassium feldspar itself. The lead content of one of the Vietnamese feldspars was determined by energy-dispersive X-ray spectroscopy to be 0.29 wt.% PbO, and it had a formula of $K_{0.84}Na_{0.15}Pb_{0.004}AlSi_3O_8$. Even higher contents of lead (0.5 wt.% PbO) were measured in feldspar from this region by Ponahlo et al. (2001). The green color of the orthoclase results from the

Figure 10. These transparent green orthoclase gemstones from Vietnam weigh 1.31–3.68 ct. Courtesy of Pala International; photo by C. D. Mengason.
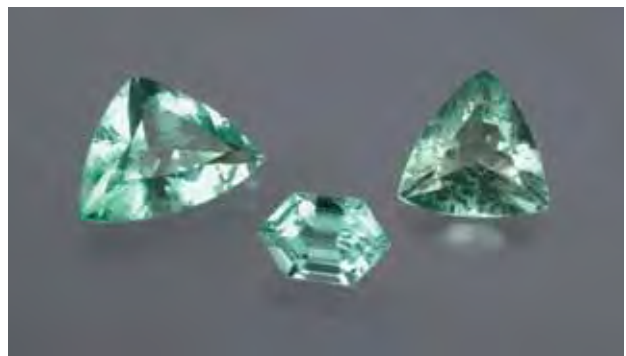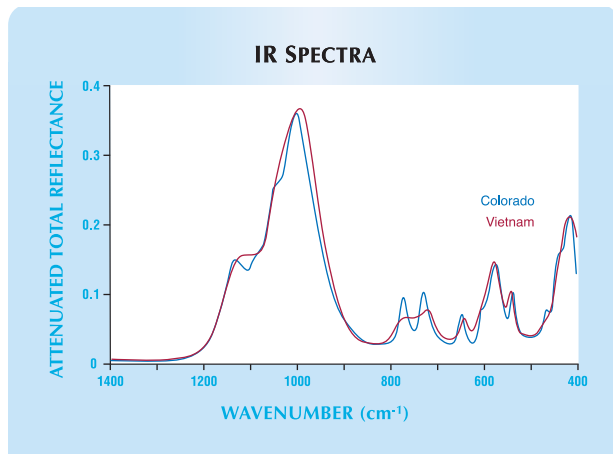
IR SPECTRA

Figure 11. These IR spectra were taken of powdered green and blue-green samples of K-feldspar from Vietnam and Colorado, respectively. Greater Al/Si ordering produces sharper spectral features, as seen in the microcline (highly ordered) from Colorado. In contrast, the less-resolved spectral features (particularly in the 750 cm^{-1} region) shown by the Vietnamese K-feldspar correlate to an intermediate amount of ordering, indicating that it is orthoclase.

presence of a broad absorption band centered at 720 nm (figure 12) that is strongly dependent on crystallographic orientation (producing the corresponding pleochroism). This band is not easily seen with a hand spectroscope due to its broad nature.

Figure 12. A broad absorption band centered at 720 nm is responsible for the green color of the Vietnamese orthoclase. This absorption was strongly dependent on crystallographic orientation, producing the distinct pleochroism shown by the material. These spectra were obtained from a sample approximately 1 cm thick, and were normalized to 1 cm in each crystallographic direction.

VIS-NIR SPECTRA
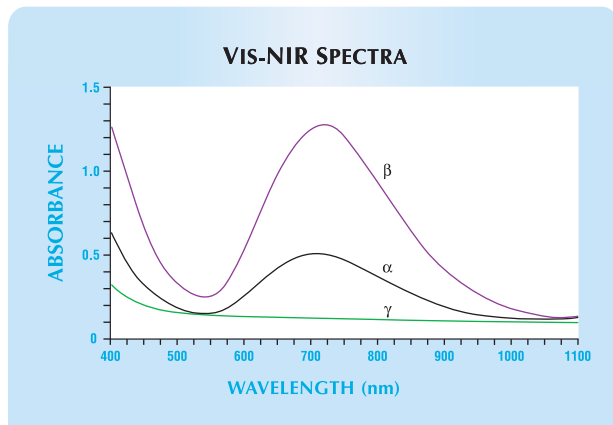
This gem feldspar from Vietnam is typically sold as *amazonite*, which is a varietal name referring to blue-to-green K-feldspar (generally microcline, rather than orthoclase). Transparent green microcline is unknown to these contributors in the gem market, and it is very uncommon for green orthoclase to be facetable. Such material was previously documented from just two localities: Broken Hill, New South Wales, Australia (F. Čech et al., "A green lead-containing orthoclase," *Tschermaks Mineralogische und Petrographische Meitteilungen*, Vol. 15, Issue 3, 1971, pp. 213–231) and Minas Gerais, Brazil (J. Karfunkel and M. L. S. C. Chaves, "Transparenter, schleifwuerdiger, gruener Barium-Orthoklas aus Minas Gerais, Brasilien [Transparent, polishable, green barium orthoclase from Minas Gerais, Brazil]," *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 43, Issue 1–2, 1994, pp. 5–13).

Interestingly, Mr. Larson recently brought to our attention some nearly transparent green feldspar (figure 13) that was reportedly mined from Pazunseik in the Mogok area of Myanmar (Burma).

BML

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Figure 13. This crystal and cabochon (12.7 ct) of green feldspar are from the Mogok area of Myanmar. Courtesy of Pala International; photo © Jeff Scovil.

New discoveries of painite in Myanmar (Burma). Painite was discovered in the early 1950s in the vicinity of Mogok, Burma. For many years, only two crystals of painite (1.7 and 2.1 g) were known to exist. Much later, a third crystal was discovered in a batch of gem rough at GIA (J. E. Shigley et al., "New data on painite," *Mineralogical Magazine*, Vol. 50, 1986, pp. 267–270). The extreme rarity of painite began to change in 2001, with the discovery of an 11 g (55 ct) crystal, also near Mogok. The local gemologists suspected that it was painite, but they did not have the means to make a firm identification. A small portion of the crystal was removed and sent to this contributor's laboratory, where it was confirmed as painite. Shortly thereafter, an approximately 2.5 ct faceted painite was identified at a gem-testing laboratory in Thailand.

According to a Burmese source, additional specimens of painite were discovered in secondary deposits around Mogok in 2004, and local miners and geologists rushed to locate the primary source. In May 2005, these efforts were rewarded in an area near Mogok with the discovery of *in-situ* painite at Thurein-taung and at the Wetloo mine.

More than a thousand crystals and crystal fragments have been recovered. Although only a small percentage of the rough was suitable for faceting, numerous stones have been cut, mostly in small sizes. Of the more than 167 faceted painites that are currently known to this contributor, most range from 0.05 to 0.30 ct, although stones weighing up to 1.32 ct have been cut (figure 14). In addition, a 2.02 ct painite was recently faceted (see www.aigslaboratory.com/painite.php).

Interest in painite grew with the discovery of another source in northern Myanmar, near the village of Namya (or Nanyaseik) in 2002. The discovery occurred when this contributor identified two painite crystals in a bag of heavy mineral concentrates from this area that was remained after the gems had been picked out. The concentrates contained mostly spinel, some corundum, and minor zircon. The painite from Namya is pale pink, much different from the dark reddish to orangy brown material found in the Mogok region. In addition, the few crystals of Namya painite found to date are all quite small (most are <1 ct).

A detailed chronology of painite discoveries, as well as absorption spectra, are available on the Internet at http://minerals.gps.caltech.edu/FILES/Visible/painite/Index.htm. Further information on the gemological and chemical properties of painite from Mogok will be reported in a future article.

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Gem plagioclase reportedly from Tibet. Facetable labradorite has been known from Oregon for many years (see, e.g., C. L. Johnston et al., "Sunstone labradorite from the Ponderosa mine, Oregon," Winter 1991 *Gems & Gemology*, pp. 220–233); and more recently, gem-quality plagioclase was reported to come from the Democratic Republic of the Congo (Spring 2002 Gem News International, pp. 94–95). The Spring 2002 GNI entry documented the physical properties of three red samples of this feldspar, indicating that they were andesine with slightly less than 50% anorthite content. A later study illustrated a variety of colors, including red, green, pale yellow, and colorless, and chemical analysis of three samples showed that they were labradorite, with an anorthite content of An_{52-55} (M. S. Krzemnicki, "Red and green labradorite feldspar from Congo," *Journal of Gemmology*, Vol. 29, No. 1, 2003, pp. 15–23).

Since this colorful "Congolese" plagioclase first appeared on the market in 2002, various gem dealers have attempted to verify its origin and obtain rough material, but both endeavors proved elusive. Some dealers pointed to China as the most likely source of the material. In July 2005, GIA received a donation of rough gem feldspar, reportedly from China, from Mark Smith (Thai Lanka Trading Ltd., Bangkok, Thailand). He had been obtaining such material since 2002 from a reliable Chinese supplier, who indicated that it was from a deposit in western China that is mined on a seasonal basis due to cold winter weather.

Additional information and rough samples were provided in October 2005 by mine owner Jackie Li (Do Win Development Co. Ltd., Tianjin, China) and her U.S. marketing partner, Bob Schwarztrauber (Buffalo, New York). They claim that their deposit is located in an isolated mountainous area of central Tibet near Nyima. Organized mining began in October 2002. The area is underlain by volcanic rocks, and the best feldspar production has occurred from secondary deposits to a depth of about 4 m. The deepest pits reach down to 10 m, and have been excavated using only

Figure 14. Recent finds of painite near Mogok, Myanmar, have increased the availability of this rare gem. The faceted examples shown here range up to 1.32 ct. Courtesy of Bill Larson (Pala International, Fallbrook, California) and Mark Kaufman (Kaufman Enterprises, San Diego); photo by Shane F. McClure.

Figure 15. Tibet is reportedly the source of these faceted plagioclases (up to 2.22 ct). The samples on the right show the bright orange-red color that is typical of the better-quality production from the deposit. Strong direct lighting was used to display the brownish red color of the stone on the far left; when viewed in diffused light, this sample appears green. Photo by Jackie Li.

hand methods due to the remoteness of the locality. Because of the cold winters, the mine is closed from November to April. During the mining season they recover enough rough to produce about 300–800 carats of faceted stones each month. These commonly weigh 2–3 ct (figure 15), but a few clean stones of ~30 ct have been cut. The rough material typically ranges up to 4 g, and most of it is orange-red with a small amount of green produced. In addition, the deposit has yielded rare pieces that appear green in diffused light and red when illuminated with a pinpoint light source, as documented by Krzemnicki (2003). The mining area also produces brown, orange, yellow, and colorless material, similar to the range of colors documented by Krzemnicki (2003). However, the latter color varieties are generally not collected by the miners due to the low demand for such material.

A preliminary chemical analysis was made on a faceted red sample of this feldspar that was obtained by GIA at the 2005 JCK show in Las Vegas, where it was represented as Chinese sunstone. The analysis was performed using energy-dispersive X-ray spectroscopy by Dr. George Rossman at the California Institute of Technology, Pasadena, and indicated that the feldspar was andesine (An_{46}) with traces of Fe, Cu, and Ti.

BML

Spinel from southern China. In June 2005, John Bailey (Klamath Falls, Oregon) sent GIA a parcel of spinel that was reportedly from China. He purchased the rough at the 2005 Tucson gem shows from a Chinese dealer who stated the material was from the Jinping area (Yunnan Province), near the border with Vietnam. Mr. Bailey indicated that most of the rough appeared alluvial, with varying degrees of wear. Some of the pieces in the first parcel he obtained showed variable presentation of octahedral faces, whereas

all of the rough in a second parcel was completely rounded. The largest stone he has faceted is a dark red 6.56 ct round checkerboard cut, but most of the stones cut so far range from 0.5 to 2 ct.

Mr. Bailey loaned and donated several rough and cut samples to GIA for examination. The gemological properties of five faceted stones (0.97–6.56 ct; see, e.g., figure 16) were recorded by GIA staff gemologist Eric Fritz: color—pink to purple or purplish red to brownish red to red; R.I.—1.716 (±0.001); and S.G.—3.59–3.61. Two samples (pink and purplish red) exhibited very weak red fluorescence to long-wave UV radiation; the remaining three were inert. All of the samples were inert to short-wave UV radiation. When viewed with a desk-model spectroscope, there was a weak broad region of absorption below 600 nm in three of the samples. The pink and the purple-red spinels also showed an absorption cutoff at 430 nm, and the pink sample also showed "chrome lines." There was no reaction to a Chelsea color filter.

The rough spinel parcels obtained by Mr. Bailey contained some pieces that were doubly refractive. Raman analysis at GIA of a reddish orange sample that was cut from one of these pieces (again, see figure 16) identified the stone as a member of the humite group, with the closest spectral match to clinohumite. In our experience, reddish orange is an unusual color for clinohumite.

BML

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Update on tourmaline from Mt. Mica, Maine. Gem miners are notorious for predicting that bigger and better discoveries will happen if they dig a little deeper. In July 2005, this came true for one of us (GF, together with Coromoto Minerals LLC mining crew Jim Clanin and Richard Edwards) at the Mt. Mica tourmaline mine in Oxford County, Maine. As stated in a recent *Gems & Gemology* article on Mt. Mica (W. B. Simmons et al., "Mt. Mica: A

Figure 16. The four stones on the left (0.81–1.80 ct) show colors typical of the spinel from China. The 0.49 ct round brilliant on the far right was cut from the same parcel, but it proved to be a member of the humite group (probably clinohumite). Courtesy of John Bailey; photo by C. D. Mengason.
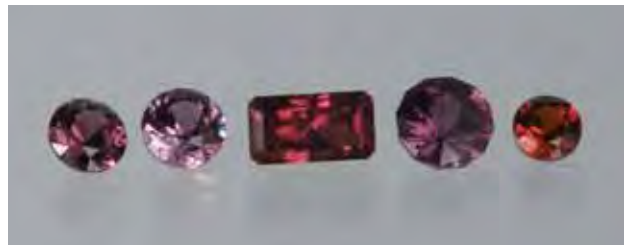
Figure 17. In July 2005, a very large cavity containing quartz, tourmaline, and other minerals was found at the end of an approximately 25-m-long tunnel at Mt. Mica, Maine. The sides of the tunnel consist of pegmatite rock, whereas the dark-colored ceiling is the metamorphic host rock. Several small vugs were found along this tunnel before the large pocket was encountered a few meters beyond the orange fan. Photo by B. M. Laurs.

renaissance in Maine's gem tourmaline production," Summer 2005, pp. 150–163), additional mineralization was expected down-dip of the zone explored by Coromoto

Figure 18. After several weeks of excavation, the cavity at Mt. Mica measured approximately 11 m long. A ramp was constructed for transporting buckets of pocket material through a small passageway into the main tunnel. Here, mine owner Gary Freeman digs material from the base of the pocket while miner Richard Edwards looks on. Note the mud-encrusted quartz crystals on the pocket wall in the right foreground. Photo by B. M. Laurs.

Minerals from May 2004 to June 2005. Work has continued in the tunnel (figure 17), and on July 7 the initial section of 2005 pocket number 11 was discovered (see G. Freeman, "August 2005 Mount Mica update," *Rocks & Minerals*, Vol. 80, No. 6, 2005, pp. 409–410). Once fully excavated, this may prove to be the largest cavity ever recorded at Mt. Mica.

The first sign of the large pocket came when a small satellite cavity was discovered while drilling, and a large volume of water exited the pocket system. Initially more than 2,000 liters/day of water poured from the hole, providing a strong indication that the cavity was extremely large. After two weeks of mining, the main cavity was intercepted. Over the following six weeks, a chamber was partially excavated that measured approximately 11 m long, up to 2.1 m tall, and 1.5 m wide. The pocket was accessed through a narrow opening of approximately 0.5 m in diameter, thus preserving as much of the cavity walls as possible. Once inside the pocket, there was plenty of room to work; a ramp was installed and a hand-pulled sled used to transport 5-gallon buckets of material into the main tunnel (figure 18). Up to three buckets at a time could be moved out of the pocket in this fashion.

In late August 2005, one of these contributors (BML) visited Mt. Mica with filmmaker Pedro Padua from GIA's Course Development Department. By this time, much of the pocket had been excavated, but there were three areas that continued to yield material. Because everything in the pocket was wet and covered with sticky red-brown clay, it was difficult to see the mineralization and excavations were done mostly "by feel." In addition, as with earlier cavities encountered at Mt. Mica, the pocket contents were pervasively iron-stained. Limited exposures of the cavity

Figure 19. Possible extensions of the mineralization were explored by drilling a few carefully placed holes to depths up to 2 m. The drill is powered by compressed air and the bit is cooled by water, so even a few minutes of drilling produces a fine mist. Photo by B. M. Laurs.

Figure 20. This green tourmaline (approximately 3 cm wide) is shown shortly after its discovery, still embedded in the pocket mud next to a quartz crystal. The screwdriver (left) was used to carefully excavate the mud from around the crystals. Photo by B. M. Laurs.

Figure 21. After it was removed and the mud wiped off its faces, the tourmaline in figure 20 was found to be part of a larger crystal; this segment measured approximately 3 × 8 cm. Photo by B. M. Laurs.

Figure 22. A stacked screening apparatus with two mesh sizes was constructed by Mt. Mica miner Jim Clanin, who is shown here hand-picking tourmaline from the lower screen with helper Missy Robinson. Several buckets of pocket material can be washed and picked each hour. The inset shows a green tourmaline that was found during the initial washing of a bucket of pocket material. Photos by B. M. Laurs.

walls revealed areas of cleavelandite, massive quartz, lepidolite, black tourmaline, and quartz crystals with a pale smoky color. To plan directions for future mining and test for possible extensions of the mineralization, a few carefully placed holes were drilled into the pocket walls (figure 19), and two of these revealed continuations of the pocket. From one of these areas, groundwater seeped continuously into the pocket. A small pump operated during the day, but the pocket was left to flood each night, so the ice-cold water would discourage highgraders.

The pocket contents consisted mostly of quartz and feldspar fragments with some large (>100 kg) well-formed quartz crystals, as well as quartz clusters and irregular plates, that were covered with yellow-brown mud. Although most of the tourmaline crystals were not revealed from the mud until the material was washed, the larger, visible crystals were carefully worked out by hand from the surrounding quartz crystals and other pocket debris (figure 20). The largest tourmaline found during this visit was a green crystal section that measured approximately 3 × 8 cm (figure 21). Much larger tourmalines were produced during the initial stages of the pocket excavation, including a 20-cm-long specimen that is pictured by Freeman (2005). In addition, a few colorless to pale pink beryl crystals also were recovered.

After the pocket material was transported to the surface, it was washed on a stacked screening apparatus (figure 22). Two mesh sizes (1 cm and 0.3 cm) were used, and the smaller fraction was stockpiled after hand picking for future jigging. The vast majority of the tourmaline production from this pocket consisted of small crystals (typically 1–3 cm long and 0.5 cm in diameter). Most were pale green, but yellow-green, dark green, colorless, pink, and bicolored pink-green crystals were also seen (see, e.g., figure 23). Some of the pink or green crystals had flat black terminations, such as those analyzed by Simmons et al. (2005) as foitite. In total, the pocket produced approxi-

Figure 23. Most of the tourmaline in the pocket was green, although bicolored crystals were common and a limited amount of pink material (some showing chatoyancy) was recovered. The largest crystal shown here measures 13 × 13 × 10 cm. Photo by Leonard Himes.

mately 90 kg of tourmaline, with less than 1% suitable for faceting. A few medium to light green stones have been cut so far, ranging from melee to about 4 ct. The facet-grade rough is being stockpiled along with the material from prior pockets.

Some interesting geologic observations were made during the excavation of this unusually large pocket. First, it is quite uncommon for a single pocket to yield so many colors of tourmaline. The tourmaline also showed good luster, in contrast to most of the material recovered from the other large cavities at Mt. Mica—such as 2004 pocket number 28, documented by Simmons et al. (2005) and in a later article ("New tourmaline production from Mount Mica, Maine," *Rocks & Minerals*, Vol. 80, No. 6, 2005, pp. 396–408). Also of note is the fact that large pegmatite pockets do not necessarily produce large tourmaline crystals. In fact, the best-quality gem material found at Mt. Mica was actually recovered from small vugs.

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Cu- and Mn-bearing tourmaline: More production from Mozambique. The Fall 2004 issue of *Gems & Gemology* reported on a new source of copper- and manganese-bearing tourmaline from Mozambique (see Lab Notes, pp. 250–251), and additional data on these samples were pres-

ented in the Summer 2005 issue (Lab Notes, pp. 173–175). During the September 2005 Hong Kong International Jewelry Fair, one of us (AA) saw several brightly colored tourmalines, from what is reportedly a new find in Mozambique, at the booth of W. Constantin Wild & Co. (Idar-Oberstein, Germany). According to a press release issued by that company (www.gemstone.de/gemstones/news/unheatedTourmaline.php), the material was mined in May 2005 from the Alto Ligonha region. The tourmalines occurred in a variety of colors, including violet, pink, and blue to green, and were faceted into stones ranging up to 6 ct.

In August 2005, the research laboratory of the Gemmological Association of All Japan (GAAJ) received 12 faceted samples of the highly saturated blue and blue-green Mozambique tourmalines, ranging from 0.70 to 6.11 ct (see, e.g., figure 24), for examination. Standard gemological properties were obtained on all samples: R.I.—n_e=1.620 (±0.001), n_o=1.639 (±0.002); birefringence—0.019 (±0.001); and fluorescence—inert to short-wave UV radiation and inert or yellow-green to long-wave UV. Strong pleochroism was displayed, with green-blue parallel to the optic axis and blue perpendicular to the optic axis in the blue stones. The corresponding pleochroic colors in the blue-green stones were blue and green. The internal features consisted of fluid inclusions, two-phase fluid-and-gas inclusions, and healed fractures typical of tourmaline; no particles of native copper were observed, such as those seen in tourmalines of these colors from Paraíba, Brazil and Edeko, Nigeria.

Chemical analysis of the seven blue samples with EDXRF showed small amounts of Cu and Mn, as well as trace amounts of Ca, Ga, Pb, and Bi; no Ti or Fe was detected. The five blue-green tourmalines contained relatively high concentrations of Cu and Mn, as well as the other

Figure 24. Bright blue and blue-green colors are displayed by these Cu- and Mn-bearing tourmalines from Mozambique (0.36–2.53 ct). Photo by H. Kitawaki.

trace elements detected above plus Zn. Quantitative chemical analysis performed with an LA-ICP-MS system recorded 0.26–0.51 wt.% CuO and 0.03–0.40 wt.% MnO in the blue tourmalines. Significantly greater amounts of these elements were found in the blue-green samples: 2.08–3.21 wt.% CuO and 3.55–4.81 wt.% MnO. Additional trace-element data on these new tourmalines, including a comparison to Cu- and Mn-bearing tourmalines from other localities, will be reported in a future article.

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SYNTHETICS AND SIMULANTS

Lizard in amber? A private collector brought an impressive sample of what appeared to be a well-preserved lizard in yellow amber (figure 25) to the SSEF Swiss Gemmological Institute for identification. The piece, which measured 15 × 8 × 2.5 cm and weighed 196 g, looked almost too good to be true: The reptile was in excellent condition, and its scales were still green and sharply defined. The top of the sample was polished with a domed surface, while the bottom was rough and chipped.

The characterization of such an item requires identification of the resin and confirmation that the sample was not assembled or otherwise created artificially. The rough bottom surface made it easy to remove a minute amount of the material for an FTIR powder spectrum (KBr pellet method), which was performed by Dr. Stefan Graeser of the Mineralogical-Petrographic Institute at Basel University. While the recorded spectrum was consistent with a natural resin, unfortunately it did not allow discrimination between the three possibilities: amber, copal, and kauri gum. When the sample was rubbed with a piece of fabric, a strong aromatic smell was produced. This ruled out amber, since the material clearly contained unevaporated volatiles. Further rubbing with a cotton swab dipped in ether had no effect on the sample; this ruled out copal, which would have dissolved slightly.

For comparison with a known specimen of lizard in amber, we contacted the Natural History Museum of Basel and were given permission to examine a well-known *Anolis* lizard in Dominican amber (see E. J. Gübelin and J. I. Koivula, *Photoatlas of Inclusions in Gemstones*, ABC Edition, Zurich, 1986, p. 227). This sample displayed clear anomalous double refraction between crossed polarizers (figure 26), whereas the client's piece showed no strain in the material, around either the lizard or the numerous bubbles. Magnification revealed that the feet of the museum's reptile were dark brown and almost dissolved, while delicate features in the feet of the client's lizard were still intact (figure 27). X-radiography also produced some interesting results: While the *Anolis* lizard had only a weak skeletal outline, the bones and even soft tissue of the client's lizard were clear and sharp (figure 28). The latter

Figure 25. This most unusual sample (15 × 8 × 2.5 cm) proved to consist of a modern lizard that was artificially embedded in a natural resin. Photo by H. A. Hänni; © SSEF.

image also showed broken bones in both upper arms, as well as the presence of fine shrinkage fissures in the resin along the length of the lizard.

Because we still lacked sufficient information to make a definitive identification, we decided to send some detailed pictures to a specialist in the field, Dr. David Grimaldi of the American Museum of Natural History in New York. He concluded from the submitted information that the sample was one of a number of specimens of lizards in kauri gum from New Zealand that were known to have been

Figure 26. For comparison with the sample in figure 25, we examined a well-known specimen (7.1 cm long) of a lizard in amber from the Museum of Natural History in Basel. Observation of this sample between crossed polarizers revealed the strong anomalous double refraction that is typically seen around inclusions in true amber. This reaction was not present in the manufactured sample. Photo by H. A. Hänni; © SSEF.

Figure 27. Delicate features are preserved in the feet of the lizard in the manufactured specimen. This degree of preservation was not seen in the museum's reference specimen. Photo by H. A. Hänni; © SSEF.

Figure 29. Though presenting a convincing appearance as a pebble of sapphire or tanzanite, this sample (34 × 21 × 20 mm) proved to be manufactured from cubic zirconia. Photo by Min Htut.

manufactured at the beginning of the 20th century and subsequently mounted for display by naturalists. The surface of the sample had evidently aged enough so that no reaction occurred when it was rubbed with a cotton swab dipped in ether. We reported to the client that this was a modern lizard artificially embedded in a recent natural resin.

HAH

Cubic ziconia as rough sapphire imitation. Recently, a 38.44 g dark blue "pebble" was submitted to the AGTA laboratory for identification. It had been purchased in Africa by missionaries, and the client wanted to know if it was a sapphire or a tanzanite.

Figure 28. An X-radiograph of the manufactured sample produced a clear, sharp image of the lizard's skeleton, as shown here. By comparison, the fossilized lizard in the museum's specimen showed only a weak skeletal outline. Image by H. A. Hänni; © SSEF.

The sample superficially resembled waterworn gem rough. As can be seen in figure 29, its surface was covered with pits and grooves that were filled with a yellowish brown soil-like substance, making it appear very dark. Only with transmitted light was the transparent blue nature of the sample apparent. Because there was no polished surface, a refractive index could not be taken.

When the piece was exposed to long-wave UV radiation, we observed a strong green reaction, which excluded both sapphire and tanzanite. In short-wave UV, the stone displayed a weak chalky white fluorescence. The rough surface made it difficult to look inside the sample for inclusions, and only a few fractures could be seen.

Chemical analysis with EDXRF showed Zr and Y with minor Hf, Fe, Cl, K, and Ca, but no Al or Si as would be expected in a natural stone. A Raman spectrum confirmed that this unusual fake was manufactured from cubic zirconia.

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Barium-rich glass sold as diamond rough. Recently a parcel of what was represented as octahedral diamond rough was submitted to the GIA Gem Tech Lab for identification. All of the material was pale yellow except for one colorless piece. This 1.53 ct rounded octahedron also caught our attention because of the condition of its edges, which had a granular appearance (figure 30) unlike anything we had previously seen on diamond rough. No inclusions were visible in this octahedron at 10× magnification or when it was examined in immersion at higher magnification.

The octahedron showed strong blue fluorescence to long-wave UV radiation (figure 31) and moderate blue fluorescence to short-wave UV. This reaction was similar to that seen in some natural diamonds. However, when this piece was examined between crossed polarizers, we observed a cross-like strain pattern (figure 32), which is

Figure 30. At first glance, this 1.53 ct rounded octahedron has the appearance of a rough diamond crystal. The granular surfaces seen along its edges raised suspicions about its origin, and it proved to have been manufactured from barium-rich glass. Photo by A. Respinger; magnified 16×.

Figure 31. The barium-rich glass octahedron displayed strong blue fluorescence to long-wave UV radiation, quite similar to the reaction shown by some diamonds. Photo by A. Respinger.

typical for glass but very rare in diamond. The spot refractive index was approximately 1.53 and the specific gravity (obtained hydrostatically) was 2.63, both of which ruled out diamond. Testing with a Presidium gem tester showed no reaction, indicating that the sample had very low thermal conductivity.

Qualitative chemical analysis by EDXRF revealed Ba, K, Ca, and Si as major elements, with minor amounts of

Fe, Zn, Cl, and Al. Infrared spectroscopy (figure 33) showed complete absorption below 2000 cm^{-1}, which is typical for most silicates and oxides. In addition, there was some resemblance to type IIa diamond in the three-phonon range (4000–2500 cm^{-1}).

We concluded that this material was very likely a silicate, and the cross-like birefringence pattern, chemical composition, infrared spectroscopy, and lack of visible inclusions identified it as glass shaped to resemble diamond rough. The overall appearance and similarity in fluorescence behavior between this barium-rich glass and diamond made the material a convincing rough diamond imitation.

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Figure 32. When viewed between crossed polarizers, the octahedron exhibited the cross-like strain pattern that is typical of glass. Photo by A. Respinger; magnified 16×.

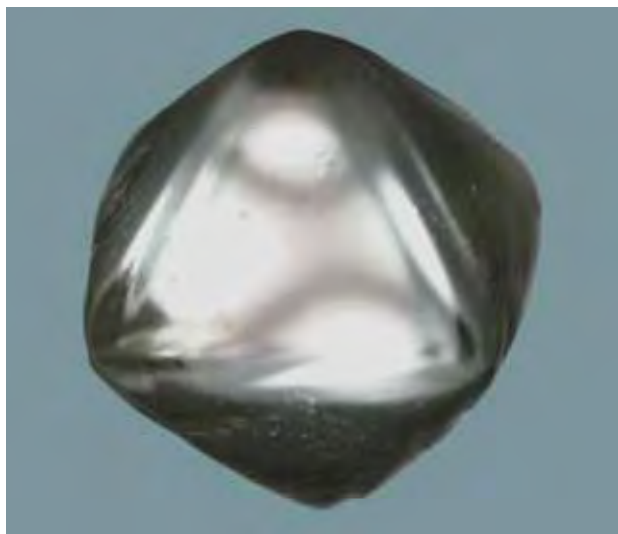Figure 33. The infrared spectrum of the barium-rich glass showed complete absorption below 2000 cm^{-1}. Although quite different from diamond in that region, the absorption of the glass did somewhat resemble that of a natural type IIa diamond in the 4000–2500 cm^{-1} region.
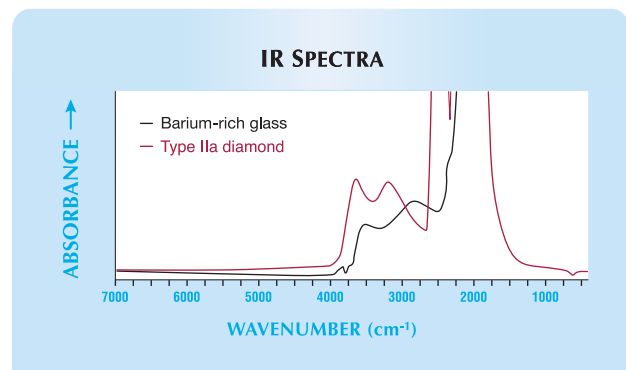
Figure 34. A manufactured glass called Purple Zandrite was new to this year's Tucson show. The material shows a "color change" from violetish blue in some fluorescent light sources (left) to reddish purple in incandescent light (right; a similar reaction is seen when the sample is viewed with a daylight-equivalent fluorescent lamp). GIA Collection no. 31754; gift of Samuel Gullo. Photos by Maha Calderon.

"Color-change" glass update. In the Spring 2004 Gem News International section (pp. 73–74), one of us (EPQ) reported on a glass imitation of alexandrite being sold as "Zandrite." New to the 2005 Tucson gem show was yet another manufactured "color-change" glass, which had a tanzanite-like appearance (violetish blue) in some sources of fluorescent light and a reddish purple color in both incandescent and daylight-equivalent 6,500 K fluorescent light. Tsavo Gem Imports, Painted Post, New York—of which House of Williams, the source of the alexandrite imitation glass in the previous report, is a subsidiary—had this "Purple Zandrite" at the GJX show.

The 5.14 ct triangular modified brilliant in figure 34, donated to GIA's collection by Samuel Gullo of Tsavo Gem Imports, was examined for this report. The R.I. and hydrostatic S.G. values (1.538 and 2.82, respectively) were slightly higher than those recorded for the green-to-pink material (1.521 and 2.66) reported last year. The blue-to-purple sample showed weak anomalous double refraction and a very weak orangy pink Chelsea filter reaction, and was inert to both long- and short-wave UV radiation. This material had a rare-earth spectrum that was similar to that of the green-to-pink glass. A desk-model spectroscope revealed moderate-to-strong lines and bands at 435, 475, 480, 510, 520–535, 565–595, and 670 nm, as well as weak lines at 465 and 620 nm. EDXRF spectroscopy found Si as a major constituent, and trace amounts of K, Cu, Zn, Zr, Ce, and Nd. A UV-Vis spectrum, acquired with a Hitachi U-4001 spectrometer, showed features that were very similar to those of the alexandrite imitation. The only significant differences were the lack of two relatively small overlapping absorption peaks at 439 and 444 nm, and a stronger overall absorption in the Purple Zandrite.

Cu, Ce, and Nd are the only elements detected that could be responsible for the color; however, the UV-Vis spectrum was consistent with Nd as the sole cause (see H. Scholze, transl. by M. J. Larkin, *Glass*, Springer-Verlag, New York, 1991, p. 239; and R. Tilley, *Colour and the Optical Properties of Materials*, John Wiley & Sons, New York, 2000, p. 167). The stronger overall absorption in the Purple Zandrite appears to be due to a higher concentration of Nd, and this may also explain the different appearances of the two glasses. As documented by Y. Liu et al. ("Colour hue change of a gem tourmaline from the Umba Valley, Tanzania," *Journal of Gemmology*, Vol. 26, No. 6, 1999, pp. 386–396), hue variations in materials have been attributed to differences in overall colorant concentration. The cause of the 439 and 444 nm peaks in the Zandrite is unknown, but these peaks may also contribute to the differences in the colors shown by the two glasses, particularly in fluorescent light.

Although the Spring 2004 GNI entry described Zandrite as an alexandrite imitation, this is actually not the case with respect to the standard definition of color-change phenomena (i.e., a material that changes hue from daylight or daylight-equivalent light to incandescent light; see also the erratum on p. 369 of this issue). That glass, like the Purple Zandrite described here, only shifted color slightly between daylight and incandescent sources, rather than showing a distinct change in hue. Instead, a hue change occurred in these materials when they were viewed in some other, non-daylight-equivalent fluorescent light sources and in incandescent light.

Fluorescent lamps are not broadband sources like sunlight or incandescent light. They produce a set of emission bands in various parts of the visible spectrum. Daylight-equivalent fluorescent tubes balance the emission bands to simulate the color-temperature of "true north" daylight. The fluorescent tubes GIA uses (which are manufactured by Greytag-MacBeth) are balanced for 6,500 K, which is the

standard used in many industries for color evaluation. Most fluorescent light sources are not balanced in this fashion and produce light that is weighted in one or more parts of the spectrum—and therefore is not truly white (i.e., it may be slightly green, pink, or some other color). As mentioned above, rare-earth elements such as Nd can produce numerous sharp absorption bands in many parts of the spectrum. We propose that the combination of emission bands from the different light sources with the numerous absorption bands of the Nd-bearing glasses is causing the changes in color we are observing. The exact nature of this interaction would require further research. It is interesting to note that the Zandrite turned different colors in at least two non-daylight-equivalent fluorescent light sources (i.e., brown-yellow in 5,400 K and bluish green in 6,000 K, both manufactured by Osram), whereas it was purplish pink in both natural daylight and incandescent light. The Purple Zandrite did not exhibit as many hue changes.

It is also interesting to note that there are fluorescent lamps marketed as "daylight" sources that induce variable color changes in materials such as the glasses described here. While these lamps fall into the color-temperature range of natural daylight (approximately 5,000 K to 7,500 K), they are not balanced to produce a daylight-equivalent source like the 6,500 K source GIA uses. As evidenced here, light sources can clearly have very different effects on certain gem materials.

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CONFERENCE REPORTS

Diamond 2005. The 16th European Conference on Diamond, Diamond-Like Materials, Carbon Nanotubes, and Nitrides, was held September 11–16 in Toulouse, France. The conference consisted of more than 400 oral and poster presentations related to growth techniques, doping, superconductivity, optical characterization, and biological applications of natural and synthetic diamond as well as carbon-based materials. Topics of particular interest to the gemological community included growth of synthetic diamond crystals by chemical vapor deposition (CVD), the classification of natural diamonds, and high pressure/high temperature (HPHT) treatment.

Dr. Yogesh Vohra from the University of Alabama at Birmingham presented an update on the rapid growth of CVD synthetic diamond crystals. By modifying the hydrogen/methane/nitrogen concentrations in the growth chamber, he reported growth rates as high as 200 microns/hour. Most of the CVD products shown were dark brown. **Dr. Jocelyn Achard** from the Université Paris 13, France, and coauthors discussed the modification of CVD growth

parameters, particularly increasing the plasma density, in order to increase growth rate. Using pulsed discharge of the microwave power, they were able to almost double the growth rates of very pure, colorless CVD synthetic diamond (i.e., from 11 to 19 microns/hour) while maintaining a very good–quality product. **Dr. Wuyi Wang** of the GIA Laboratory in New York and coauthors presented several characteristics that help distinguish high-purity CVD synthetic diamonds from natural colorless type IIa diamonds. Key identification features of these CVD products are a weak 737 nm luminescence peak related to trace silicon impurities and irregular strain patterns that are controlled by the substrate.

Dr. Emmanuel Fritsch of the University of Nantes, France, and coauthors introduced a new classification of natural brown diamonds. They proposed five groups: (1) type I and II diamonds with brown graining and amber color centers; (2) hydrogen-rich stones with no graining; (3) type Ib, high-nitrogen diamonds; (4) CO_2-rich diamonds; and (5) lonsdaleite-bearing diamonds. Dr. Fritsch also presented evidence for diamond dissolution along planar features associated with plastic deformation (graining) in pink and brown diamonds. **Benjamin Rondeau** from the Muséum National d'Histoire Naturelle, Paris, addressed cubic diamond growth morphology, describing four groups: *cubic*, *cuboid*, *fibrous pseudo-cubic*, and *re-entrant* (figure 35). **Dr. A. V. Ukhanov** and coauthors from the Vernadsky Institute in Moscow presented carbon isotope measurements of diamonds from Russia's Yakutia Province. Their data spanned most of the isotopic range reported for natural diamond ($\delta^{13}C$ from –34 to 0‰). However, many samples from kimberlite pipes gave $\delta^{13}C$ values that were consistent with the mantle (–9 to –2‰), and those from placer deposits gave isotopically lighter values (–18 to –25‰), suggesting alteration by groundwater. **This contributor** and coauthors presented evidence for isolated zones of strong H3 green luminescence in type Ib and cape natural diamonds. They correlated the H3 abundance with increasing intensity of color and graining to describe a trend of natural heating of these diamonds.

Filip De Weerdt of the Diamond High Council (HRD) in Antwerp described changes in the 3107 cm^{-1} hydrogen defect in diamond following HPHT treatment. Depending on the HPHT conditions and duration, the intensity of this defect was shown to have increased, decreased, or done both in successive treatments. **Dr. Victor Vins** of New Diamonds of Siberia Ltd., Novosibirsk, Russia, presented a new system for color grading Lucent Diamond's "Imperial Red" treated-color natural diamonds. These diamonds have undergone HPHT and irradiation/annealing treatments to produce the red color (see W. Wang et al., "Treated-color pink-to-red diamonds from Lucent Diamonds Inc.," Spring 2005 *Gems & Gemology*, pp. 6–19). The proposed new color grading system involves comparison to Munsell color references rather than natural master stones, which are not widely available in pink and red. **Eloïse Gaillou** and coauthors from the University of Nantes, France, discussed photoinduced
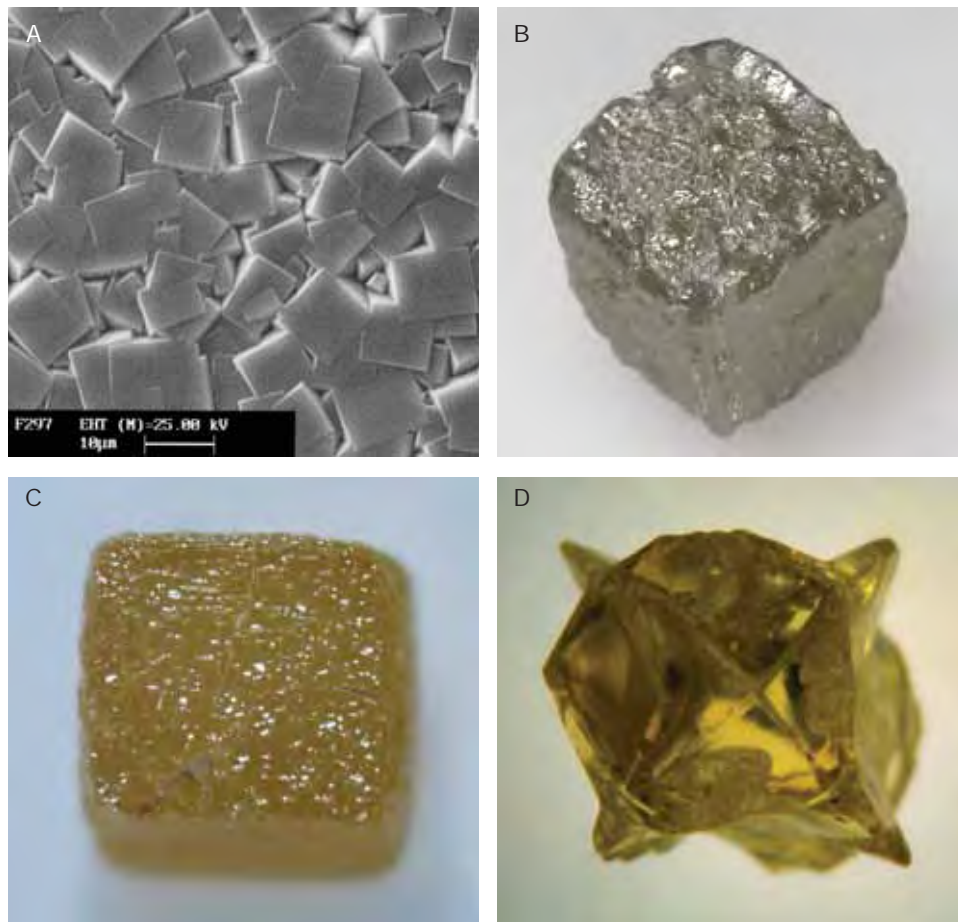
Figure 35. Shown here are several types of cubic diamond crystals. (A) This scanning electron microscope image of a CVD synthetic diamond film shows the cubic morphology of the individual crystals. (B) This 25.11 ct natural cuboid diamond shows wavy, undulating growth surfaces. (C) This 2.5-mm-wide fibrous pseudo-cubic diamond has granular surfaces that result from the juxtaposition of numerous crystal fibers. (D) A re-entrant cube (here, 3 mm wide) is formed by a combination of cuboid and octahedral crystal habits, and is sometimes erroneously referred to as a hopper crystal. Courtesy of LIMHP-CNRS, Université Paris 13 (A), Benjamin Rondeau (B and C), and Emmanuel Fritsch (D).

absorptions in natural and treated diamonds. They indicated that in a few rare yellow-to-orange treated diamonds, H1b and H1c absorptions temporarily (for as long as 24 hours) increased in intensity with exposure to UV radiation. In natural orangy brown diamonds, new photoinduced absorption features ranging from 3040 to 4850 cm^{-1} were described.

Branko Deljanin and coauthors from EGL-USA, Vancouver, B.C., Canada, described a new organizational structure for storing data collected from diamonds submitted to their laboratory. The fully searchable system, consisting of three levels of information incorporating gemological properties and various advanced testing results, is intended for easy communication between labs.

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Geological Society of America 2005. The 117th Annual Meeting of the Geological Society of America was held October 16–19 in Salt Lake City, Utah. This conference included a few presentations related to gem materials, diamond exploration, mineral databases, and gem localities; abstracts are available on the Internet at http://gsa.confex.com/gsa/2005AM/finalprogram.

Dr. Russell Hemley of the Geochemical Laboratory at the Carnegie Institution of Washington, DC, and coauthors discussed new technological developments that allow rapid growth of >10 mm thick single-crystal synthetic diamond by chemical vapor deposition (CVD). He indicated that the properties of these CVD synthetic diamonds can be easily manipulated and that one-inch crystals are now possible.

One of these contributors (**AHS**) and coauthors described a 5.04 ct gem diamond that contained solid CO_2-rich inclusions (see Summer 2005 Lab Notes, pp. 165–166). Another one of these contributors (**CMB**) and coauthors characterized chameleon diamonds, which temporarily change color from green to yellow in response to heating or being left in darkness. The color transformation was shown to be caused by the broadening of a 480 nm absorption band during heating. Complex internal structures consisting of hydrogen-rich and hydrogen-poor zones were documented in the diamonds using photoluminescence spectroscopy and DiamondView imagery.

Dr. John Gurney of the University of Cape Town, South Africa, and coauthors presented an overview of worldwide diamond formation and distribution. He discussed metasomatic events at ~3.4 ±0.2 billion years ago that created the earliest diamonds, as well as the formation of much younger diamonds from CO_2-rich fluids in the earth's crust. A detailed model of diamond development in the Kaapvaal craton was also described. **Brian Goldner** of

Gustavus Adolphus College, St. Peter, Minnesota, and coauthors evaluated the possibility of distinguishing garnet indicator minerals using color rather than chemistry. While such a color correlation would increase efficiency in diamond exploration, this approach was problematic for some types of indicator garnets.

Ren Lu and **Patrick Mooney** of the University of Arizona, Tucson, and coauthors introduced the RRUFF mineral database project, which is a compilation of Raman spectra, X-ray diffraction data, and electron-microprobe analyses for a large number of mineral specimens. The database is publicly accessible on the Internet at http://rruff.geo.arizona.edu/rruff.

Michel Rakotondrazafy of the Université d'Antananarivo in Madagascar and coauthors discussed the geochemistry and fluid inclusions in gem corundum deposits from two localities in Madagascar. Rubies from Antanifotsy were magmatic in origin and associated with alkali basalts, whereas sapphires from Andranondambo were related to fluid movement during metamorphism and occur in metasomatic pegmatites. **Sharon Hull** of the University of Tennessee, Knoxville, and coauthors presented a method for determining the source locality for archeo-

logically important turquoise samples that had been used by prehistoric Southwestern and Mesoamerican cultures. Using a combination of copper and hydrogen isotopic analyses, they were able to successfully determine the source and extent of alteration in the turquoise (figure 36). **Dr. Paul Bartos** of the Colorado School of Mines, Golden, and coauthors described the formation of exquisite gem-quality crystals of rhodochrosite at the Sweet Home mine near Alma, Colorado. The mineral deposit was part of a single-pulse, Si-rich, porphyry-molybdenum hydrothermal system that was enriched in fluorine. Rhodochrosite mineralization was likely facilitated by the transport of Mn as fluorine complexes at elevated temperatures and salinities.

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World Diamond Conference, Perth, Australia. Approximately 145 people attended this year's conference, which was held November 21–22 in conjunction with the Australian Diamond Conference. There were 25 presentations and a concluding panel discussion, with five presenters from outside Australia. The opening address was given by **Ewen Tyler**, the "grandfather of Australian diamond exploration" and chairman of North Australian Diamonds, Perth, Western Australia (formerly Striker Resources), who reviewed the history of diamond exploration and globalization. **James Allan** of James Allan and Associates, London, addressed the current state of the diamond market. To promote sales, De Beers is targeting advertising to specific customer groups identified by gender, age, and income. Many cutting centers are in debt and have to rely more than ever on credit. He reiterated that by 2010 there will be a US$3 billion shortfall in the supply of rough, and therefore prices will rise. This has greatly encouraged both major and junior diamond exploration companies to increase their efforts and has contributed to the general feeling of optimism in the diamond exploration industry.

Peter Gillin of Tahera Diamond Corp., Toronto, Canada, said that construction was on track for the opening of the new Jericho mine in mid-2006, with a planned production of 500,000 carats annually over nine years. **Lee Spencer** of BDI Diamond Corp., London, reported that the Cempaka diamond mine near Banjarmasin in southeastern Kalimantan (Borneo) began production in 2005 at a rate of 65,000 carats annually with a value of >US$300/ct. In addition, byproducts obtained from the fine fraction include gold, platinum-group minerals, and good-quality small diamonds (~$80/ct). The Honorable **Hencock Ya Kasita**, Deputy Minister of Mines and Energy of Namibia, stated that although mining provides 10% of his nation's gross domestic product (GDP) and 40% of its export earnings, Namibia was still comparatively underexplored. A new mining act should encourage future exploration. **Wolfgang Sommer** of Opsort, Schenefeld, Germany, summarized the advantages of recovering diamonds by optical means (using a strong light and a directed air blow). This method does

Figure 36. A combination of Cu and H (deuterium) isotope analyses of turquoise samples from archeologically important sources in the southwestern U.S. has been used to evaluate alteration due to weathering, and this has led to a breakthrough in determining the geographic origin of turquoise from this region. The circled areas correspond to unaltered turquoise from three mining areas, whereas altered turquoise from one of these mines clearly shows a different isotopic signature. Courtesy of Mostafa Fayek, University of Tennessee, Knoxville.
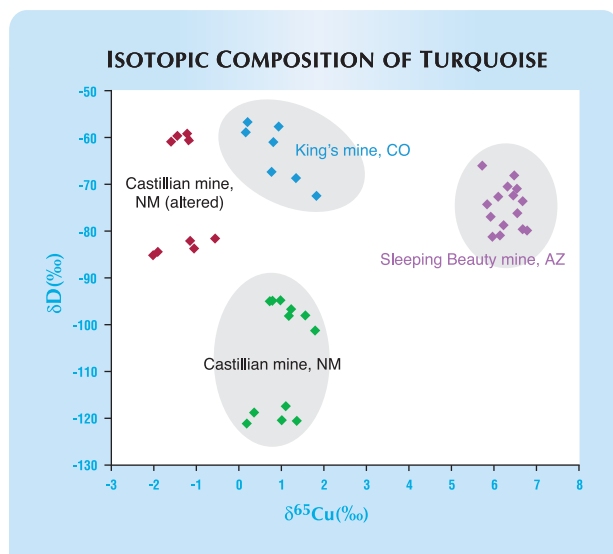
not involve hazardous X-rays, can detect nonfluorescent diamonds, can be applied to particles as small as 1 mm, and needs virtually no water. **Dr. Frieder Reichhardt** of MSA Geoservices, Johannesburg, gave an overview of the current diamond exploration scene in Africa, with Angola and the Democratic Republic of the Congo (DRC) being most active. In a separate talk, he gave a case history of the Marsfontein mine in South Africa. Though a small mine, in its short life (from late 1998 to early 2001), Marsfontein produced 1.9 Mct worth $246 million, including numerous diamonds weighing more than 10.8 ct.

Other conference speakers, most of whom were locally based, reported on the latest results of their respective companies. **Miles Kennedy** of Kimberley Diamond Co., Perth, reported on the Ellendale mine. From the commencement of mining in 2002 to June 30, 2005, the company has recovered over 236,000 carats (mainly from the Ellendale 9 lamproite pipe) worth $50 million, for an average value of $212/ct. The diamonds are predominantly gem and near-gem quality, and a significant proportion are fancy yellow (sometimes informally called *daffodil*, but designated by the company as *Kimberley Yellow*). With the Ellendale 9 plant being upgraded, and the Ellendale 4 plant commissioned to open in April 2006, annual diamond production will increase to 700,000 carats in future years. The combined diamond resource from these pipes now amounts to 68 million tonnes containing 5 Mct at a grade of 7.4 carats per hundred tonnes (cpht) and a mine life of 10 years. Kimberley Diamonds also owns 54% of Blina Diamonds (Perth, Western Australia), which has the right to explore Kimberley Diamond's lease and surrounding areas for alluvial diamonds. **Gina Rockett** of Blina Diamonds indicated that among other projects, her company recovered over 7,280 carats from 36,346 tonnes taken from its Ellendale 9 north channel, with the largest stone weighing 9.92 ct.

Tom Reddicliffe of North Australian Diamonds discussed the reopening of the Merlin mine in Australia's Northern Territory. A recent study found that 19% of Merlin's diamonds have very low to no fluorescence to X-rays, and therefore these diamonds were not recovered by the previous operator, Rio Tinto. The tailings are now being processed by the optical sorting method (see above) and are expected to yield 50,000 carats in the first of four stages of activity at Merlin. Stage 2 is the processing of remaining ore from stockpiles and the reshaping of existing small pits, which should yield 200,000 carats. Stage 3 will involve the reshaping of the neighboring Palomides and Sacramore pits into one pit to allow mining of the Palsac ore body, which is contiguous at deeper levels; this is expected to yield another 380,000 carats. Stage 4 is the potential underground mining of the Palsac and other pipes, which have an estimated reserve of 10 million tonnes containing 2.36 Mct. Merlin diamonds recovered from the tailings have been classified as 35% colorless, 5% yellow, 29% brown, and 31% "mixed" (mostly industrial

and near-gem material), with an average value of $140/ct (from Stages 1 and 2; a higher proportion of colorless and brown diamonds will come from Stages 3 and 4, and be worth $150/ct overall). Although the average weight is 0.10 ct, two large diamonds have been recovered by the optical sorting method (14.21 and 10.27 ct), as well as an additional 24 diamonds weighing more than 1 ct. With a mine life of at least 10 years, the total resource is 19.1 million tonnes containing 3.3 Mct at a grade of 17.3 cpht, worth an estimated $500+ million (at $150+/ct).

Dr. Kevin Wills of Flinders Diamonds, Adelaide, South Australia, said that up to 50 kimberlite dikes and pipes were sampled last year in the Flinders Ranges, and 20 contained diamonds. The very high proportion of diamondiferous kimberlites has encouraged the company to continue exploration in this area. Good progress was also made in the Hamersley Ranges project in Western Australia, where promising indicator minerals and microdiamonds were found, and an alliance with De Beers Australia Exploration was formed. **Ian Moody** of Gravity Diamonds, Melbourne, Victoria, described the discovery of the new Abner Range pipe, a small diamondiferous kimberlite 45 km west of Merlin. He also discussed exploration in the western Kasai province of the DRC, located north of the border with Angola's Lunda Norte Province. Regional stream sampling and subsequent aeromagnetic surveying have generated targets for detailed sampling and drilling.

Other speakers gave updates on their projects in Australia, Namibia, and South Africa, but no other significant new developments were reported. The hoped-for announcement that Rio Tinto would develop their underground mine at Argyle was not on the agenda, and Rio Tinto representatives did not attend. However, on December 8 Rio Tinto did issue a statement confirming that it would go forward with plans for a $US760 million underground mine at Argyle. The company stated that the average annual production during underground mining from 2007 to 2018 was expected to be around 60% of Argyle's historic annual average of 34 Mct and of similar quality.

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ANNOUNCEMENTS

Conferences

Visit *Gems & Gemology* in Tucson. Meet the editors and take advantage of special offers on subscriptions and back issues at the *G&G* booth in the publicly accessible Galleria section (middle floor) of the Tucson Convention Center during the AGTA show, February 1–6, 2006.

GIA Education's traveling Extension classes will offer hands-on training in Tucson with "Diamond Grading" (January 30–February 3). To enroll, call 800-421-7250, ext. 4001. Outside the U.S. and Canada, call 760-603-4001.

The GIA Alumni Association will host a Dance Party in Tucson on February 3, 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.

PDAC 2006. The Prospectors and Developers Association of Canada convention will take place March 5–8 in Toronto. Diamonds will be featured in a session called "Diamonds in Canada: Cratons to Carats," and also will be included in other sessions. Visit www.pdac.ca/pdac/conv.

WJA in New York. The Women's Jewelry Association "Women In the Know" business conference will be held on March 10, 2006 at the Fashion Institute of Technology in New York City. Topics will include leadership development, Internet business strategy, and customer service management. Visit www.womensjewelry.org.

BASELWORLD 2006. The BASELWORLD show will be held March 30–April 6 in Basel, Switzerland. During the show, *Gems & Gemology* editor-in-chief Alice Keller will be available at the GIA Booth in Hall 2, Stand W23. Visit www.baselshow.com, call 800-922-7359, or e-mail visitor@baselworld.com.

Diamonds at Materials Congress 2006. A symposium titled "Diamonds: Materials Science and Applications" will take place on April 5–6 during the Materials Congress 2006 conference in London. Topics will include diamond growth and characterization, as well as physical and optical properties of diamond. Visit www.iom3.org/congress/images/diamondA4.pdf .

GAC-MAC 2006. The 2006 joint meeting of the Geological Association of Canada and the Mineralogical Association of Canada will take place May 14–17 in Montreal. Diamonds will be covered in some of the sessions. Visit www.er.uqam.ca/nobel/gacmac/welcome.html.

ICNDST-11. The 11th International Conference of New Diamond Science and Technology will be held at the Embassy Suites Hotel in Research Triangle Park, Raleigh-Durham, North Carolina, May 15–18, 2006. Among the topics covered will be HPHT synthesis and processing and the growth of CVD synthetic diamond. Visit http://lucy.mrs.org/meetings/workshops/2006/icndst.

Bead Expo. The 2006 International Bead Expo will be held in Charleston, South Carolina, May 17–21. Over 60 workshops and educational lectures on bead jewelry design and manufacture are scheduled. E-mail info@beadexpo.com or visit www.beadexpo.com.

2006 GAA-NSW Conference. The 2006 conference of the New South Wales Division of the Gemmological Association of Australia will be held May 19–21, at the Sydney Harbour Marriott Hotel. The event will also include a jewelry design competition and a post-conference tour that will visit corundum and opal mines at Barrington Tops, Inverell–Glen Innes, and Lightning Ridge. Visit www.gem.org.au/conference.htm or e-mail nsw@gem.org.au.

Exhibits

Pearl Exhibit in Tokyo. "Pearls: A Natural History" will be on display until January 22, 2006, at the National Science Museum, Tokyo. Visit www.kahaku.go.jp/english.

Cameos at the Met. "Cameo Appearances," a display of more than 160 examples of the art of gem carving from Greco-Roman antiquity to the 19th century, will be on display until January 29, 2006, at the Metropolitan Museum of Art in New York City. Also on display at the Met (through February 12, 2006) is "The Bishop Jades," a selection of fine Chinese and Mughal Indian jades from the collection of Heber R. Bishop that was donated to the museum in 1902. Visit www.metmuseum.org or call 212-535-7710.

King Tut Returns. "Tutankhamun and the Golden Age of the Pharaohs," an exhibition of more than 130 artifacts from the tomb of King Tut and other royal tombs in Egypt's Valley of the Kings, will be on display until April 23, 2006, at the Museum of Art in Fort Lauderdale, Florida. Only a few of the artifacts in this exhibit were part of the famed 1977 exhibition, and many have never traveled outside Egypt. The exhibit will move to the Field Museum in Chicago May 26, 2006 through January 1, 2007. Visit www.kingtut.org.

ERRATUM

In the Spring 2004 Gem News International section (pp. 73–74), we reported on a glass imitation of alexandrite being sold as "Zandrite." This glass was said to exhibit an alexandrite-like color-change from slightly bluish green in sunlight or daylight-equivalent fluorescent light to purplish pink in incandescent light. Although the material did change color in different light sources, it did not change between the two light sources that define a true color-change (natural daylight or daylight-equivalent fluorescent light vs. incandescent). Instead this material actually changed from bluish green in some non-daylight-equivalent fluorescent light sources to purplish pink in both incandescent and daylight sources. This reaction is most likely due to the interaction of Nd (a rare-earth element) in the glass with the emission bands that create the "white light" produced by typical fluorescent lamps. See also the report on a similar manufactured glass in the Gem News International section of this issue (pp. 364–365).

Book **REVIEWS**

Crystals: Growth, Morphology and Perfection

By Ichiro Sunagawa, 295 pp., illus., publ. by Cambridge University Press, Cambridge, United Kingdom, 2005. US$95.00

In this book, intended for crystallography students and specialists alike, Prof. Ichiro Sunagawa clearly explains the processes that control crystallography. In the first part of the book, physical processes are described from a theoretical point of view, though always illustrated by photos of natural crystals (often taken by the author) and by readily understood diagrams. The processes of crystal nucleation, crystal growth, selection of a growth type (e.g., dendritic, massive, or spherulitic), intergrowth, and polycrystalline aggregation are addressed from a thermodynamic point of view. Equilibrium, kinetics, driving force, heat and mass transfer, role of defects, and the like are often invoked to explain the magic of crystal morphology. Microtopography is also used to understand the influence of dislocations (spiral, circular, or polygonal) and dissolution on crystal morphology. The section on homogeneity explains how growth zonation, growth sectors, and dislocations are responsible for complex features in crystals.

In the second part, special cases are examined, often from the author's experience during his long career as a crystallographer.

• Diamond is described in detail, including its structure, physical properties, growth features, and morphology. Nevertheless, one could say that the vocabulary used to describe crystals of nearly cubic shape is sometimes confusing.

• Quartz is the second well-studied example. Described are various forms of silica, crystal morphologies, prism striations, Japan and Brazil twins, curved vs. flat crystals, agate formation, and polycrystalline aggregates.

• Calcite and pyrite are also extensively described, with the author highlighting the role of formation conditions on the crystal morphologies.

• The last chapters describe the growth conditions of crystals formed by vapor growth (pegmatitic and post-volcanic deposits) and by metasomatism and metamorphism (kaolin minerals and trapiche crystals), as well as crystals formed through biological activity (e.g., in bones, teeth, and carapace).

In this reviewer's opinion, this is the most comprehensive book currently available on crystal growth and morphology.

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The Gem Merchant: How to Be One, How to Deal with One, 2nd Edition

By David Stanley Epstein, 158 pp., illus., publ. by Gem Market Publications, Piermont, NY, 2003, US$20.00*

Gem merchant David Epstein accurately covers many of the details involved in the daily practice of his profession. Every retail jeweler, manufacturer, and gemologist should read this book in order to better understand the responsibilities and risks gem merchants assume when pursuing loose stones for their clients. Although there is valuable advice for anyone considering a career in gemstone trading, Epstein aptly states that this book was written more for jewelers and manufacturers.

The book is divided into four major sections: buying, marketing, cutting, and general information. The discussion assumes a basic knowledge of gemstones and the industry, and the author's warnings and advice should deter those who are not willing to take the necessary risks. This is, after all, an industry that rewards the very few who have the endurance and patience to accept the learning curve that comes only with time and experience.

The book's first section focuses on buying and the need for product education and experience to accurately determine quality and value. Epstein also mentions the importance of keeping track of all purchases and expenses. Principles of gemstone trading and valuation are addressed, with tips on assessing such factors as cut, color, size, and pricing. The illustrations are accurate and easy to understand. This section also teaches the buyer to

*This book is available for purchase through the GIA Bookstore, 5345 Armada Drive, Carlsbad, CA 92008. Telephone: 800-421-8161; outside the U.S. 760-603-4200. Fax: 760-603-4266. E-mail: myorder@gia.edu

beware of supply and demand factors that dictate price and to always remember that gem supplies are finite. In one of the most important features of this chapter, Epstein gives sound advice on how to travel safely, stay incognito, keep goods close, use local assistants or contacts, and be aware of local trade customs.

The second section contains many useful strategies for successful marketing and sales. The first and most important step is to develop and write out a marketing plan. He explains the five steps of closing a sale by including excellent examples of evaluating and developing a customer's "attention, interest, conviction, [and] desire," and then closing the sale. The section devoted to purchase control sheets and order forms seems to focus more on Epstein's personal methods of inventory control and management than on the general idea of record keeping and good accounting practices. Epstein also gives sound advice on how to properly use the Internet as a communication and sales tool.

Section three, titled "Cutting (Manufacturing)," starts out with a strong warning to the uninitiated: Successfully buying and cutting rough takes practice, experience, and time. This section continues with valuable information on how to grade and value rough gems properly. Once again, the focus is on experience and exercising caution when venturing into the evaluation of rough. He addresses many of the basic tips that wholesalers apply by providing some useful examples and illustrations. This section ends with recutting (poorly cut, damaged, or worn gems) and contract cutting. In my opinion, however, these topics should have been featured at the beginning, since they are skills that one should acquire before cutting from rough.

The final section addresses general topics and is full of excellent advice. One of the best is the suggestion that one rely on comparison stones when buying gems for which subtle differences in color are important. Since even highly trained graders have lapses in color memory, comparison stones can help the gem dealer avoid costly mistakes. Epstein also describes the ideal color range of some of the most commonly traded gems. This section continues with illuminating examples of shams, scams, and rip-offs, as well as what one should look for in a reliable and trustworthy gem merchant. The major international gem trading centers are also briefly described and put into context by tracing their historical development and significance.

My favorite part in this final section, however, is the author's historical analysis of the gem trade. In it, he addresses the conflicting views associated with gemstone grading, past and present economic trends, the fragmentation of the colored stone industry, advances in shipping and transportation, exploration breakthroughs, and gem prices and profit margins. Epstein concludes by predicting that, because of greater competition, the gem industry will become more specialized as gem merchants are forced to focus on particular areas of expertise. These merchants will have to take advantage of innovations and use them to their advantage to compete in the rapidly changing marketplace.

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Arts and Crafts to Art Deco: The Jewellery and Silver of H. G. Murphy

By Paul Atterbury and John Benjamin, 183 pp., illus., publ. by Antique Collectors' Club, Suffolk, United Kingdom, 2005. US$69.50*

Too often, the masters of our time are admired for great works during their lives, only to be quickly forgotten after their demise. Occasionally, though, definitive works find their rightful path back into the limelight to be appreciated by new eyes. Harry Murphy is such an artist deserving our attention: His work from the early part of the 20th century has a distinct look, is outstanding in quality, and features a range of styles from Arts and Crafts to Art Deco with a modernist flair.

Published as a companion to a recent Goldsmith's Hall exhibition of items from Murphy's Falcon Studio workshop, this book can also stand alone as a reference for the aspiring artist. For the designer, silversmith, and goldsmith, studying Harry Murphy's work is a lesson in mastery of gold, silver, enameling, niello (black alloy used as inlay), and engraving.

An Englishman, Harry Murphy had a brush with greatness while still a child, when his artistic talent was recognized by William Morris, the famous British craftsman and designer. With that encouragement, Murphy pursued his talent and apprenticed with the prominent Arts and Crafts master of his time, Henry Wilson. There he learned the intricacies of enameling and niello, which he perfected to the point where it was sometimes difficult to tell the two artists' work apart. Later, Murphy studied briefly with the renowned German jeweler and silversmith, Emil Lettré.

But Harry Murphy was not a copycat. As he perfected each classic art form, he often married it with modernism, making his work fascinating and unusual. Many of his pieces featured the tree of life, signs of the zodiac, or elaborate finials. He kept pace with changing art trends as tastes moved from Arts and Crafts to the more modern Art Deco. Yet in other works, he was completely practical and tailored his designs to meet the needs of his commercial and ecclesiastical clients. Murphy always struggled to keep his studio profitable, so he recognized the importance of building business through civil and corporate works. The range of pieces he tackled is notable and evidence of his true talent as a craftsman.

This book serves as a valuable showplace for his works. Featured are various examples of the artist's jewelry and domestic silver, many of which

are amazing and intricate examples of enameling. There is a comprehensive biography, numerous color and black-and-white photos of works in silver and gold (many gem-encrusted), civil and corporate work, trophies, works for the church, studio memorabilia, fascinating illustrations and brainstorm sketches by the artist himself, and extracts from Murphy's writings on related subjects. The book is divided into six sections. While the storytelling meanders a bit, with some redundancy, overall this is a fascinating documentation of Harry Murphy's work. The reader gets a comprehensive picture of this talented man's life and creative output, drawing inspiration from it. I found myself saying "Wow!" aloud several times as I looked at this work, and I suspect any bench jeweler, enamel artist, or designer will, too.

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Daniel Swarovski: A World of Beauty

Text by Vivienne Becker, produced under the direction of Markus Langes-Swarovski, 139 pp., illus., publ. by Thames & Hudson, New York, 2005. US$75.00*

In 1895, a Bohemian craftsman named Daniel Swarovski (1862–1956) moved to the small Austrian village of Wattens to set up a factory specializing in the manufacture of cut crystals. Swarovski, a technical virtuoso who had already invented the first precision machines for cutting and polishing crystal, dreamed of unlocking the glamour of the material. The company he built became a renowned leader in the fashion and jewelry industries during the 20th century, and today it produces billions of cut crystals annually. The Daniel Swarovski collection, launched in 1989 as the company's couture signature, has continued the founder's spirit with an assortment of innovative jewelry, watches, fashion accessories, and design objects.

Daniel Swarovski: A World of Beauty is a salute to the collection's 15th anniversary. At 10 × 13 in. (25.4 × 33 cm), the book is replete with large, radiant photos of creations from the eponymous collection. The lean text, written by jewelry historian Vivienne Becker (*Art Nouveau Jewelry*, *Fabulous Fakes*, and *Swarovski: The Magic of Crystal*), begins with the remarkable story of Daniel Swarovski. Subsequent chapters eloquently pay homage to the allure of glass crystal while offering a behind-the-scenes glimpse of the company's creative process today.

This exquisitely illustrated volume is sure to be treasured by connoisseurs of crystal jewelry and accessories.

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Gemological ABSTRACTS

2005

COLORED STONES AND ORGANIC MATERIALS

Coconut pearls: A reevaluation of authenticity. W. Armstrong, *Ornament*, Vol. 28, No. 2, 2004, pp. 46–49.

An encounter with the Maharajah "coconut pearl" on display at the prestigious Fairchild Tropical Botanic Garden in Coral Gables, Florida, prompted the author, a college botany teacher, to investigate the authenticity of these controversial objects. In some parts of the world, such as Malaysia, these "pearls" (which allegedly formed in coconuts) are thought to have magical properties, are highly valued (prices as high as $60,000 are mentioned), and are set as talismans in jewelry.

Coconut "pearls" are described as a hoax in several reputable botany textbooks. In 1939, Dutch zoologist A. Reyne, chief of the Coconut Research Station at Menado, Celebes, Indonesia, studied numerous examples found in public and private collections, and concluded that many of the more famous ones were actually concretions from giant clams of the genus *Tridacna* and could not possibly have formed inside a coconut. In 1982, however, Professor Abraham Krikorian, at the State University of New York at Stony Brook, published a detailed review of the literature on the coconut concretions, and some of the references he cited suggest that they may actually exist.

Fraudulent claims with respect to the occurrence and origin of coconut "pearls" are widespread, particularly in Malaysia, where many of the artifacts are reportedly found. There is no plausible explanation for how a calcareous substance, with concentric aragonite layers characteristic of pearls from mollusks, could possibly originate inside a coconut. Further, no reputable scientist has ever seen, firsthand, a concretion in its original coconut. Hence, the only logical conclusion is that concretions from other sources have been fraudulently transplanted into

coconuts. The author, once a believer, concludes that the existence of coconut "pearls" seems to be based on faith rather than objective scientific evidence. *JEC*

The Kasumigaura pearl™. B. Dillenburger [info@perlenyukie. de], *Australian Gemmologist*, Vol. 22, No. 4, 2004, pp. 156–161.

Kasumigaura (or Kasumiga) cultured pearls are naturally colored, bead nucleated, and mostly off-round, and are cultivated in and around Japan's second largest lake, Kasumiga Ura. This pearl is cultured in a hybrid between the Japanese *ikecho-gai* mussel (*Hyriopsis schlegeli*) and the Chinese triangle mussel (*H. cumingi*).

Commercial farming of freshwater cultured pearls in Japan began in Lake Biwa in 1945, using the *ikecho-gai* mussel. Experiments that began about 1925 resulted in the eventual successful relocation of the *ikecho-gai* mussel to Lake Kasumiga, where commercial production began in 1962. The original intent was to use Lake Kasumiga as a backup for the Lake Biwa nursery and to provide production balance. However, with the increased pollution of Lake Biwa, the industry was later reestablished at Lake Kasumiga. After 1983, Lake Kasumiga also experienced environmental problems, adversely affecting the nursery. In response, pioneer cultivator Kazuhisa Yanase started using a new hybrid Japanese-Chinese mussel that proved resilient to environmental challenges. The result was the large Kasumiga cultured pearl, which is produced in sizes >8 mm, with an average diameter of 13–14 mm. The shape varies from round to baroque (only 2%, in the smallest sizes, are perfectly round), and several colors are available: off-white, "peach" to orange, pink, lavender to violet, and a rare "golden" green. Production is modest; only 25 kg were produced in 2003. *HyeJin Jang-Green*

DIAMONDS

Alkaline ultrabasic rocks in the Arkhangelsk diamond province: Present state of knowledge and prospects for studies. K. V. Garanin, *Moscow University Geology Bulletin*, Vol. 59, No. 1, 2004, pp. 35–45.

The Arkhangelsk diamond province is located in the northern part of European Russia, along the Arctic coast. The first diamond-bearing kimberlite sills were found in the late 1970s and are located along the Mela River. Throughout more than two decades of geologic exploration, more than 60 kimberlite bodies have been identified within the diamond province. However, only two were bedrock deposits with commercial diamond potential. Data collected during extensive geologic studies in the early 1990s suggest that emplacement occurred in a relatively narrow time interval of 340–370 million years ago. The igneous bodies are confined to Paleozoic faults or grabens associated with rift zones. The diamondiferous kimberlites contain extremely low concentrations of rare elements.

The Arkhangelsk diamond crystals tend to be rounded dodecahedrons and rhombododecahedrons. *EF*

Geophysical methods for kimberlite exploration in northern Canada. M. Power [aurora@klondike.com], G. Belcourt, and E. Rockel, *The Leading Edge*, Vol. 23, No. 11, 2004, pp. 1124–1129.

Kimberlite is a volatile-rich ultrabasic igneous rock that is mainly composed of olivine, clinopyroxene, micas, carbonates, and serpentine. Although diamondiferous kimberlites are found all over the world, only 1% are economic (profitable for mining). Such deposits were first discovered in Canada (Northwest Territories) in 1991. All the Canadian deposits are located in the Archean Slave Craton. Most of these kimberlite pipes intrude granitoid host rocks generally trending NNW in this craton and are Cretaceous or Eocene in age. Most contain primarily crater-facies kimberlite (i.e., the upper part of a pipe that is composed of pyroclastic kimberlites, clays, and country rock fragments, including xenoliths). As a result of differential glacial erosion, most are found under or adjacent to lakes.

Kimberlite exploration in the Slave craton normally consists of geochemical sampling to define a large potential area, followed by geophysical surveys to locate the actual pipes. In geochemical sampling, the presence and concentration of heavy minerals such as pyrope garnet, chrome diopside, and Mg-ilmenite (picroilmenite) are assessed to determine the possible presence of kimberlite. These minerals can be found in both glacial till and glaciofluvial deposits. Diamond potential can be calculated based on the Ca and Cr concentrations in pyrope garnets.

Geophysical surveys look for the contrast in physical properties between kimberlite and the surrounding host rocks. First, magnetic and electromagnetic surveys are performed by airborne methods over a large potential area. These are followed by ground geophysics, such as gravity, ground-penetrating radar (GPR), and seismic surveys. Finally, the most promising targets are tested by drilling or bulk sampling.

Strong remnant magnetism that is characteristic of kimberlite can be detected by magnetic surveying, which can also identify regional structures in the host rocks and their intersections that have potential for kimberlite intrusions. Crater-facies kimberlite shows lower electrical resistivity than the host rocks due to serpentinization and clay alteration, and this can be detected by electromagnetic surveying. Gravity measurements can detect the relatively low density of kimberlite. GPR surveying can identify differences in a kimberlite pipe's electromagnetic (i.e., dielectric) characteristics compared to its host rocks; it is also useful for locating kimberlite dikes. Seismic surveying can help delineate between a kimberlite and its host rocks, though it has not been widely used in Slave Craton exploration. *KSM*

Raman spectroscopy of diamond and doped diamond. S. Prawer [s.prawer@unimelb.edu.au] and R. J. Nemanich, *Philosophical Transactions of the Royal Society of London, Series A*, Vol. 362, No. 1824, 2004, pp. 2537–2565.

Raman spectroscopy is an essential nondestructive technique in research on diamonds and chemical vapor–deposited (CVD) synthetic diamond films. The typical Raman spectrum excited by a visible laser (2000–1000 cm^{-1} region) contains information on the phase purity and crystalline perfection of the diamond sample, while surface-enhanced Raman spectroscopy can show new and unexpected structures on diamond surfaces. Raman spectra can also be used to map stress and strain in crystallites on the micrometer scale; remotely monitor the surface temperature of diamond; and monitor defects, annealing, and doping (with, e.g., B, S, P, or Li). The Raman spectrum is sensitive to the interaction of dopants with the electronic continuum, and it is the carrier concentration rather than the dopant concentration to which the technique is most sensitive.

RAH

Xenoliths—a diamond's nest. M. Anand [m.anand@rhm.ac.uk] and L. Taylor, *Rough Diamond Review*, No. 5, 2004, pp. 12–14.

Pieces of diamond-bearing mantle host rock that are transported to the earth's surface in kimberlite pipes are known as xenoliths. These rocks provide valuable opportunities to study diamond growth conditions and the interrelationship between diamonds, inclusions, and host minerals. A three-dimensional reconstruction of a xenolith's mineral constituents can be generated using high-resolution X-ray computed tomography (HRXCT). These 3-D models clearly reveal the spatial relationships between diamonds and surrounding minerals (sulfides, silicates, etc.).

HRXCT imaging of a xenolith from Yakutia, Siberia, showed that diamonds and sulfides were evenly distributed throughout the sample, and were not spatially associated with one another. Instead, diamonds were associated with areas of secondary mineralization or alteration zones, suggesting they did not form at the same time as the xenolith host rock. The study also showed that the diamonds were always separated from the primary silicate minerals by these alteration zones.

Diamonds extracted from an unspecified number of Yakutian xenoliths ranged from 0.03 to 5 ct and for the most part were near colorless. They had well-defined faces (as expected from their lack of contact with corrosive kimberlitic magma), and most formed perfect octahedra; also present were cuboctahedra, macle twins, and a few polycrystalline aggregates.

Growth patterns were revealed using cathodoluminescence of sawn diamonds that had been extracted from the xenoliths. Electron-microprobe analysis and secondary ion mass spectrometry also were performed on diamonds and their inclusions. The inclusions provided information about diamond formation conditions during various stages of their growth. The chemical compositions of the diamonds, diamond inclusions, and other minerals in an eclogitic xenolith showed variabilities that reflect the ambiguous nature of diamond genesis.

DMK

GEM LOCALITIES

African blue lace agate: Namibia's blue quartz gem is one of nature's finest. B. L. Cross, *Rock & Gem*, Vol. 35, No. 5, 2005, pp. 88–90.

Blue lace agate is found in a remote area of southern Namibia, about 43 miles (69 km) southwest of the town of Grunau, and less than 80 miles (129 km) from the country's coastal diamond deposits. The material is hosted by a hard, fine-grained dolerite that is about 1.1 billion years old. The agate is estimated to be about 54 million years old, and is found as two separate vein systems of varying thickness with no other mineralization.

The deposit was discovered in 1962, and the veins were mined intermittently until 1976 in narrow, hand-dug trenches reaching approximately 50 feet (15 m) deep. Mechanized mining commenced in 1977. The ore zone is broken by selective blasting and pneumatic hammers. Approximately 100–150 pounds (45–68 kg) of host rock must be removed to yield one pound of agate.

Some hand cobbing is done at the mine site, and the rough material is then transferred to Springbok, South Africa, for final cobbing. The material is then washed and graded according to vein thickness and color intensity. In general, the color of the agate tends to improve with depth in the vein. Large, straight, thick specimens with good color are the most prized. Mining the deposit is expensive in many ways, with large taxes placed on vehicles, equipment, and agate rough crossing the Namibia/ South Africa border in either direction.

JEC

Elemental analysis of Australian amorphous banded opals by laser-ablation ICP-MS. L. D. Brown [leslie.brown@uts.edu.au], A. S. Ray, and P. S. Thomas, *Neues Jahrbuch für Mineralogie, Monatshefte*, Vol. 9, 2004, pp. 411–424.

Several banded Australian opal-AG (amorphous gel-like) samples were found to contain darker-colored black or gray bands adjacent to lighter-colored white or clear bands. A study of the distribution of trace elements between these bands showed that the darker bands contained significantly higher concentrations of trace elements (Ti, Co, V, Ni, Cu, Zn, Y, La, and Ce) than the lighter bands. A solution depletion model, involving the charge neutralization of silica colloids by highly charged transition metal cations, is proposed to explain these results. Irrespective of the origin of the opal, the distribution of the trace elements in white, translucent, and play-of-color opal bands was shown to be similar, which is consistent with the proposed model.

RAH

L'aspidolite fluorée: Rôle des évaporites dans la genèse du rubis des marbres de Nangimali (Azad-Kashmir, Pakistan) [Fluorine-rich aspidolite: The role of evaporites in the genesis of ruby in marbles at Nangimali (Azad-Kashmir, Pakistan)]. V. Garnier, D. Ohnenstetter [dohnen@crpg.cnrs-nancy.fr], and G. Giuliani, *Comptes Rendus (C.R.) Geoscience*, Vol. 336, No. 14, 2004, pp. 1245–1253 [in French with English abstract].

Aspidolite ($NaMg_3AlSi_3O_{10}[OH,F]_2$) is a sodium-rich mica that is an analogue to potassium-rich phlogopite. It occurs with other micas (phlogopite, phengite, and paragonite) at the Nangimali ruby deposit. Electron-microprobe analyses revealed that both the aspidolite and phlogopite are enriched in fluorine (up to 3.23 wt.% F). According to these authors, when combined with the occurrence of salt inclusions in certain minerals and the existence of anhydrite in the deposit, the presence of these F-rich micas implies that evaporation of an ancient body of water played a role in the genesis of gem ruby at marble-hosted occurrences such as Nangimali. *JES*

Opals from Java. H. Sujatmiko, H. C. Einfalt, and U. Henn, *Australian Gemmologist*, Vol. 22, No. 6, 2005, pp. 254–259.

Since the early 1970s, opal has been mined in the Rangkasbitung area of western Java from a highly altered pumice layer in a late Tertiary volcaniclastic sequence. The varieties range from common opal to hyalite, fire opal, and play-of-color material (with a white or black bodycolor) displaying flashes of red, orange, and green. The refractive indices of these opals are in the range of 1.435 to 1.468, with specific gravity values of 1.98 to 2.06; the lower values of both properties corresponded to the colorless and transparent opals. *RAH*

INSTRUMENTS AND TECHNIQUES

Krüss refractometer—ER 6010. T. Linton, R. Beatie, and K. Hughes, *Australian Gemmologist*, Vol. 22, No. 2, 2005, pp. 260–262.

This report evaluates the features and performance of the Krüss ER 6010 refractometer, a relatively inexpensive, quality gemological instrument. The design is based on a hemicylinder of high-index glass with a spherical exit face. The instrument will measure refractive indices in the 1.30 to 1.83 range. The refractometer has a removable cover with a height of 32 mm to allow ring-mounted stones to be safely positioned on the surface of the hemicylinder. *RAH*

Using SIMS to diagnose color changes in heat treated gem sapphires. S. W. Novak [snovak@evanseast.com], C. W. Magee, T. Moses, and W. Wang, *Applied Surface Science*, Vol. 231–232, 2004, pp. 917–920.

Responding to the influx of orange sapphires in the gem trade in 2002, the authors used secondary ion mass spectroscopy to identify beryllium diffusion as the origin of color in these specimens. Subsequent experiments verified that Be diffusion can produce a broad variety of color modifications in sapphire. Routine measurements with SIMS are now employed to simultaneously detect Be and 13 other trace elements in gem sapphires. The authors discuss test protocols for faceted gems and present measurement precision data. *SW*

JEWELRY HISTORY

A compositional study of a museum jewelry collection (7th–1st BC) by means of a portable XRF spectrometer. A. G. Karydas [karydas@inp.demokritos.gr], D. Kotzamani, R. Bernard, J. N. Barrandon, and Ch. Zarkadas, *Nuclear Instruments and Methods in Physics Research B*, Vol. 226, 2004, pp. 15–28.

Thirty-four gold and four silver jewels belonging to the Benaki Museum (Athens, Greece) collection were chemically analyzed on site using a custom-made portable X-ray fluorescence (XRF) spectrometer. Limitations of the modified XRF instrument are discussed, along with the standard problems associated with the application of the XRF technique to museum artifacts.

One of the primary objectives was to identify if the metal was used as-mined (from primary or placer deposits) or was refined. Two groups were identified: One group had a relatively high Au percentage ($96.8 \pm 1.8\%$), while the other contained significant amounts of Ag. The Cu content of the first group, along with its high Au percentage, indicated that most of the metal items had undergone some refining. In the second group, the presence of Ag, as well as iron in Cu-Fe admixtures, is normal for native gold, and this group probably originated directly from unrefined gold that most likely was taken from placer deposits.

From the minor elements detected in the silver jewels, especially Au, the source for the silver was likely the Lavreion mine in Attikí, Greece. *PXJ*

Identification of pigments and gemstones on the Tours Gospel: The early 9th century Carolingian palette. R. J. H. Clark [r.j.h.clark@ucl.ac.uk] and J. van der Weerd, *Journal of Raman Spectroscopy*, Vol. 35, 2004, pp. 279–283.

Raman microscopy was used to analyze the 12 gems set into the cover of a 9th century illuminated manuscript known as the "Evangelia Quatuor" or the "Tours Gospel," so named due to its probable origin in Tours, France. According to a letter attached to the gospel, which now resides in the British Library in London, the original stones were replaced in 1828 by gems specified to be "cat's-eye," emerald, "carbuncle," sapphire, amethyst, and "oriental" topaz.

Raman/fluorescence spectra of the gems taken at 632.8 nm excitation provided the following information:

- Two stones were identified as quartz (cat's-eye, amethyst)
- Three stones showed a photoluminescence spectrum characteristic of emerald; however, confirmation of this identification was not available in this study
- Three stones were identified as iron (almandine) garnet, $Fe_3Al_2(SiO_4)_3$
- Three stones were identified as sapphire
- One stone could not be identified

The pigments used to "illuminate" the manuscript pages were also analyzed with Raman spectroscopy and found to have been produced with a palette including carbon black, indigo, lead white (lead carbonate), minium (lead oxide, also known as red lead), orpiment (arsenic sulfide), vermillion (mercuric sulfide), and gold.

SW

JEWELRY RETAILING

It's all in the numbers. K. Gassman, *AJM*, May 2005, pp. 51–55.

This article predicts that jewelry sales will increase by an average of 5.6% per year between 2000 and 2010. One reason is that more than 80 million people were born in the U.S. between 1978 and 1998, forming a generation called the *Millennials*. Unlike the more financially conservative "Generation X," this group loves to shop and buy—and jewelry is a priority on their list. In addition, the percentage of affluent households will increase greatly, from 14% in 2003 to 18% by 2010, which will drive the average ticket price higher, as well as cause higher unit sales. The article also notes that the number of marriages—and opportunities for engagement rings and bridal jewelry—is rising strongly, along with demand from various ethnic groups, particularly Hispanics.

RS

PRECIOUS METALS

Investigation and development of the karat gold alloys for jewelries (1): Colored and white karat gold alloys; (2) Metallurgical features and strengthening mechanism of the karat gold alloys for jewelries. Y. Zhang and G. Li, *Precious Metal*, **Part 1.** Vol. 25, No.1, 2004, pp. 47–54; **Part 2.** Vol. 25, No. 2, 2004, pp. 41–47 [in Chinese with English abstracts].

Gold and karat-gold alloys have been employed for jewelry use throughout recorded history. Recently, however, new gold alloys have come into use. To help jewelers and consumers better understand the properties of these gold alloys, the authors of this article systematically review the classification and basic properties of colored and white gold alloys (part 1) and their metallurgical features and strengthening mechanisms (part 2).

The use of "green" gold can be traced to 862 BC, when the Lydians (a people in ancient Turkey) adopted it for coinage; this alloy had a composition of 73% Au and 27% Ag. [*Editor's note:* Most numismatic authorities place the date of the first Lydian coinage around 650–600 BC.] "Red" gold can be traced to ~1300 BC; the Chimú people of Peru used a composition of 70% Cu and 30% Au to fashion ornamental objects. The appearance of these colors can be explained by band theory, since Au and Cu are the only two colored metallic elements.

Metallurgically, colored gold alloys can be divided into three categories: (1) the Au-Ag-Cu alloy system, (2) intermetallic compounds, and (3) surface oxidized layers. Intermetallic compounds include "purple" gold, which is mainly a Au-Al alloy, and "blue" gold, which is mainly a $AuIn_2$ or $AuGa_2$ alloy. These alloys are relatively brittle. The 18K "Spangold" alloy (so-called because of the spangled, multicolored appearance of its surface) invented in 1993 is a Au-Cu-Al compound. The altered crystal structure causing the surface appearance is created by a special annealing process. Surface oxidized layers are usually created by heat treatment in an oxidizing atmosphere, with the addition of elements such as Fe, Ti, Cr, Ag, Cu, Ni, and Co.

The physical properties of these alloys can be changed, sometimes dramatically, by the addition of certain impurities or by alterations in treatment processes. The so-called pure gold (990 gold) is one successful example in recent years. In white gold alloys, Ni, Pd (palladium), and Ag are the major additives causing the "white" color. About 76% of white gold jewelry on the market is made from Ni alloys; Pd alloys make up about 15%.

Metallurgical properties such as hardness, ductility, and strength are strongly related to composition, structure, and grain size, as well as to specific treatment processes. Strength is usually inversely proportional to grain size. Manufacturing techniques such as those employing the Happ-Petch effect (to control grain size), cold-work hardening, solid-solution hardening, and various heat-treatment processes are used for strengthening, and examples of these methods with the Au-Ag-Cu alloy system are reviewed. Phase diagrams as well as tables listing the metallurgical properties are also given.

TL

SYNTHETICS AND SIMULANTS

Characterization of nitrogen doped chemical vapor deposited single crystal diamond before and after high pressure, high temperature annealing. S. J. Charles, J. E. Butler [butler@ccf.nrl.navy.mil], B. N. Feygelson, M. E. Newton, D. L. Carroll, J. W. Steeds, H. Darwish, C.-S. Yan, H. K. Mao, and R. J. Hemley, *Physica Status Solidi (A)*, Vol. 201, No. 11, 2004, pp. 2473–2485.

A nitrogen-containing (~1.5 ppm total N), 820 micron–thick synthetic diamond layer, grown epitaxially on a type Ib synthetic diamond seed by the microwave plasma CVD method, was characterized by five spectroscopic techniques (photoluminescence, UV-Vis, IR, cathodoluminescence, and electron paramagnetic resonance) both before and after high pressure/high temperature (HPHT) annealing. The color of the as-grown material was dark brown to black. Annealing of one portion of the sample at 6.5 GPa and 1,900°C for one hour resulted in a change to light gray/blue. Treatment of other portions at 7 GPa and 2,200°C for one hour and 10 hours, respectively, resulted in a change from dark brown to colorless. The decolorization occurred when structural defects causing the dark coloration were "healed" during HPHT annealing.

In the as-grown portion, spectral features indicated the presence of nitrogen vacancy–related centers (NV, NV⁻, NVH⁻); these disappeared or were transformed by the annealing into more complex centers (H3 and N3, believed to be the N-V-N and N-N-N-V centers, respectively). The portion annealed at the lower temperature showed evidence of NV-center dissociation and vacancy diffusion, but little evidence of nitrogen diffusion in the lattice. The two portions annealed at the higher temperature displayed evidence of nitrogen diffusion to form N-N–related centers. Details of the observed changes in the spectra of the before- and after-annealing portions are discussed. Although apparently similar changes in color are now obtained commercially during the HPHT decolorization treatment of brown type IIa natural diamonds, it is unclear if the details of the processes used for the natural and CVD synthetic diamonds are the same. *JES*

Study on mineralogy of synthetic jadeite jade stone. R. Wei, B. Zhang, and C. Shen, *Journal of Gems and Gemmology*, Vol. 6, No. 2, 2004, pp. 7–9 [in Chinese with English abstract].

Mineralogical and other properties of four specimens of synthetic jadeite (source not given) were determined by microscopy, X-ray diffraction (XRD) analysis, infrared spectroscopy (FTIR), electron-microprobe analysis (EMPA), and Raman spectroscopy. All of the samples were a dull green color, contained both transparent and translucent-to-opaque areas that were separated by a gradual transition zone, and also had both glassy and crystalline phases. The results were compared to those obtained from natural jadeite samples.

The crystalline phases were composed of small (3–5 mm) crystals with well-developed prismatic forms that were characteristic of the translucent-to-opaque regions; glassy material with an R.I. of 1.541 was characteristic of the transparent regions. Dark inclusions were observed mainly along fractures. XRD data from the crystalline synthetic areas were close to those of natural jadeite. Raman spectra from the crystallized areas showed prominent peaks at 1036, 698, and 373 cm⁻¹, which closely matched

those of natural jadeite at 1038, 699, and 374 cm⁻¹, but the intensities of the former were weaker due to the strong fluorescence of the synthetic samples. However, FTIR spectra from the crystallized synthetic regions contained a band at 494 cm⁻¹ that was not seen in the natural samples; small shifts in some major peaks were also observed between synthetic and natural materials. EMPA results from the crystallized materials contained areas with chemical compositions similar to that of natural jadeite ($NaAlSi_2O_6$) but with lower contents of Na_2O and CaO, and higher contents of K_2O, TiO_2, MnO, and NiO; the glassy areas had higher contents of Al_2O_3 and SiO_2, and much lower contents of Na_2O compared to natural jadeite. The textures of the synthetic jadeite samples were simpler than those of natural jadeite. *TL*

Ultrahard diamond single crystals from chemical vapor deposition. C-S. Yan [c.yan@gl.ciw.edu], H.-K. Mao, W. Li, J. Qian, Y. Zhao, and R. J. Hemley, *Physica Status Solidi (A)*, Vol. 201, No. 4, 2004, pp. R25–R27.

Recent advances in chemical vapor deposition (CVD) single-crystal diamond growth techniques have resulted in increasingly larger samples and faster growth rates. These new materials exhibit notable mechanical properties, including high fracture toughness and high intrinsic hardness caused by work hardening as a result of post-growth high pressure/high temperature (HPHT) annealing. Single-crystal synthetic diamonds up to 4.5 mm thick were epitaxially grown by microwave plasma CVD on type Ib synthetic diamond plates using the following conditions: N_2/CH_4 = 0.2–5.0%, CH_4/H_2 = 12–20%, pressure = 120–220 torr, temperature = 900–1500°C. Vickers hardness was measured at 50–110 GPa and fracture toughness at 6–18 MPa/m on the brown, as-grown CVD samples. After annealing at 2,000°C and 5–7 GPa for 10 minutes in a belt-type HPHT apparatus, the CVD synthetic diamonds turned colorless and became ultra hard (>160 GPa Vickers hardness). This measurement exceeds all known hardness data for synthetic and natural type Ib, Ia, and IIa diamonds, and the true value is probably higher, as some annealed CVD material damaged the indenters during hardness testing. The indented surfaces showed square crack patterns along softer <110> and <111> directions, but no cross-like crack lines along <100> as seen in annealed type IIa natural diamonds. *CMB*

TREATMENTS

Disruption of *B1* nitrogen defects in 1aB natural diamonds by plastic deformation and behavior of the defects created on the *PT* treatment. V. A. Nadolinnyi [spectr@che.nsk.su], O. P. Yur'eva, A. P. Yelisseyev, N. P. Pokhilenko, and A. A. Chepurov, *Doklady Earth Sciences*, Vol. 399A, No. 9, 2004, pp. 1268–1272.

Most natural diamonds contain nitrogen impurities and dislocations. However, the interaction between nitrogen centers, particularly B-aggregates, and dislocations is not well understood. Sixty-three inclusion-free, greenish to brown colored, type IaB diamond crystals with traces of plastic deformation from the Udachnaya pipe in Russia and the Snap Lake deposit in Canada were examined. Each was analyzed by photoluminescence (PL) and electron paramagnetic resonance (EPR) before and after HPHT treatment. Two-stage annealing was performed from 1,850 to 2,000°C at 7 GPa for 12 hours using a split-sphere apparatus.

Before annealing, the PL spectra (collected at 77 K) were dominated by an intense N3 (415 nm) system; afterward, the 415 nm line was more intense, but an H3 (503.2 nm) system had also appeared and was responsible for a more greenish color. The EPR spectra before treatment showed only a broad P2 center at 300 K (room temperature), which disappeared with cooling to 77 K. Photoexcitation (<380 nm) restored the P2 feature and also produced a P1 EPR feature. After annealing, intense P1 and P2 centers were both present at 300 K without photoexcitation. These changes were attributed to plastic deformation features. Before treatment, charge transfer between P2 centers and dislocations generated the changes caused by cooling and photoexcitation. After treatment, the dislocations, as well as the charge transfer, had been removed, causing both P1 and P2 centers to be visible without excitation. The migration of dislocations through the crystals during the annealing of plastic deformation features disrupted complex nitrogen defects (A and B centers) and created the simpler forms of nitrogen (P1, P2, H3) observed using EPR and PL following the treatment. These results indicate that plastic deformation features play an important role in the HPHT treatment of type IaB diamonds to change their color.   *CMB*

The identification of impregnated nephrite. J. Li [geoli@vip.sina.com], *Australian Gemmologist*, Vol. 22, No. 3, 2005, pp. 310–317.

The much-treasured white nephrite from Hetian, Xinjiang Province, China, is becoming increasingly scarce. This has resulted in large amounts of lower-quality white nephrite from Russia and Qinghai Province, China, coming into the market. Some of this material is bleached and impregnated to imitate Hetian white nephrite. The author argues that this is an unacceptable treatment that must be disclosed. It is shown that these treated nephrites can be positively identified using IR spectrometry, with diagnostic absorption bands between 2560 and 2460 cm^{-1}; treatment with epoxy resin can be detected by the presence of absorption peaks from 3060 to 2850 cm^{-1}.   *RAH*

Why does polycrystalline natural diamond turn black after annealing? B. Willems [bert.willems@ua.ac.be], K. De Corte, and G. Van Tendeloo, *Physica Status Solidi (A)*, Vol. 201, No. 11, 2004, pp. 2486–2491.

The polycrystalline exteriors of several translucent natural "coated" diamonds of various colors were found to turn black after annealing for several hours in a vacuum at temperatures above 1,000°C. Detailed optical examination revealed that the transparent inner cores of these coated crystals remained essentially unchanged after the annealing, whereas the coatings themselves darkened as a result of the formation of numerous small cracks and black inclusions. Spectra recorded before and after annealing showed a broadening, but no change in position, of the 1330 cm^{-1} first-order diamond Raman line. A broad Raman peak at 1600 cm^{-1} was observed to have an inverse relationship in peak intensity with the 1330 cm^{-1} line, with increasing annealing temperatures and times (the former increased, whereas the latter decreased, in intensity after sample heating for 6 hours at 1,500°C). The authors attribute the 1600 cm^{-1} band, along with the bands at 1585 and 1350 cm^{-1}, to various nondiamond carbon phases (such as graphite, amorphous carbon, and disordered glassy carbon). Electron diffraction and transmission electron microscopy demonstrated that these phases were created during the annealing as tiny inclusions, and along crack and grain boundaries. Formation of these nondiamond alteration products along with other dislocations was responsible for the observed darkening of these polycrystalline coated diamonds during high-temperature annealing.   *JES*

MISCELLANEOUS

After the mines. H. T. Schupak, *JCK*, Vol. 176, No. 1, 2005, pp. 92–96.

The article explains the measures that De Beers is taking to develop projects in communities near its mines to ensure the communities' sustainability after the diamonds are depleted. The Masete Primary School, established near the Venetia mine in South Africa, houses 1,600 students, and is supported jointly by the government and De Beers. De Beers has ongoing projects to equip classrooms and improve facilities. The company has also established an AIDS awareness program and farming projects in nearby villages in the province, one of the country's poorest.

De Beers is also developing environmental programs. It has established the 80,300 acre Venetia-Limpopo Nature Reserve near Venetia and set aside an additional 469,300 acres as conservation land. It has reintroduced wildlife species into the area, including wild dogs, African elephants, and black rhinoceroses, and also established a conservation research center. The company has partnered with the South African government on many of these initiatives.

                    RS

A cost-benefit analysis of projects implemented to assist the black pearl industry in Manihiki Lagoon, Cook Islands. E. McKenzie, *SPC Fisheries Newsletter*, No. 110, 2004, pp. 37–40.

In November 2000, black pearl aquaculture in Manihiki Lagoon, Cook Islands, was severely affected by an oyster disease. The causes were determined to be overstocking, poor handling of pearl oysters, and adverse environmental conditions. In response, the Cook Islands Ministry of Marine Resources and other organizations sponsored certain projects intended to study and promote sustainable farming of black cultured pearls in this lagoon. This article describes some of these projects and their benefits to pearl farming.

The physical projects in place at Manihiki Lagoon revolve around monitoring the oysters and the lagoon conditions. Buoys provide data on parameters such as water temperature and dissolved oxygen; bathymetry (underwater mapping) aids farm layouts; and oyster-health surveys and censuses monitor potential threats and ensure sustainable oyster populations. In addition to these tools, the study considered other endeavors, such as training courses for seeding technicians that would lessen the industry's dependence on foreign labor. The study also recommended that good management structure be adopted, project data arrive promptly, and farmers be trained to properly interpret the data. A pearl farming management plan that will provide a system of rules and regulations to effectively manage the lagoon's use is already in draft stage.　　*DMK*

Guanxi and regulation in networks: The Yunnanese jade trade between Burma and Thailand, 1962–88. W.-C. Chang [wenchinchang@yahoo.com], *Journal of Southeast Asian Studies*, Vol. 35, No. 3, 2004, pp. 479–501.

Northern Myanmar (Burma) borders the Chinese province of Yunnan. Over the centuries, and especially after the 1949 revolution, many ethnic Chinese settled in this area. This article is a review of the effects that Yunnanese migrants and their social networks (*guanxi*) have had on the jadeite trade between Burma and Thailand.

The famed Burmese jadeite deposits are located in Kachin State. Though local use is thought to have started centuries earlier, wide-scale jadeite mining did not begin until large numbers of Yunnanese miners and traders came to Burma in the second half of the 18th century. Most of the jade leaving Burma passed through Yunnan until the border with China was closed in 1949. The replacement route—south through Rangoon and thence to Hong Kong by sea or air—was itself shut down after the 1962 military coup nationalized the Burmese economy. However, because the jadeite mining regions were controlled by Burmese rebel groups and Kuomintang (Chinese Nationalist) militias who had fled Yunnan in 1949, illicit jadeite trade continued, this time through Thailand (frequently alongside the opium trade). Although mining was controlled by various ethnic groups, it was the Yunnanese who controlled the jadeite trading because of their well-organized *guanxi* networks of relatives or close friends throughout the area. Mae Sai, a Thai border town, became the major jade trading market, and Yunnanese on the Thai side of the border helped legalize and ship the jadeite once it was in Thailand. From the 1960s to the 1980s, four major jade companies in Mae Sai and Chiang Mai (another town in northern Thailand), all established by ethnic Chinese, dominated the jadeite trade. Though marred by some conflict, this trade was governed by strict though unofficial regulations that the author again ties to the *guanxi* networks.

The author traces the strength of the *guanxi* networks to the topography of Yunnan province, which is composed of high mountains separating one village from another. This has led to close affiliations among Yunnanese migrants from the same county or village. Although these affiliations provided an incentive to create the trading networks, the jade trade was also based on trust (*xinyong*) and familism. However, trust and ties alone were not sufficient to establish a long-term business, not only because of the complicated nature of jade trading but also because of human fallibilities, such as cheating. Only with the additional regulation discussed above could the trade thrive.　　*KSM*

"Lucy in the Sky with Diamonds": Airline liability for checked-in jewelry. E. C. Rodriguez-Dod, *Journal of Air Law and Commerce*, Vol. 69, No. 4, 2004, pp. 743–768.

This article reviews various legal developments concerning the rights of airline passengers to collect compensation from carriers for jewelry lost or stolen from luggage on both domestic and international flights. On domestic flights, once-rigid liability limits have, since deregulation in the late 1970s, gradually given way to allow passengers to collect higher compensation for lost or stolen jewelry where airline negligence is involved or the airline has not followed its own stated procedures for handling valuable items. For international flights, a 2003 treaty, the Montreal Convention, has eased some requirements of the old Warsaw Convention that had governed international travel since 1947. A significant change has been to remove airline liability based on the weight of the lost or pilfered bag, instead replacing it with a fixed limit (~$1,350). The Montreal Convention allows passengers to be compensated over the liability limit stated on the ticket if the loss was caused by "an act or omission of the air carrier that was intentional or reckless."

However, increased security measures after September 11, 2001, have complicated issues. Theft from luggage has skyrocketed, and neither domestic laws nor the Montreal Convention address liability when bags are inspected by the Transportation Safety Administration. Although both the TSA and the airlines suggest placing valuables in carry-on bags, TSA screeners could deem some jewelry items too sharp to be carried on board a plane.　　*RS*

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AUTHOR INDEX

This index lists, in alphabetical order, the authors of all articles that appeared in the four issues of Volume 41 of GEMS & GEMOLOGY, together with the full title and inclusive page numbers of each article and the issue (in parentheses). Full citation is given under the first author only, with reference made from joint authors.

The
G&G Digital Archives
1934–1980

In addition to GIA's educational, laboratory, and instrument services, Institute founder Robert M. Shipley envisioned a technical journal dedicated to serving the needs of the professional jeweler. Three years after GIA opened its doors, Shipley's dream was realized in January 1934 with the first issue of *Gems & Gemology*. The look of that inaugural issue—black-and-white, a small $5\frac{1}{2} \times 8\frac{1}{2}$ inch format, and a slender 32 pages—remained essentially unchanged until 1981.

Yet the modest appearance of these early issues belies the value of their content. While the first few issues were a reflection of the nascent gemological movement, featuring lighter pieces such as selling tips for jewelers and the lore of famous gems, *G&G* quickly matured into a forum for ground-breaking research. Within a few years, seminal articles on identification techniques, new gem localities, and detecting the synthetics and imitations of the day had become the cornerstone of the journal's coverage. Among the regular contributors to *G&G* during this era were some of the world's most influential gemologists, including Basil W. Anderson, Sydney Ball, Edward J. Gübelin, Edward Kraus, Karl Schlossmacher, and Robert Webster, as well as GIA's own Richard T. Liddicoat and G. Robert Crowningshield.

On the eve of the Institute's 75th anniversary, we are pleased to offer free, unlimited electronic access to these early issues on our website. Visit **www.gia.edu/gemsandgemology** and click on the **"1934–1980 Back Issues"** button to find links to PDF files of all 192 issues (for those doing the math, *G&G* was published bimonthly during its first two years). To view and download the complete contents, you simply need to have Adobe Reader installed on your computer; this free software can be downloaded easily at www.adobe.com/products/acrobat/readstep2.html.

To help users retrieve the information they need, the "1934–1980 Back Issues" page also contains searchable subject and author indexes for every issue through 1968 (the final 12 years are still in the works). These indexes were compiled over the last two years by a pair of distinguished academics, **Dr. Richard V. Dietrich** of Central Michigan University and the late **Dr. Alfred A. Levinson** of the University of Calgary (see p. 297). Our heartfelt thanks go to Drs. Dietrich and Levinson for volunteering their time to create this immensely useful guide to the journal's first 35 years.

So visit our website and explore the wealth of information in the 1934–1980 back issue archives. We hope this will be a useful and interesting resource for gemologists everywhere. If you have thoughts on the archives or the index, please send us an e-mail at gandg@gia.edu.

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Photo by Karen Myers

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