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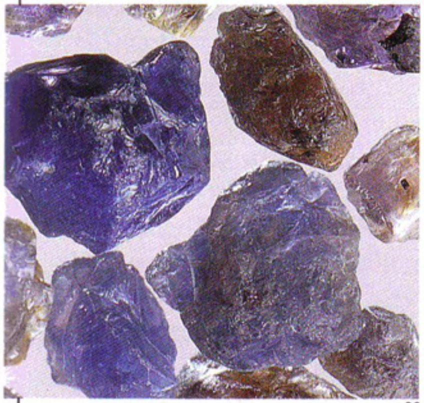

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EDITORIAL

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REGULAR FEATURES

ABOUT THE COVER: Amethyst-citrine quartz, known in the trade as ametrine, is one of the most enigmatic gem materials to appear on the market in recent years. Early reports suggested that it might actually be a synthetic, or the product of treatment. The lead article in this issue, by Drs. Vasconcelos, Wenk, and Rossman, takes the reader to the actual deposit in Bolivia where thousands of kilos of ametrine have been mined, shares the fashioning of the crystals, and discusses the cause of the unusual color zoning. Contemporary cutters and carvers have discovered the exciting artistic possibilities that this material offers. The 78-ct ametrine illustrated here set in an 18k gold "collar" was fashioned by master German designer and gem carver Bernd Munsteiner, of Idar-Oberstein, the innovator in such "fantasy" carvings. The three loose ametrine carvings—142, 44, and 263 ct—are by renowned American lapidary artist Michael M. Dyber, Rumney, New Hampshire.

Photo © Harold & Erica Van Pelt—Photographers, Los Angeles, CA.

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THE GEMS & GEMOLOGY MOST VALUABLE ARTICLE AWARD

Alice S. Keller, Editor

Your choices for the "Most Valuable Article" of 1993 were diverse—reflecting the variety of topics that today's gem and jewelry professional *must* know. The first-place award goes to the comprehensive, informative, and beautifully illustrated "Jewels of the Edwardians," by Elise Misiorowski and Nancy Hays, which appeared in the Fall issue. With synthetic diamond probably the most talked about "gem" of the year, second place is awarded to the Winter 1993 article that represents the cutting edge of research into this very important gemological problem: "The Gemological Properties of Russian Gem-Quality Yellow Synthetic Diamonds," by James Shigley, Emmanuel Fritsch, John Koivula, Nikolai Sobolev, Igor Malinovsky, and Yuri Pal'yanov. Reiterating the importance of learning about and identifying treatments, readers selected for third place "Update on Diffusion-Treated Corundum: Red and Other Colors," by Shane McClure, Robert Kammerling, and Emmanuel Fritsch, which appeared in the Spring 1993 issue.

The authors of these three articles will share cash prizes of $1,000, $500, and $300, respectively. Photographs and brief biographies of the winning authors appear below. Congratulations also to Sira Haydeé of San Juan, Puerto Rico, who was randomly chosen from the ballots to win the five-year subscription to *Gems & Gemology.*

On the subject of awards . . . we are pleased to report that, for the second year in a row, *Gems & Gemology* won the coveted American Society of Association Executives Gold Circle award for best journal. Among the hundreds of organizations that participated in 1993, *Gems & Gemology* was one of the very few to receive a second Gold Circle award, this one for best scientific/educational feature article—"Diamond Sources and Production: Past, Present, and Future," by Alfred A. Levinson, John J. Gurney, and Melissa B. Kirkley. GIA Director of Marketing Kathryn Kimmel accepted the awards in New York on behalf of *Gems & Gemology.* Editor-in-Chief Richard T. Liddicoat and I would like to take this opportunity to thank the dozens of people who have contributed to the journal's success as authors, editors, reviewers, and abstracters. *Gems & Gemology* is the product of a team that literally spans the globe, and we are proud to see all of these efforts recognized. Our special thanks to Art Director Lisa Joko-Gleeson, Assistant Editor Irv Dierdorff, Technical Editor Carol Stockton, and Production Artist Carol Silver for making it all come together in its award-winning form.

FIRST PLACE

Elise B. Misiorowski • Nancy K. Hays

Elise B. Misiorowski is a research librarian at the Richard T. Liddicoat Gemological Library and Information Center, GIA, Santa Monica. A prolific author and formerly a diamond grader in the West Coast GIA Gem Trade Laboratory, Ms. Misiorowski lectures on antique and period jewelry. **Nancy K. Hays** was assistant editor of *Gems & Gemology* and managing editor of *In Focus,* the GIA alumni magazine, for five years. A graduate of Northwestern University, Ms. Hays is now an editor at Jems Communications in Carlsbad, California.

Elise B. Misiorowski, left, and Nancy K. Hays

SECOND PLACE

James E. Shigley • Emmanuel Fritsch • John I. Koivula
Nikolai V. Sobolev • Igor Y. Malinovsky
Yuri N. Pal'yanov

James E. Shigley, who received his doctorate in geology from Stanford University, is director of GIA Research. He has written many articles on natural, treated, and synthetic gems, and directs research on the identification of these types of gem materials. Manager of GIA Research **Emmanuel Fritsch** specializes in the application of spectroscopy to gemology, the origin of color in gem materials, and treated and synthetic gems. A native of France, he has an advanced degree in geological engineering from the Geology School in Nancy, France, and his Ph.D. from the Sorbonne in Paris. **John I. Koivula,** GIA Gem Trade Laboratory's chief research gemologist, is world renowned for his expertise in inclusions and photomicrography. He is coauthor—with Dr. Eduard J. Gübelin—of the *Photoatlas of Inclusions in Gemstones.* Mr. Koivula also holds bachelor's degrees in chemistry and mineralogy from Eastern Washington State University. **Nikolai V. Sobolev** is director of, and **Igor Y. Malinovsky** is senior researcher at, the Institute of Mineralogy and Petrography, Russian Academy of Sciences (Siberian Branch) in Novosibirsk. Dr. Sobolev, a Foreign Associate of the National Academy of Sciences (U.S.), has written much about his main fields of research—diamonds, upper-mantle petrology, and high-pressure crustal petrology. Dr. Malinovsky is involved in the study of high-pressure experimental petrology. **Yuri N. Pal'yanov** is deputy director of the Design and Technological Institute of Monocrystals, Russian Academy of Sciences (Siberian Branch), also in Novosibirsk. He is researching diamond growth and crystallography.

From left—Emmanuel Fritsch, James E. Shigley, John I. Koivula

Igor Y. Malinovsky

Nikolai V. Sobolev

THIRD PLACE

Shane F. McClure • Robert C. Kammerling
Emmanuel Fritsch

Shane F. McClure is supervisor of identification services in the GIA Gem Trade Laboratory, Santa Monica. Mr. McClure has 16 years of experience in the gem field. He is also an accomplished gem and jewelry photographer. Director of identification and research at the GIA Gem Trade Laboratory in Santa Monica, **Robert C. Kammerling** is an associate editor of *Gems & Gemology* and coeditor of the Gem Trade Lab Notes and Gem News sections, the latter along with Mr. Koivula and Dr. Fritsch. He coauthored—with Dr. Cornelius Hurlbut—the book *Gemology.* A regular contributor to numerous publications worldwide, Mr. Kammerling has a B.A. from the University of Illinois. The biography for Emmanuel Fritsch appears above.

From left—Robert C. Kammerling, Emmanuel Fritsch, Shane F. McClure

THE ANAHÍ AMETRINE MINE, BOLIVIA

By Paulo M. Vasconcelos, Hans-Rudolf Wenk, and George R. Rossman

The Anahí mine, Bolivia, has produced large amounts of amethyst, citrine, and amethyst-citrine for the gem market. Field and experimental investigations conclusively show that the amethyst-citrine color combination in quartz crystals from Anahí is natural and does not result from laboratory treatment. The unusual color patterns probably result from the uncommon geologic conditions under which these quartz crystals formed, although the crystal chemical properties controlling the sector color zoning still elude explanation. From 1989 to the present, more than 100 tons of ametrine crystals, yielding 40–80 kg of cutting rough per ton, have been produced.

ABOUT THE AUTHORS

Dr. Vasconcelos is lecturer in economic geology, Department of Earth Sciences, University of Queensland, Brisbane, Queensland, Australia; Dr. Wenk is professor of geology, Department of Geology and Geophysics, University of California, Berkeley; and Dr. Rossman is professor of mineralogy, Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena.

Acknowledgments: The authors thank M&M personnel, particularly Don Ramiro Rivero, for providing access to the Anahí mine, field support, samples, and information on mine production. The White Rose Foundation kindly supported laboratory studies. The senior author also thanks Francisco Mansur, Domingos Reis, Roberto Colen, Anne Marie Kitos, Brent Lords, and John Donovan for their contributions.

Gems & Gemology, *Vol. 30, No. 1, pp. 4–23*

One of the most interesting gem materials to appear on the market in recent years is the bicolored variety of quartz known as amethyst-citrine, bicolored amethyst, bolivianite, or ametrine* (figure 1). Although this material was well received when it first entered the international market in the 1970s, the natural or artificial origin of ametrine has been the subject of much controversy over the past decade. In 1981, Nassau showed that an amethyst-citrine color combination could be produced artificially in a natural Brazilian amethyst sample by combined irradiation and heat treatment. Simultaneously, North American gem traders received conflicting reports about where the material was being mined (Vargas and Vargas, 1980; Nassau, 1981). As a result, speculation arose that ametrine was artificially produced.

Now, however, the open-door policy practiced by the current owners of the mine has made it possible to disseminate reliable information about the natural occurrence of ametrine (Verbin, 1993; Jones, 1993). The Anahí (pronounced ä-nä-ē) ametrine mine is located in eastern Bolivia, near the border with Brazil (figure 2). The Anahí mine produces ametrine crystals, which are then selectively cut into amethyst, citrine, or amethyst-citrine. To gather information on the geology of the deposit and the formation of ametrine, as well as to collect material for further testing, the authors traveled to the mine in October 1992 (PMV) and August 1993 (PMV, HRW, and GRR). In this article, we present the results of these geologic and mineralogic studies, review mining and production at Anahí, and provide information on the properties of this material and on the possible cause of the unusual color combination found in this variety of quartz.

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*Crystal chemical investigations indicate that this material is composed of intergrown amethyst and citrine. In this article, we will use the name ametrine to refer to this bicolored variety of quartz, since it has correct mineralogic implications and is already widely used in the gemstone trade.

Figure 1. Large quantities of the unusual bicolored quartz known as ametrine have entered the gem market in recent years. Produced at the Anahí mine in eastern Bolivia, most of this material was originally cut as amethyst or, in lesser amounts, citrine. However, the unusual bicolored nature of the original crystals lends itself to classic faceting as well as to fantasy cuts. Faceted stones (largest—362.37 ct) courtesy of Minerales y Metales del Oriente S.R.L. and P. Vasconcelos; fantasy cut (41.70 ct) carved by Michael M. Dyber. Photo © Harold & Erica Van Pelt.

HISTORY OF THE MINE

The mining of ametrine is shrouded in legends, mystery, and international intrigue. According to Jean Marc Tressiére (1993), Europeans first learned of ametrine in the 17th century, when a Spanish conquistador presented samples to his monarch; the conquistador had received the ametrine mine as a dowry when he married a native princess—named Anahí—of the Ayoreos tribe. There is no further record of ametrine until the 20th century, although it is rumored to have reappeared in the 19th century in the hands of Uruguayan, Paraguayan, and Brazilian dealers. Note that Holden (1925) described bicolored amethyst-citrine quartz and Lemmlein (1951; as cited in Balitsky and Balitskaya, 1986) described similar material purportedly from Brazil. There are also some accounts that the deposit was exploited sporadically by Indians from the local Ayoreos tribe, who sold their production in a missionary post in Rincón del Tigre to gemstone dealers from Puerto Suárez (figure 2; R. Colen and D. Reis, pers. comm., 1993).

We do know that gem production restarted sporadically in the 1960s (Litherland et al., 1986). Active exploitation did not occur until the late 1970s, when demand for gem-cutting material propelled Brazilian gem dealers and Brazilian, Bolivian, and Paraguayan miners into the area. Because the deposit was located in a Bolivian state fiscal reserve, however, it was constitutionally closed to private mining. In fact, a military station was established nearby specifically to prevent such activities. Mining did continue, though, according to personal accounts by Brazilian miners/dealers who ventured into the region at the time, in exchange for "fees" negotiated with some of the local military authorities (R. Colen, pers. comm., 1993). The gem explorers traveled by boat along the Paraguay River to the village of Amolar (figure 2). From Amolar, they traveled west on jungle trails for 30 km, a two-day journey by foot. The miners hand-carried all the

Figure 2. The Anahí mine has remained virtually unknown because of difficult access to the often flooded Pantanal/Chaco region of South America. Although there is a small airstrip near the mine, the area is commonly reached by traveling via boat from Puerto Suárez to the Mandioré Lagoon, and then from the lagoon to the mine over 29 km of jungle trail. Because of legal restrictions (until 1989) on mining in the Anahí area and on importing the gem material into Brazil, early reports identified the source as being in Mato Grosso do Sul or Uruguay. Today, production from the Anahí mine is processed largely in the Brazilian gem centers of Belo Horizonte (BH), Governador Valaderes (GV), and Teófilo Otoni (TO). Also abbreviated on the map is Santa Cruz de la Sierra (SCS).

tools and supplies necessary. They cobbed the rough material at the mine site, keeping only the gem-quality portions of the crystals. Often a new military commander or inspector would arrive unannounced in the area, forcing the illicit miners to flee through the jungle with their tools and whatever gem rough they had been able to recover.

Not only did the Bolivian government forbid mining in the Anahí area during this period, but the Brazilian government also had strict import restrictions that made it virtually impossible for gems mined in Bolivia to enter Brazil legally. To circumvent these restrictions, the miners smuggled the Bolivian ametrine into the state of Mato Grosso (now Mato Grosso do Sul), Brazil (again, see figure 2). The gems were then registered with Brazilian fiscal authorities in Corumbá, as if they had been mined in Brazil. It was because of their need to protect their sources and trade ametrine within Brazil that gem dealers disseminated conflicting accounts about the mine location. Brazil near the Bolivian border (Aines and Rossman, 1986), Brazil near the Uruguayan border (Vargas and Vargas, 1980), and the Brazilian state of Mato Grosso (Sauer, 1982) were claimed as production localities for ametrine. Other sources—including Bolivia (Nassau, 1981), Uruguay (Vargas and Vargas, 1980), and Brazil, Uruguay, and Bolivia (Balitsky and Balitskaya, 1986)—were also cited in the international literature. Unfortunately, this ambiguity about the geographic source of ametrine contributed to the widespread belief that ametrine was manufactured in a laboratory in Brazil.

Although Nassau (1981) indeed showed that amethyst-citrine could be artificially generated from natural amethyst, there appear to be visual differences between the artificially generated sample illustrated in Nassau's article and the ametrine available in the market. Our efforts to reproduce Nassau's experiments (heat treating and irradiating Marabá amethyst) resulted in a bicolored stone that showed citrine and smoky amethyst, again very unlike the appearance of natural ametrine. In preliminary experiments, we have also observed differences in the optical spectra of Anahí citrine and those of citrine formed by heating Marabá amethyst. From a practical perspective, the quantities of ametrine commercially available and their low value at the time did not support the hypothesis that they had been produced by a complicated, expensive combination of irradiation and heat treatment. Furthermore, accounts by researchers and reputable gem dealers acquainted with the complex and politically sensitive situation in the ametrine mine explained the scarcity of published and official information (Koivula, 1987; Koivula and Kammerling, 1989). In addition, as early as 1986 some dealers displayed natural ametrine crystal

Figure 3. This aerial view of the Anahí deposit and mining operations shows the major dump site (D) at the base of the hill and the entrance to the main mining tunnel (T). Photo courtesy of Minerales y Metales del Oriente S.R.L.

specimens during the Tucson gem and mineral shows that were morphologically unlike any commercially produced synthetic quartz. Even so, rumors still persist that ametrine is only produced by treating amethyst or by synthesis.

In 1989, changes in the Bolivian constitution and mining code legalized mining in the fiscal reserves. A Bolivian company, Minerales y Metales del Oriente S.R.L. (M&M), acquired the concessions, officially named the mine Anahí in honor of the Ayorean princess, and restructured the mining and trading of ametrine. Simultaneously, a change in Brazilian law legalized the importation of rough gem materials. Since then (up to July 1993), approximately 100 metric tons of mine-run ametrine has been traded at M&M's offices in Puerto Suarez and Santa Cruz de la Sierra. Brazilian dealers buy most of the rough material and then have it processed at the gem-cutting centers of Belo Horizonte, Governador Valadares, and Teófilo Otoni for export. More recently, Brazilian dealers have been exporting large quantities of cobbed rough to Oriental cutting centers. Some of the rough has been used in carvings, and crystal specimens were again available at both the 1993 and 1994 Tucson shows (e.g., Koivula et al., 1993).

LOCATION AND ACCESS

The Anahí mine is located in Santa Cruz province, eastern Bolivia (figure 2), at 18°03'S, 57°48'42"W, approximately 30 km west of the border with Brazil. This region, known as *Pantanal* in Brazil and as *Chaco* in Bolivia and Paraguay, is characterized by lush tropical vegetation in the highlands and swamp vegetation in the flood plains of the Paraguay River. Access to the Anahí mine continues to be very difficult. To reach the Bolivian border town of Puerto Suárez, most visitors travel by air from La Paz via Santa Cruz de la Sierra or by air from Rio de Janeiro. The quickest route from Puerto Suárez to the mining area is by chartered single-engine aircraft. A small dirt landing strip is operational during dry periods. A 3-km trail from the landing field to the mine can be traveled by foot or in the mining company truck. Access from Puerto Suárez is also possible by taking a six-hour speed boat trip up the Paraguay River to the Mandioré lagoon; from the lagoon to the mine, the traveler ventures along 29 km of jungle track. In recent months, the mining company has begun to use two boats to carry passengers and cargo to and from the mine.

GEOLOGY AND MINERALIZATION

The Anahí deposit (figures 3 and 4) occurs at the northern base of a dolomitic limestone hill, which is part of a north-south trending ridge that rises 200 m above the surrounding Pantanal plains. These north-south ridges are the surface expression of a 70-km-long regional fault system (figure 4). In the mineralized areas, these topographic features are probably formed by the hydrothermal alteration

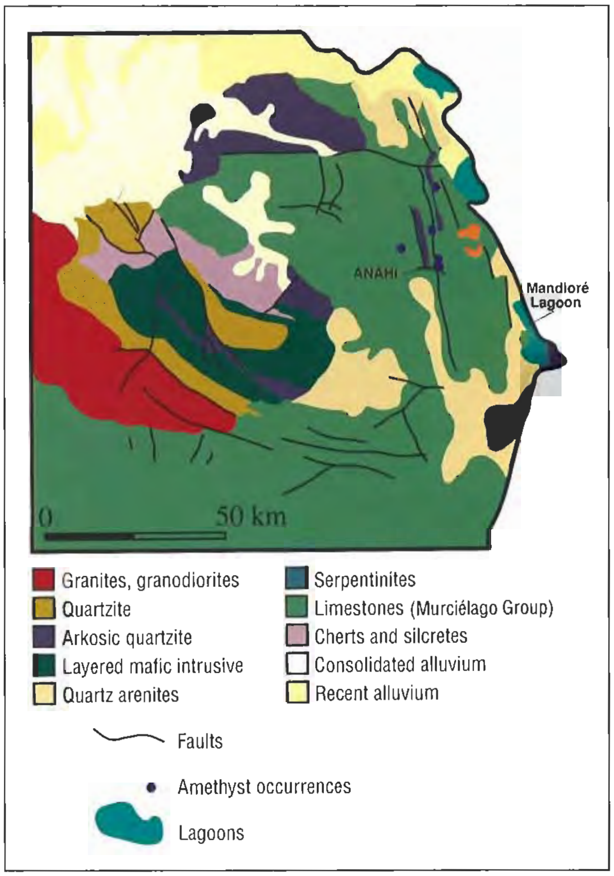


Figure 4. The Anahí ametrine deposit occurs along a major regional fault system, along which other quartz deposits have been identified. In the immediate area of Anahí, the dominant host rock is a dolomitic limestone from the Murciélago Group.

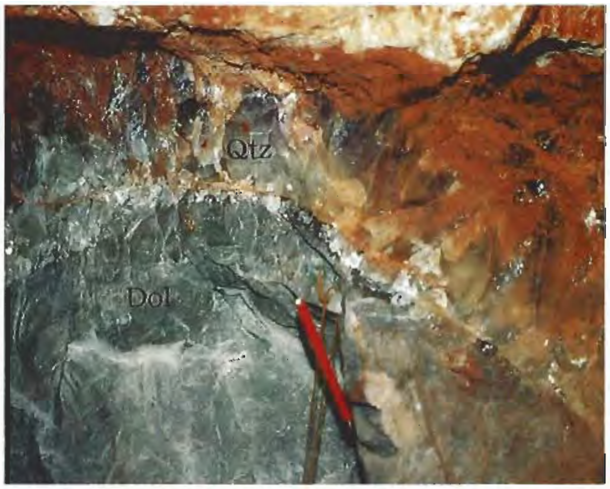
and silicification of the limestones, which renders them more resistant to weathering and erosion. Several quartz deposits occur along this regional fault system (Litherland et al., 1986), but significant amounts of gem-quality ametrine have been found only at Anahí. A nearby mine, appropriately named Mina Pobre (Poor Mine), also produces some low-quality (turbid) ametrine.

The carbonate rocks hosting the Anahí deposit belong to the Murciélago Group, a 500-m-thick flat-lying sequence of limestones. The carbonates are thought to have been deposited during a period of widening of a shallow continental sea, and they overlie a series of conglomerates, volcanic rocks, sandstones, shales, and banded iron and manganese formations, which rest unconformably on basement rocks. The deposition of the Murciélago carbonates and their subsequent folding are thought to have occurred during the Brasiliano Orogeny, between 500 and 900 million years (My) ago, when north-trending regional fault systems also developed (Litherland et al., 1986).

In the area of the Anahí mine, the Murciélago limestones occur as laminated grayish units with reddish, iron-stained horizons and as cream-colored massive carbonate rocks. X-ray diffraction analyses indicate that these rocks are dolomitic limestones. Our petrographic studies also indicate that the horizons are rich in iron oxides (mostly hematite), detrital quartz, and fine-grained white micas, probably muscovite.

The Murciélago carbonate units strike S53°E and dip 35° to the southwest, but rotated and upright blocks are often found in the vicinity of the mine. The dolomite beds were strongly faulted and silicified in the mine area, with rotated limestone blocks cemented by massive milky quartz (figure 5). The contact between the limestone and the quartz overgrowth is abrupt, and some limestone was dissolved before silica precipitation took place. In areas where the limestone blocks are large (up to 10 m) and open cavities between adjacent blocks are wide, the massive quartz overgrowth gradually becomes

Figure 5. Quartz (Qtz) precipitates on the walls of vugs formed by dolomite (Dol) brecciation. Because these dolomite blocks are massive, they are routinely blasted to allow access to new pockets. At the contact with the dolomite, quartz is microcrystalline; it becomes coarse crystalline and milky away from the contact, and it eventually forms euhedral crystals with tips that are purple and orange-yellow. The quartz-bearing cavities are often filled with clay minerals. Photo by P. Vasconcelos.



euhedral, forming crystals that are colored purple and orange-yellow toward the tip. These crystals grow toward the center of the open spaces. Some chambers are up to 5 m long, 3 m wide, and 5 m high—completely lined with prismatic quartz crystals (figures 5 and 6).

This style of mineralization, characterized by faulted and rotated blocks showing evidence of explosive fracturing followed by initially rapid mineral precipitation, is known as hydrothermal breccia (figure 7). The mineralizing solutions at Anahí were silica-rich, and quartz precipitated as a result of the decompression caused by limestone brecciation. The large sizes in which the crystals can occur suggest the migration of massive quantities of silica-rich solutions after initial brecciation. When hydrothermal fluids are suddenly depressurized they boil, in a manner similar to the loss of CO_2 when a soda bottle is opened. Boiling can be recognized by the presence of primary fluid inclusions with widely varying proportions of vapor and liquid phases within a single specimen (Roedder, 1984, p. 255). In quartz crystals from the Anahí mine, we

Figure 6. Large euhedral ametrine crystals and clay minerals line the walls of one of the mineral cavities at Anahí. To recover the ametrine crystals, miners pry them from the milky base, often leaving gem-quality areas embedded in the matrix. The chamber shown here produced more than 10 metric tons of ametrine crystals. Photo by P. Vasconcelos.

Figure 7. This schematic cross-section depicts the geologic evolution of the deposit through time. When hot mineralized solutions form in the crust and migrate upward along porous and permeable rocks, they may reach a barrier presented by a less permeable horizon (A). The solutions get trapped by the obstacle, and the hydrostatic (water) pressure builds up. When the hydrostatic pressure becomes greater than the lithostatic (rock) pressure, the rocks burst open (B). The newly created fractures allow the solutions to migrate again. With the sudden release of pressure, the solutions are less able to hold dissolved constituents. This leads to rapid mineral precipitation. Overlying shales are subsequently weathered and eroded.

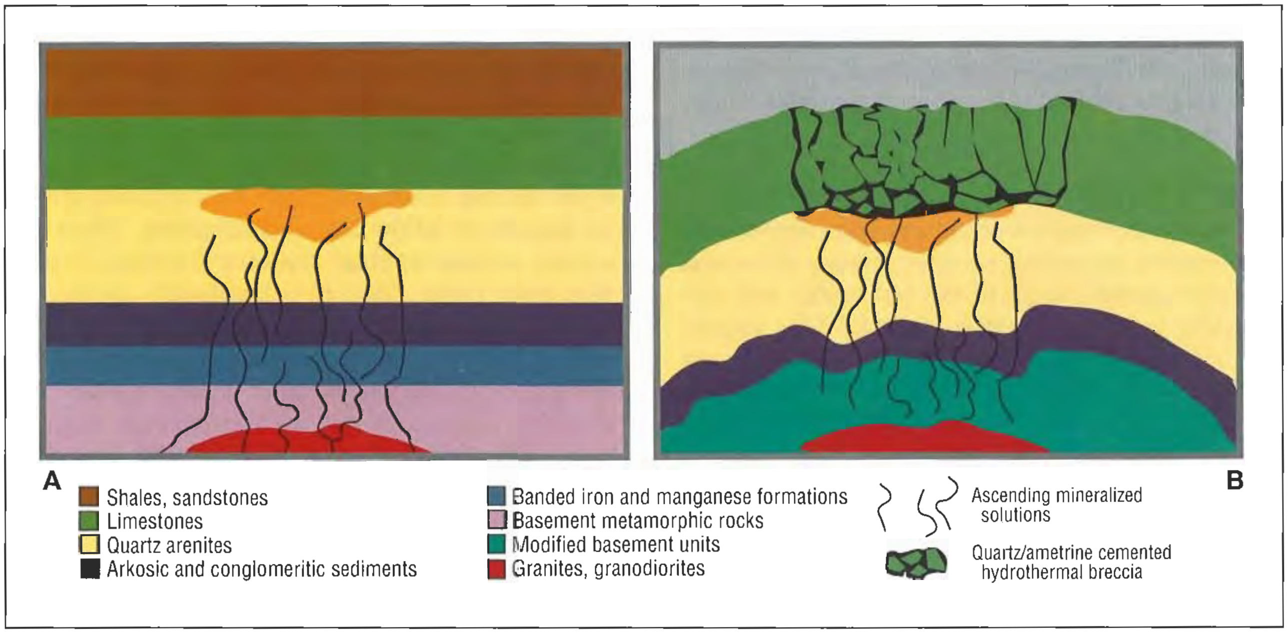


Figure 8. Miners transport barren host rock and clay to the dump sites in wheelbarrows. Note the large, brecciated limestone blocks. Photo courtesy of Minerales y Metales del Oriente S.R.L.

observed inclusions ranging from pure liquid to pure vapor, which further suggests that the deposit was formed by silica precipitation when the hydrothermal fluids boiled.

Ametrine-bearing vugs and chambers are often half-filled with white and red clay minerals (again, see figure 6). X-ray diffraction analyses indicate the presence of kaolinite, some smectites, quartz, hematite, goethite, and minor muscovite in the clay matrix.

MINING METHODS

The initial exploitation of the ametrine deposit was rudimentary; according to early miners, there was enough material buried in the soil profile and outcropping vugs that mining progressed by digging shallow pits and trenches. As the surface layers became depleted, small shafts and tunnels were lowered into bedrock, always following the trends of outcropping veins and cavities.

Currently, mining in Anahí proceeds solely by underground tunnels and shafts. Modernization and implementation of more efficient underground mining techniques was initially accomplished with the help of gem miners from Brazil, who worked on a contract basis. At present, the mine is solely operated by M&M personnel, under the direction of a Bolivian mining engineer. Approximately 60 miners work the deposit, a single nine-hour shift for six days a week.

The main breccia zone, where most of the ametrine-bearing vugs occur, is aligned approximately east-west on the hillside. Two main tunnels, roughly oriented north-south, reach this mineralized zone (figure 3). Within this zone, the irregular distribution of quartz veins and pods in the hydrothermal breccias requires mining along irregular tunnels to follow the mineralization. When the miners encounter large, massive dolomite blocks, they blast them. Blasting is commonly conducted twice a day, in the morning and late afternoon. The intricate network of interconnected tunnels makes air circulation difficult, and air quality is poor, particularly after blasting; a compressor is used to pump surface air into the tunnels. Barren host rock and the clay filling the cavities are removed in wheelbarrows (figure 8). Loose ametrine crystals are recovered from the mud; those attached to the milky quartz are pried from the walls. At the end of the shift, the daily ametrine production is removed

Figure 9. This 37.5-kg ametrine cluster was collected by the senior author from one of the producing gem pockets at Anahí. Photo by P. Vasconcelos.

from the tunnels, weighed, and stored in a fortified cabin. After washing and partial cobbing, the mine production is shipped to Puerto Suárez.

Until recently, the mine was actively exploited on only one level. Now, however, a vertical shaft has been lowered through mineralized host rock into a second level 15 m below the main tunnel. There is ample indication that this second level will be as productive as the first. The vertical continuity of the breccia system is still unknown, and the mine operators are planning a drilling program to determine the extent of future reserves. The mine is undergoing mechanization, and the gangue and mineralized products will soon be transported to the entrance by a small rail system.

ROUGH YIELD AND MARKETING

To assess the gem yield of typical Anahí mine run, one ametrine cluster weighing 37.5 kg (figure 9) was cobbed (figure 10), preformed, and cut (figure 11), yielding 1,763 ct of faceted stones from 1,942 grams of gem rough. These recoveries correspond closely to those obtained by cutting operations that process large quantities of ametrine, although tests run on 1,000-kg lots by M&M resulted in significantly lower yields.

Before cobbing, the crystals are bathed in boiling water to help shatter the milky areas. According to some cutters, this makes it easier to extract the best gem material, which is in the cores. In the laboratory, however, we subjected a series of ametrine slices cut perpendicular to the c-axis to thermal shock in hot water. We found that fractures will propagate from the milky crystal surfaces into the flawless cores, generally along a plane parallel to one of the prism faces. This result indicates that the thermal treatment potentially destroys perfectly viable and valuable gem material. The propagated fractures seem to correspond to the cleavage planes of quartz, as suggested by Frondel (1962, p. 106).

It is impossible to assess the total production of ametrine since the modern discovery of the Anahí deposit, because there are no records for the years of illicit mining activities. From 1989 to the present, however, M&M has recovered approximately 100 metric tons of rough crystals. Most of this material has been cut in Brazil, from where it has entered the gem market. M&M plans to establish a more vertically integrated operation, which will include—in addition to mining—cutting and marketing of loose gemstones, carvings, and collector items. To achieve these goals, ametrine will be cobbed and sawed in a cutting operation in Santa Cruz de la Sierra before being released to the market.

MATERIALS AND METHODS

Field observations included precursory examination of several thousand crystals. On the order of 200 crystals were collected for more careful laboratory

Figure 10. Masking tape protects the fingers of this miner to prevent cuts from the sharp quartz shards during cobbing. This is one of the good gem-quality pieces recovered from the large crystal cluster shown in figure 9. Note the zones of citrine and amethyst and especially the pure purple-violet hues of the amethyst sector. Photo by P. Vasconcelos.

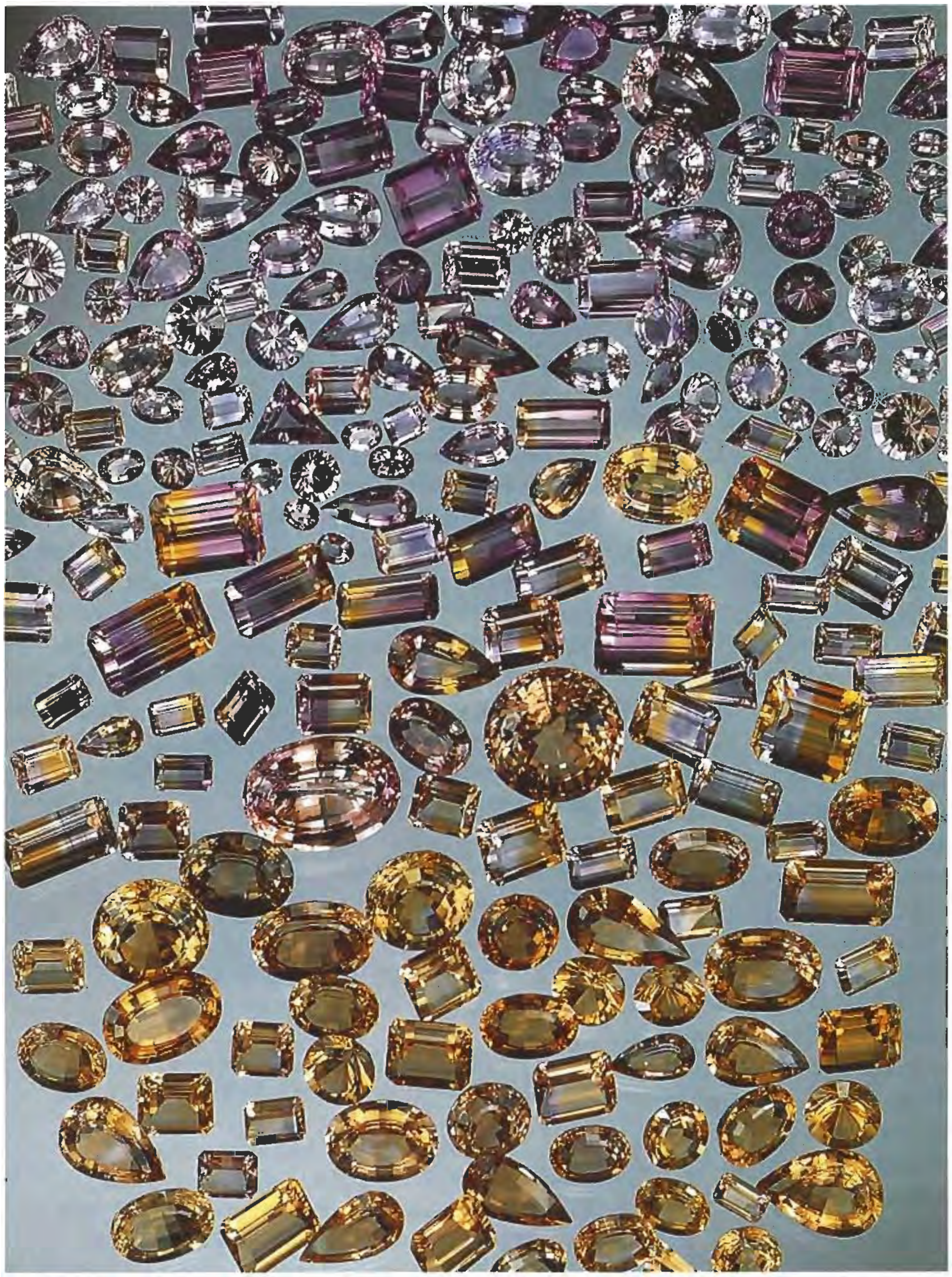


Figure 11. The crystal cluster shown in figure 9 yielded approximately 1,760 ct of faceted amethyst, ametrine, and citrine, as well as the "champagne"-colored material, in the range of hues and saturations shown here. Photo © Harold & Erica Van Pelt.

examination, and approximately 50 crystals were analyzed in detail by Fourier transform infrared (FTIR) spectroscopy, optical absorption spectroscopy, electron microprobe analysis, transmission electron microscope analysis, and optical microscopy. We commissioned the cutting of approximately 3,000 ct of stones (ametrines, citrines, and amethyst) from several crystals obtained at the Anahí mine. Specific-gravity measurement was performed on one representative citrine and one representative amethyst sample. The senior author measured the refractive indices of 8–10 samples of each variety at the GIA research laboratory.

The electron microprobe analyses were performed on the ARL-SEMQ electron microprobe at the University of California, Berkeley. Sample current was 60 nA, accelerating voltage was 20 kV, and the beam diameter was 2–3 μm. Standards used were Al_2O_3 for Al and $FeSiO_4$ for Fe; the results were checked by analyzing National Bureau of Standards trace-element standards 611, 612, and 614, and also analyzing Berkeley synthetic quartz standard 914 (~10 ppm Al determined independently by atomic absorption spectroscopy) as unknowns. The calculated detection limits for the electron microprobe analyses were ~10 ppm for Al and 20 ppm for Fe. Two samples were also analyzed by micro X-ray fluorescence, a newly perfected technique (Gurvich, 1993), in the Fissons Instruments research laboratory in San Carlos, California.

Infrared spectra were obtained using a Nicolet 60SX FTIR spectrophotometer at the California Institute of Technology (Caltech). Specimens were examined in the form of basal slabs ranging from 1 mm to 1 cm thick. Individual regions were defined by 1-mm-diameter circular metal apertures. Our results were obtained at room temperature. On the order of 60 regions in eight samples were analyzed.

Optical absorption spectra were recorded at Caltech using a locally constructed diode array spectrometer designed to obtain spectra from small areas. It employs 1,024 cooled silicon diodes in an illuminated polychrometer which receives light from the area of interest in the sample directed through fiber-optic cable. All areas analyzed by FTIR were also investigated for their optical absorption spectra.

Transmission electron microscopy of one amethyst and one citrine sector from an Anahí crystal was performed in a Jeol 100-kV transmission electron microscope (EM) at the University of California, Berkeley. The ametrine crystal was polished into a 30 μm section that was subsequently thinned by ion ablation for EM investigation.

Specific gravity was calculated by the immersion method. Refractive indices were measured using a Duplex II refractometer.

MINERALOGY

Ametrine crystals vary widely in crystal habit, size, and mode of occurrence. Some of the crystals are small (1–8 cm in length) and occur embedded in a clay and carbonate matrix. These specimens are well crystallized, showing euhedral habits and lustrous crystal faces (figure 12). The crystals are often gem quality, but the colors are not intense. An interesting feature of these small crystals is that the rhombohedral faces terminate in a *c* face, which is invariably etched. It is yet unclear whether the *c* faces are growth faces or the result of partial dissolution of the rhombohedral faces. Larger (10–40 cm long) crystals that lack *c* faces also occur loosely held in the clay matrix. The intensely colored, flawless areas commonly seen in these crystals yield the best gems from the deposit.

Most commonly seen at Anahí, however, are large, complex points and clusters (again, see figure 9) growing from a milky quartz base. These crystals line the walls of cavities, and they are attached to their neighbors near the base (again, see figures 5, 6, and 9). They display well-formed rhombohedral terminations devoid of *c* faces, but instead of hexagonal prisms there is a complex intergrowth of satellite crystals.

To date, two vugs in the Anahí mine revealed deeply etched crystals found floating in the red clay matrix (figure 13). They display a complex etching pattern: The prism faces are completely resorbed and the rhombohedral faces, where still preserved, display deep etching pits oriented at approximately 45° to the c-axis. The crystals invariably display frosty *c* faces or very low angle rhombohedral faces. The etching process consumes most of the prisms, but often does not dissolve the rhombohedral faces, except at the tip of the crystal. The etched crystals occur in two main cavities located at the center of the mineralized area and associated with the major trend of mineralization. This suggests that they

Figure 12. Small euhedral ametrine crystals—here, approximately 4 cm high—are found embedded in a clay-calcite matrix in veins between limestone blocks. These veins are not actively mined because the crystals are too small, and although gem-quality, they tend to be pale. These small gem-quality euhedral crystals typically have lustrous faces, which readily reveal the color zoning. Notice also the etched c *face (at the very top of the crystal), which is common to these small crystals. Photo by Robert Weldon.*

Figure 13. Deeply etched crystals (here, 15 cm high) have been found in two main pockets within the mine; their appearance may reflect resorption of quartz during waning of the hydrothermal system. Rounded and etched cobbles and pebbles (here, about 5 cm in diameter) found around the mine are not significant economically, but they provide insight into the deposit's geologic and geomorphologic history. They indicate that some ametrine may have been transported in a paleo river channel that once existed in the area. Note from the polished pebble the high-quality ametrine found in these unusual specimens. Crystal and pebbles courtesy of Minerales y Metales del Oriente S.R.L.; photo © Harold & Erica Van Pelt.

may be located within the feeder zone of the hydrothermal system. During the late stages of hydrothermal circulation, the solutions may have become diluted and undersaturated with respect to silica, causing the partial dissolution of previously precipitated quartz. Etching of these crystals by weathering solutions, although possible, is not likely because crystals from other gem pockets rich in deeply weathered clays show no signs of etching.

Ametrine also occurs as rounded pebbles and cobbles that have been etched and abraded (again, see figure 13), which suggests significant mechanical weathering during transport in a sedimentary environment. Unfortunately, the area around the mine has been disturbed by previous mining activities, and it is not possible to identify if these cobbles came from ancient stream channels. One of the mine owners (Mario Urriolagoitia, pers. comm., 1993) indicated that some cobbles and pebbles were mined from the mud matrix within underground vugs. During geologic mapping, we noted that some underground cavities were filled with clay minerals, rock, and plant fragments which appeared to have fallen in from the surface, probably when the limestone "roof" weathered through. The cobbles and pebbles may have resulted from weathering and erosion of outcropping veins on the top of the mountain.

In addition to ametrine, the deposit also contains minor amounts of amethyst, milky white quartz, and smoky quartz crystals. The smoky crystals always occur in massive hematite/quartz veins sporadically associated with the breccia. The crystals are euhedral, very clean, and transparent, and up to 3 cm long.

COLOR

The most striking characteristic of ametrines is their complex color distribution (figure 14). This color zoning is fairly consistent: The major rhombohedral $r\ \{10\bar{1}1\}$ sectors are purple, and the minor rhombohedral $z\ \{01\bar{1}1\}$ sectors are orange-yellow. The purple r sectors are invariably Brazil-twinned with both right- and left-handed quartz, while the orange-yellow z sectors show no Brazil-twinning. This can be established by viewing a slab with polarized light (as seen in figure 14D). Initial measurements suggest that the citrine sectors are either untwinned right-handed or untwinned left-handed quartz (K. Zito, pers. comm., 1994). The boundaries between left- and right-handed quartz appear dark under crossed polarizers and are known as Brewster fringes (Brewster, 1823). The Brewster fringes appear dark under polarizers because when light travels through equal distances of right- and left-handed quartz, the state of polarization is unchanged (McLaren and Pitkethly, 1982). The distance between Brewster fringes varies from one crystal to another, but it generally ranges from 0.1 to 1 mm. Examination of Brewster fringes in the

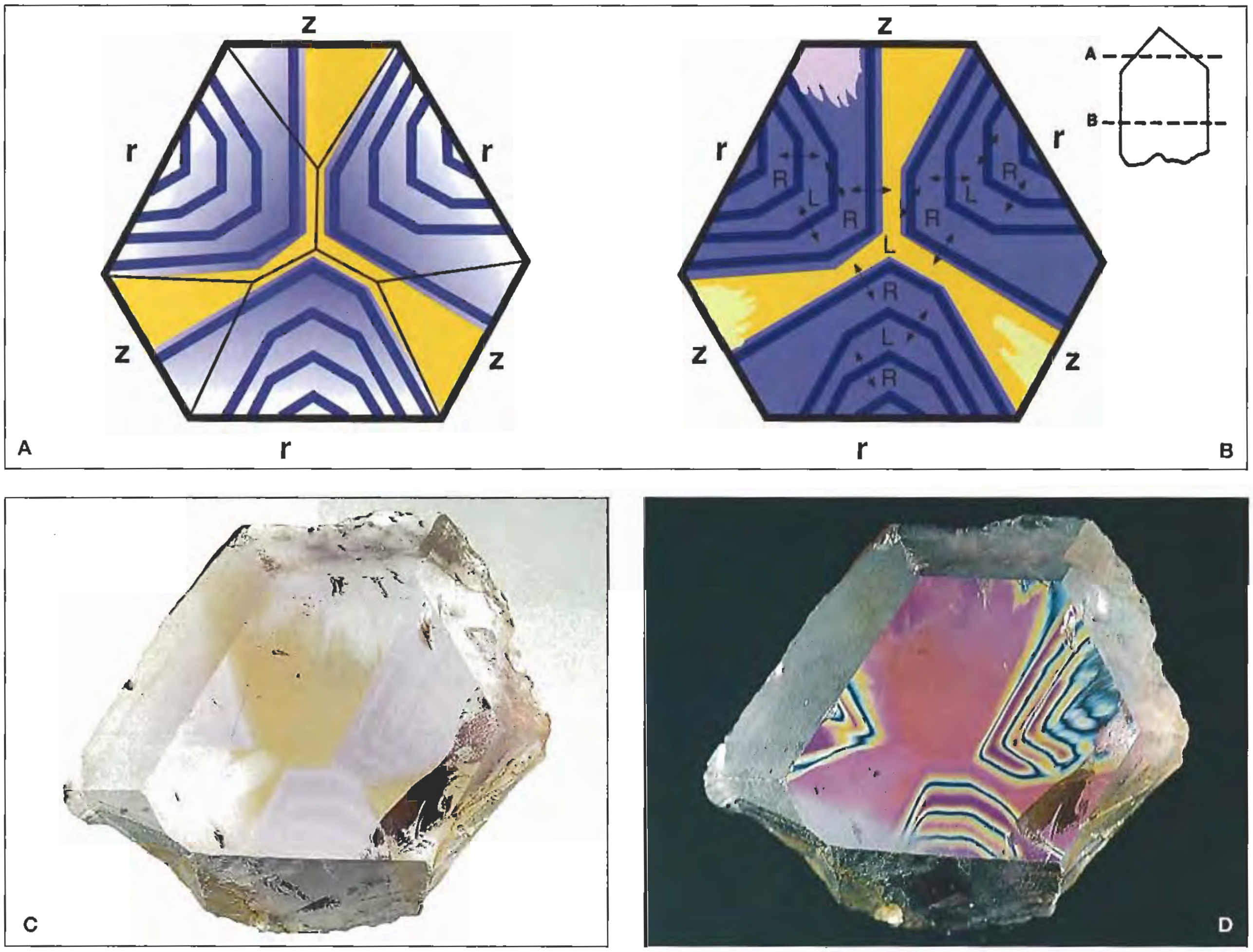


Figure 14. A slice of an idealized ametrine crystal, cut perpendicular to the c-axis and through the rhombohedral faces, is illustrated in part A. The r $\{10\bar{1}1\}$ *sectors are Brazil twinned, and the* z $\{01\bar{1}1\}$ *sectors are untwinned. Schematic illustration B shows a slice of the same crystal cut through the prism faces; it also displays Brazil-twinned* r $\{10\bar{1}0\}$ *and untwinned* z $\{01\bar{1}0\}$ *sectors. The diagram also illustrates the decrease in intensity—and even absence of color—in the birefringent zones near the crystal edges. When a crystal section is viewed in ordinary, unpolarized light (C), the untwinned orange-yellow sectors and the color banding in the twinned purple sectors are evident; when the slice is observed between crossed polars (D), one can see the details of the contacts between* r *and* z *sectors. Brewster fringes (dark) separate left-handed from right-handed quartz. The boundary between citrine and amethyst is a sharp crystallographic plane which the Brewster fringes roughly parallel. The citrine-amethyst boundary corresponds to the boundary of a significant change in trace-element composition. Photos by Robert Weldon.*

transmission electron microscope indicates the presence of many planar defects, oriented in two directions, which were also noted by McLaren and Phakey (1965). These defects are only present in the amethyst-colored zones and have not been observed in the citrine zones.

Large ametrine crystals display complex color distributions (figure 15). The major prism in the illustrated crystal shows the six-sector color zoning in the center, but each overgrowth displays subsidiary color zoning, resulting in a complex pattern. At the base, these crystals are generally milky, with small flawless sectors at the center which are either colorless or very slightly purple or orange-yellow. The flawless centers grow toward the tip of the prism, and the color becomes progressively darker. We sectioned 20 such crystals, and found that the most strongly colored, gem-quality sectors invariably occur at the confluence of the prism and the rhombohedral faces. Regions of increased birefringence in crystal slices cut perpendicular to the c-axis are always associated with lower-intensity hues or the absence of amethyst and citrine color.

Four ametrine crystals were sectioned perpen-

Figure 15. Cross-sections through large complex crystals beautifully illustrate the separation between the amethyst and citrine zones, as well as the intergrowth of many subsidiary crystals at the perimeter. The slab is 11 cm at its widest point and 1.3 cm thick. Photo © Harold & Erica Van Pelt.

dicular to the c-axis, and the purple, orange-yellow, and colorless zones were analyzed by electron microprobe to determine differences in Fe and Al contents. The microprobe results (figure 16) indicate that the orange-yellow sectors invariably have a higher iron (Fe) content (68–125 ppm [parts per million] average) than the purple (19–40 ppm average) or the colorless (~17 ppm average) sectors. There is no noticeable variation in aluminum (Al) content between the sectors; but because the results obtained are near the calculated Al detection limits of the technique (10 ppm), it is impossible to rule out Al variability. We also analyzed 2-mm-diameter areas in the amethyst and citrine sectors by micro X-ray fluorescence. The results independently confirm the ranges and trends for Fe concentration identified by electron microprobe analysis.

Infrared spectroscopy also showed differences between the orange-yellow and purple sectors (figure 17). The room-temperature I.R. spectra of purple sec-

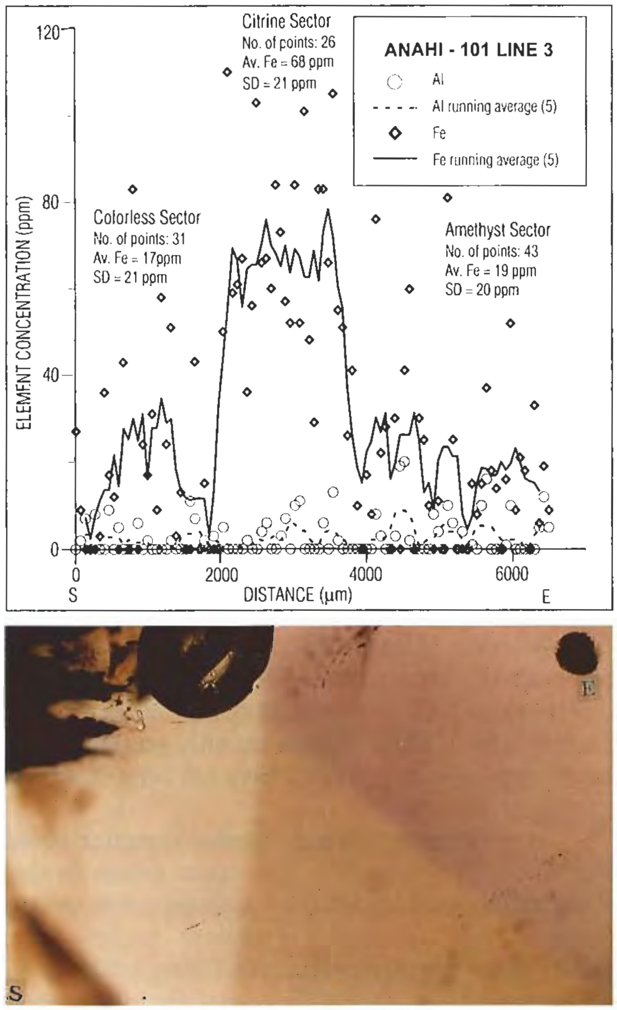


Figure 16. Electron microprobe analyses, taken across the three color sectors of the ametrine specimen shown here, indicate high iron concentrations in the untwinned citrine sectors, with lower total Fe contents for the Brazil-twinned amethyst (and colorless) sectors. Given the limitations of current analytical procedures, we could not resolve the Al content variation, if any. Start (S) and end (E) of traverse is shown in the photomicrograph.

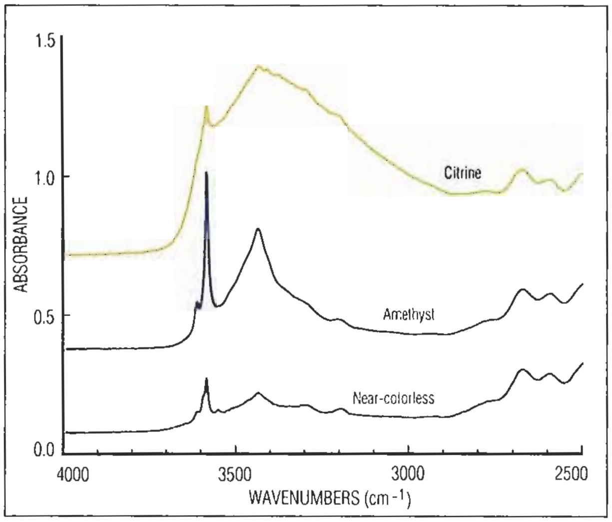


Figure 17. Infrared spectra of near-colorless, amethyst, and citrine regions of an Anahí amethyst-citrine crystal [unpolarized spectra of (0001) slabs run at 25°C; presented normalized to 2.0-mm thickness and offset from zero for clarity] indicate a marked difference in peak shape between the amethyst and citrine sectors. The broad-band absorption in the citrine sector has been interpreted as indicating the presence of molecular water (Aines and Rossman, 1986).

tors display sharp peaks, arising from OH^- groups, as previously shown by Aines and Rossman (1986). The citrine sectors display similar spectra, except for the addition of a broad band superimposed on the sharp peaks that also occur in the amethyst sectors. This broad band has been attributed to small groups of water molecules trapped in the quartz structure during crystal growth, indicating that the orange-yellow bands are more hydrous than the purple bands (Aines and Rossman, 1984).

The optical absorption spectra of the ametrines display a strong absorption at 540 nm in the amethyst sectors and a slight absorption at the same wavelength for both the near-colorless regions and the citrine sectors (figure 18). The color of the citrine is controlled by the rising absorption in the violet end of the spectrum (400–500 nm), which favors the transmission of long-wavelength light. The color of the amethyst is controlled by the transmission windows centered near 440 nm and 730 nm, which favor the transmission of violet and red. Optical absorption spectroscopy of an oriented amethyst cube shows that the amethyst sectors are pleochroic, a feature commonly observed in amethyst in general. A similarly cut citrine cube showed only a slight difference in absorption of light traveling perpendicular and parallel to the c-axis.

To test the color saturation in natural ametrine samples, we had a crystal slice submitted to 88 days of exposure to ^{137}Cs gamma rays at Caltech (a total dose of 92 megarad). Comparison between the irradiated slice and a control sample indicates that radiation does not induce any significant color changes in ametrines. This result is significant, because most amethysts and citrines will turn smoky when irradiated.

GEMOLOGICAL PROPERTIES

Three distinct varieties of quartz are extracted from the ametrine crystals: citrine, amethyst, and ametrine (see figures 1, 11, and 19). The gemological properties of each variety are discussed separately below.

Citrine. The Anahí mine is one of the few commercial occurrences of natural citrine; most citrines available in the gem market today are produced by heat treating amethyst from Marabá (to a bright "golden" orange-yellow) or Rio Grande do Sul and Uruguay (to orange to orange-brown; Epstein, 1988).

In thicknesses of a few millimeters to 1 cm, Anahí citrines typically range from orange-yellow to brownish/greenish yellow (figure 19) and are only weakly dichroic. The weak dichroism is consistent with small differences in the intensities of the optical absorption bands observed with light parallel

Figure 18. Optical absorption spectra of the near-colorless, amethyst, and citrine regions of the sample used for figure 17 [unpolarized spectra of (0001) slabs run at 25°C; presented normalized to 2.0-mm thickness and offset from zero for clarity] show differences in the absorption at 540 nm.

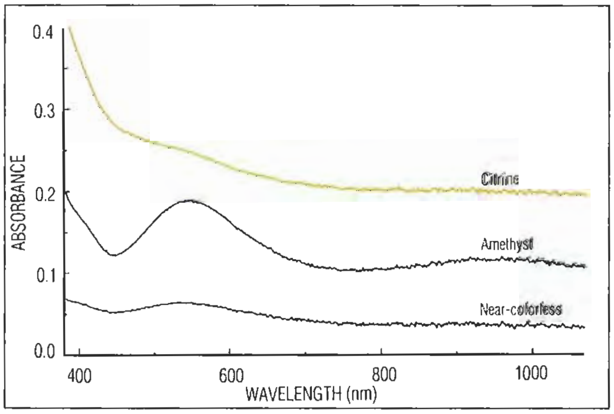


Figure 19. The ametrine crystals from Anahí produce citrine, amethyst, and ametrine gems in a broad range of hues. The largest stone in this photo, a round brilliant citrine, weighs 28.82 ct; the smallest, also a round brilliant, weighs 5.66 ct. Photo © GIA and Tino Hammid.

to—as compared to perpendicular to—the c-axis. At 400°C, heat treatment causes the color to become slightly paler and to lose some of the brownish or greenish hue. The color fades completely between 450° and 500°C. We did not observe any loss of color in the samples subjected to the sunlight fading tests described in the amethyst section below.

On the eight stones tested, we recorded typical refractive indices of $\omega = 1.541$ and $\varepsilon = 1.550$. The specific gravity, measured hydrostatically, is 2.65.

The citrines we examined were generally inclusion free. When inclusions were present, they were usually two-phase fluid inclusions associated with secondary fractures in the crystals. We did not observe solid inclusions in any of the samples examined.

Amethyst. This is the principal gem produced in the Anahí mine, because of both its greater abundance and its economic value. Anahí amethysts range from near-colorless to intense violet-purple (figure 19). The amethyst sectors are strongly zoned, because of the irregular distribution of coloring agents controlled by the Brazil-twinning, and color zoning is visible in stones cut with the table nearly perpendicular to the c-axis. In general, fashioned amethysts from Anahí are a "purer" violet-purple, with none of the brown or yellow modification seen in amethyst from mines such as Marabá and Rio Grande do Sul, because the color zoning of the Anahí material forces gem cutters to totally eliminate the citrine bands from the amethyst rough during sawing. Amethysts from other mines are often cut incorporating both the "pure" purple-violet of the *r* sectors and the brownish purple-violet of the *z* sectors in the same stone. These mixed-sector stones often display the brownish undertone characteristic of *z* sectors.

Figure 20. The lower portion of this 12-cm-diameter ametrine slice was exposed to direct sunlight for 47 days on a rooftop in Oakland, California. The upper portion was retained in darkness, as a control. Spectroscopic measurement indicates that 33% of the amethyst color faded during this exposure. Photo by G. Rossman.

The refractive indices of typical Anahí amethyst, obtained from 10 stones, are ω = 1.541 and ε = 1.550; again, S.G. was recorded to be 2.65. Because the amethyst is pleochroic, the color may vary from "pure" violet-purple to pinkish purple to blue, depending on the viewing angle relative to the optic axis.

Heat treatment will cause the amethyst color to fade progressively and finally disappear at 400°C. We found that the amethyst color also fades with long-term exposure to sunlight. We exposed half of an ametrine slice to direct sunlight on a rooftop in Oakland, California, from July 6 to August 21, 1993. Comparison between the control sample and the sample exposed to sunlight—both visually and with the optical spectrometer—indicates the loss of 33% of the color intensity during the experiment (figure 20). Along these same lines, it is interesting to note that crystals found on the surface of the hill above the mine often display only the citrine color. When one of these crystals was submitted to two days of ^{137}Cs gamma rays at the California Institute of Technology (2.1 Mrad total dose), the amethyst color was restored to the *r* sectors. Fading from prolonged exposure to sunlight appears to be a characteristic of amethyst in general. As is the case with all amethyst, amethyst or ametrine from the Anahí mine should not be worn for extended periods in bright light.

All of the Anahí amethysts we have examined so far are free from solid inclusions. However, we did note abundant fluid inclusions—both primary and secondary—which may cause a substantial decrease in yield. Primary fluid inclusions are oriented along the twin planes in the amethyst sectors. Partially healed fractures in the amethyst sectors are affected by the Brazil-twinning, which results in internal features referred to as a "rippled fracture inclusion" (Webster, 1983), "zebra striation" (Gübelin and Koivula, 1986), or "tiger stripes" (Webster, 1983). These internal features are characterized by liquid and two-phase inclusions (Schmetzer, 1987). Some inclusions appear to be 100% vapor, although a thin liquid film may actually wet the inclusion walls.

Ametrine. Until the late 1970s, according to Domingos Reis, one of the pioneers in ametrine cutting, most of the rough material from Anahí that reached the cutting centers in Brazil was selectively sawed, and only the amethyst sectors were used because the citrine color was considered undesirable. Two dealers in ametrine rough, Silvio Sbaraine and Erni Rolderbal, from Rio Grande do Sul, were among the first to suggest, in 1978 (D. Reis, pers. comm., 1993), that if tourmaline could be marketed in bicolored stones, then why not market bicolored quartz?

Figure 21. The 156-ct ametrine in this 18k gold pendant was fashioned by Paul Tapley to mix the colors within the stone. Courtesy of Paula Crevoshay, Upton, MA; photo by Robert Weldon.

Ametrine encompasses the gemological properties described above for amethyst and citrine. Ametrine is unusual both for its sharp color zoning, which is due to the fact that the boundaries

Figure 22. The attractive and often complex color combinations in ametrine are particularly well suited for use in carvings, like this 68.18-ct ametrine fish. Carved by Michael Peuster; courtesy of Neal Litman Co., Burlingame, CA. Photo by Shane F. McClure.

between the citrine and amethyst zones are crystallographically controlled, and the large size of the amethyst and citrine zones (again, see figure 14). Ametrines are typically cut to enhance the two colors, with the color boundary perpendicular to the table. Rectangular, parallelogram, square, or other shapes of angular geometry, together with step patterns of faceting, are commonly used (again, see figures 1, 11, and 19), rather than brilliant cuts, which mix colors through internal reflection. However, brilliant cuts have been used successfully in jewelry (figure 21). In addition, the color combination is ideal for carvings (figure 22), and new fashioning techniques that incorporate the amethyst and citrine sectors as part of an overall work of art have recently come into vogue (see cover to this issue, figure 1, and figure 23). Faceted pieces that contain mostly citrine intermixed with small sectors of amethyst attain a pleasant "champagne" or "peach" color (again, see figure 1).

In addition to the traditional cuts, some ametrine crystals can also be sliced perpendicular to the c-axis, yielding a zoned "star-fruit" color combination, similar to that shown in figure 15.

DISCUSSION

All other significant amethyst deposits in production today (see, e.g., Epstein, 1988) occur as geodes in intermediate-to-acid flows in flood basalt provinces (Rio Grande do Sul), as veins in quartzites and quartz-arenites (Marabá, Jacobina, Vitória da Conquista), or as late-stage crystallization around the quartz cores of pegmatites (Minas Gerais and Espírito Santo). The geologic conditions in which the Anahí ametrine deposit formed, hosted by carbonate rocks displaying evidence of hydrothermal brecciation, are fairly unusual. The silica-bearing fluids probably became alkaline by reacting with the limestone host rocks. These fluids were moderately enriched in Fe, as indicated by the precipitation of hematite bands within the breccia zones. The fine-grained muscovite found in the gem pockets, if precipitated by the hydrothermal solutions, indicates that these solutions were also K-rich. The style of mineralization indicates fast quartz precipitation immediately after brecciation, and slower quartz precipitation—conducive to the formation of large crystals—as the silica-bearing solutions migrated through the system.

It is likely that the temperature gradient within each gem pocket was small because of the substantial amount of hydrothermal solution that was probably trapped below the deposit before brecciation. Potassium in the system may have provided the natural radioactivity required for the formation of the color centers, although the present K contents in the cavities are too low to have provided the necessary background radioactivity (XRD analysis showed that muscovite, the K-bearing phase, was a minor phase in the gem pockets, although

Figure 23. Ametrine has become an important medium for some unusual works of gem art. The piece in this pendant was fashioned from a slice of the material cut perpendicular to the c-axis of the crystal. Small hemispherical carvings enhance the citrine portion of the slice, while frosting on the back of the amethyst portion makes the Brazil twinning part of the design. Gem carving and jewelry designed by Michael M. Dyber, Rumney, NH; photo by Robert Weldon

greater amounts may once have been present and subsequently destroyed during weathering).

Iron-rich potassium-carbonate alkaline solutions and a low temperature gradient in a hydrothermal cell are precisely the conditions necessary to produce the amethyst-citrine color combination in synthetic quartz, according to Balitsky and Balitskaya (1986), who attribute the bicoloration to growth rates:

> All this evidence suggests that the amethyst-citrine dichromatism in synthetic quartz crystals grown on rhombohedral seeds must be related to certain threshold (critical) growth rates for the major and minor rhombohedral faces which govern the incorporation of either the amethyst-causing or the citrine-causing impurities by these faces. Below these critical values a face absorbs the amethyst-causing impurities, above them the citrine-causing ones. As the growth rates approach the critical values, both types of impurities are assimilated.

The amethyst color is traditionally attributed to the presence of Fe^{4+} in quartz, in either interstitial (Cohen, 1985) or both interstitial and substitutional (Lehman and Bambauer, 1973) sites in the crystal structure. Citrine color in heat-treated amethyst has been attributed to submicroscopic particles of an iron oxide (Lehman and Bambauer, 1973), but the origin of color in natural citrine such as that from the Anahí mine has not been studied previously. The mechanisms believed to be involved in the formation of the color centers in amethyst are present in the Anahí deposit. They are: (1) a moderate amount (30–300 ppm) of Fe^{3+} impurities in the proper crystal sites; (2) a source of ionizing radiation to produce the Fe^{4+} centers; (3) low amounts of aluminum, otherwise, the sample becomes smoky; and (4) a thermal history that does not subject the sample to temperatures exceeding 400–500°C, otherwise the amethyst precursors are lost.

Aines and Rossman (1986) attributed the amethyst-citrine color combination to the high water content in the orange-yellow *z* sectors. They suggested that this water undergoes radiolysis (the breakdown of water into O_2 and H_2 by nuclear reactions) during natural irradiation, and the H_2 generated quenches the Fe^{4+} color centers, preventing the development of the amethyst color. To test whether the high water content in the *z* sectors could account for the unusual amethyst-citrine bicoloration in ametrines, we also analyzed amethyst crystals from Marabá by the techniques above. The Marabá amethysts revealed similar variations in trace Fe contents, slightly higher Al contents, Brazil-law twinning in the *r* sectors, and the same water-content variations displayed by the ametrine crystals. Yet, the Marabá crystals had a different color-zoning pattern, with amethyst corresponding to the *r* sectors and smoky amethyst corresponding to the *z* sectors. Thus, the high water content in the *z* sector is not unique to ametrines and probably does not solely account for the amethyst-citrine bicoloration.

Heat can produce the citrine coloration, as evidenced by the commercial production of citrine by heating amethyst. Nassau (1981) has shown that amethyst-citrine bicoloration in Fe-bearing quartz can be produced by appropriate combinations of irradiation and heat treatment. Neumann and Schmetzer (1984) have also shown that progressive heat treatment of amethyst from some localities may lead to the development of citrine color in the *z* sectors, while the *r* sectors remain amethystine. Our own observations show that Marabá amethyst, when heat treated to 475°C, will turn orange-yellow in the *z* sectors and colorless in the *r* sectors, and that irradiation and subsequent heat treatment as described by Nassau can restore a brownish amethystine color to the *r* sectors. Whether these observations are relevant to natural ametrine is uncertain.

After extensive geologic and experimental studies, we can only speculate that the amethyst-citrine bicoloration results from quartz precipitation at very specific geochemical conditions, temperatures, and growth rates. Unfortunately, no crystal-chemical mechanism to account for the bicoloration can be proposed, because the present understanding of the fundamental controls of color centers in amethyst and citrines is poor. Lack of reliable *in situ* trace-element data and infrared and optical spectra for amethysts from other important localities also makes a comparison between the properties of ametrine and those of regular amethyst difficult.

CONCLUSIONS

The history of ametrine shows that gemologists must be careful when extrapolating experimental evidence to the marketplace. Experimental results are essential for testing the origin of gem materials and for protecting consumers from exposure to undisclosed treatments and synthetic gem materials. However, these experimental results must be weighed against other information in the community (i.e., political and economic factors that may hinder direct access to mining areas; cost to treat natural or produce synthetic materials; physical resemblance and similarity in properties between treated/synthetic materials and natural analogues; etc.). Consideration of all these factors—combined with closer links and the exchange of reliable information between producers, researchers, and consumers—may help avoid misconceptions in the gem trade.

The information we have presented about the Anahí mine should finally settle the discussion of the natural versus artificial origin of ametrine. The ametrine available in the market today is mined in Bolivia, it occurs in a hydrothermal breccia deposit hosted by carbonate rocks, and the amethyst-citrine color combination is ubiquitous in this deposit. Mineralogic investigations indicate that the amethyst sectors are Brazil-twinned, and that they contain less iron and water trace impurities than the (untwinned) citrine sectors. The ametrine crystals were probably precipitated from an alkaline, Si-, Fe-, and K-rich hydrothermal solution during pressure release by hydrothermal brecciation. However, more geologic, mineralogic, and crystallographic work is needed to determine the exact conditions necessary for the development of amethyst-citrine bicoloration in quartz.

In addition to its production of ametrine gems, the Anahí mine is a major source of high-quality faceting-grade amethyst. A substantial amount of amethyst from this mine has already entered the world gem market. Carving-grade amethyst and ametrine are increasingly important products of this mine. The Anahí deposit also represents the first substantial source of natural, iron-containing citrine (i.e., in which the color was not developed by heat or other treatment) that has been documented in the literature. Specimen-grade ametrine crystals and slabs are yet another product of this mine that are entering the market in significant quantitities. It is hoped that the inferred large reserves in the Anahí deposit will guarantee a steady supply of good-quality amethyst, citrine, and ametrine for some time into the future.

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THE INDAIA SAPPHIRE DEPOSITS OF MINAS GERAIS, BRAZIL

By David S. Epstein, Warren Brennan, and Julio C. Mendes

The discovery of significant quantities of gem-quality sapphire in Minas Gerais could add corundum to the formidable list of gem species already commercially produced in Brazil. The presence of sapphire has been confirmed over a wide area within a 42-km^2 mining claim, and exploration has yielded over 500 ct of corundum per square meter from alluvium in a small section of the claim. Faceting-quality stones typically range from 0.5 to 2 ct; some are purple or violet, and many show a color change. Future production will depend primarily on the results of ongoing exploration and the feasibility of mechanizing an area of difficult access.

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Although minor occurrences of corundum in Brazil have been known for some time, production has been limited to industrial grades, some specimen pieces, very low-quality ruby cabochons, and extremely small amounts of gem sapphire, mostly under 0.5 ct. However, the recent discovery of blue (figure 1), fancy-color, and color-change sapphire in the Indaia (pronounced in-die-yuh) Creek region of Minas Gerais now raises the possibility of significant production of sapphire from Brazil.

Brazil was settled in large part as a result of the search for mineral wealth. Deposits of emerald, gold, and silver—found elsewhere in South America—encouraged exploration of the interior of Brazil. Ruby and sapphire were high on the list of desired items, but only small quantities were discovered in Ecuador and Colombia, with insignificant amounts found in Brazil. The first written reference to sapphire in South America seems to be by Codazzi in 1925. Considering the enormity of other mineral wealth and the discovery of industrial corundum and collection pieces (in places like Anage, in the state of Bahia), it seemed that geologic conditions were favorable for sapphire formation. Still, the gem deposits remained elusive.

The discovery of what appear to be significant quantities of sapphire at Indaia Creek has changed this situation. Two lots of this sapphire—25 kg and 50 kg—have been removed from two areas in this region since 1990. As sampling continues, the promise of increased production is encouraging.

HISTORY

Residents of the sparsely populated Indaia area say they have known about the unusual blue stones for many years; some stones had occasionally been found by chance during

Figure 1. *These five sapphires, ranging from 0.19 ct to 0.86 ct, are representative of the gem-quality blue sapphires that have been recovered from Indaia. Courtesy of Brainin and Davenport; photo © GIA and Tino Hammid.*

other activities but had never aroused much curiosity. The area is not near other well-known gemstone mines, and no *garimpeiros* (independent miners) lived nearby. Then, in the spring of 1984, a young boy playing near a stream close to his home happened upon a 3-gram blue sapphire (S. Davenport, pers. comm., 1991). A farmer, Osmar Filho Faustino, working near the same stream, later found another piece that he described to one of the authors (W.B.) as being about the size of a thumb (from the first joint to the tip) and of a clear, deep blue, more transparent than any previously seen. The farmer decided to show the stone to an acquaintance familiar with gems in the nearby city of Coronel Fabriciano. After being positively identified as sapphire, the stone was sold in the cutting center of Teófilo Otoni.

The identification and sale of this sapphire sparked the quest by several parties for a mineral-rights grant from the government. There had been other finds in Brazil; pieces that produced up to 2- to 3-ct cut stones had been coming from the Malacacheta region for over 25 years. Very small finds at Poxorey in Mato Grosso do Sul in 1984 and at Ipora in Goiás in 1985 also had been reported (R. Ribeiro, pers. comm., 1991). Over the last 10 years, one of the authors (D.E.) has seen 200- to 1,500-gram lots from unidentified locations, but few stones were of the size and quality described for the large piece from Indaia. The first government-recognized request for exploration rights was accepted in 1988, and several more requests by the same parties for additional land were accepted in 1989. The original exploration-rights request holders eventually sold their rights to Arysio Nunes dos Santos through an arrangement with the firm of Brainin and Davenport, which was appointed operator of the mine. Exploration rights were finally granted by

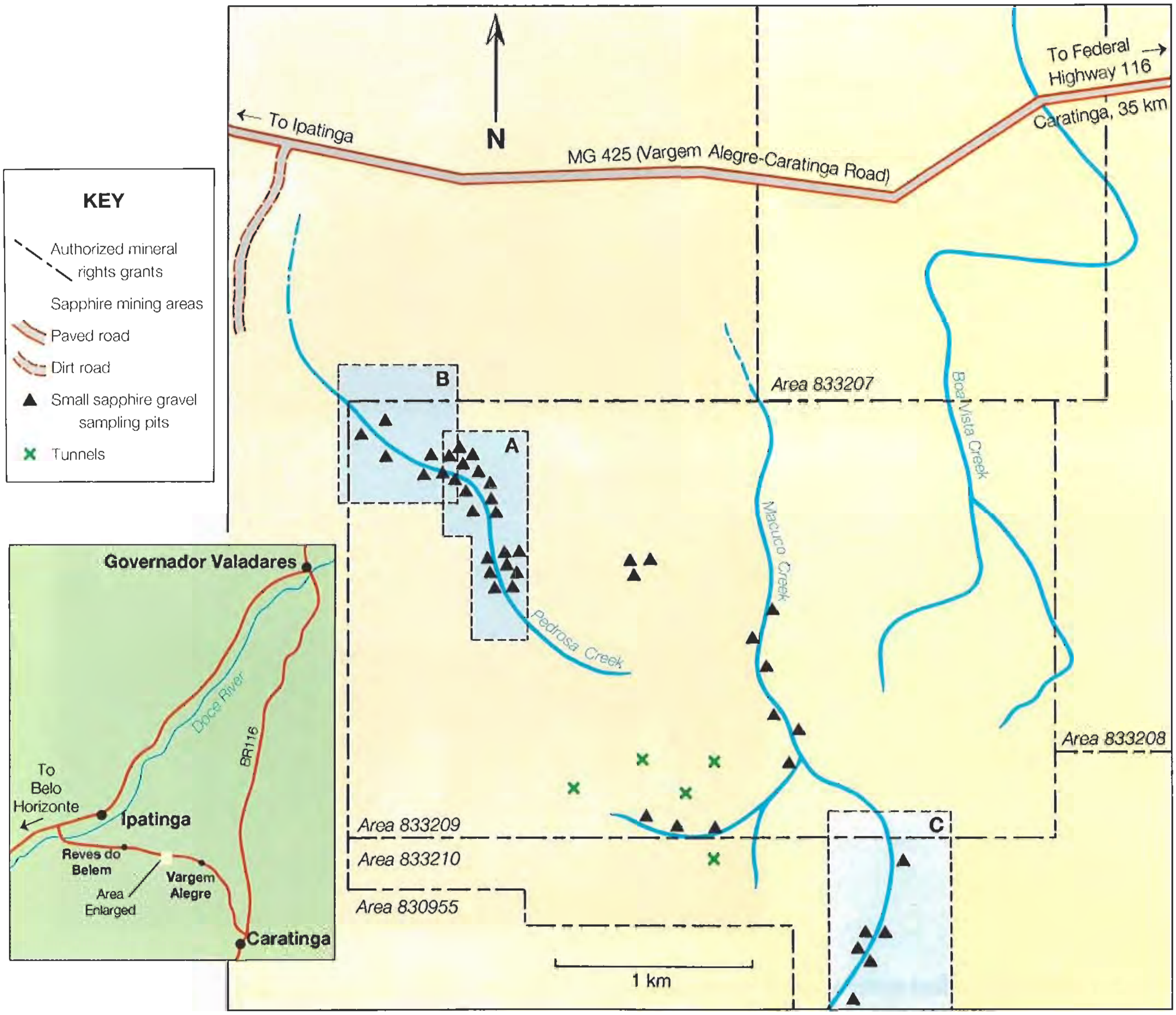

Figure 2. Thus far, three areas—A, B, and C—have been sampled and worked sporadically for sapphires in the Indaia region of Minas Gerais, Brazil.

the Brazilian National Department of Mineral Production (DNPM) to Mr. dos Santos, who intends to upgrade the grant status to the equivalent of a patented mining claim after exploration requirements have been fulfilled. This upgrade would allow the operators to start fully mechanized alluvial mining.

LOCATION AND ACCESS

The Indaia area of Minas Gerais is about 30 km by road southeast of the state's largest steel-milling city, Ipatinga (pop. 300,000; figure 2), which is just northeast of the famous "iron quadrangle" (Schorscher et al., 1982). One of the world's largest iron-ore areas, it is the type locality for the banded-iron formation known as itabirite and an important manganese- and gold-mining district.

The Indaia area is almost exclusively agricultural, producing cattle, corn, okra, rice, and an important eucalyptus crop used for cellulose pulp and paper production. The climate is subtropical, but temperatures rarely exceed 35°C (95°F). The rainy season is typically from October to March; annual rainfall averages between 150 and 200 cm (60–80 inches). Access may be impossible during the rainy season.

Areas A and B (again, see figure 2) are situated between two steep hills on either side of Pedrosa Creek (figure 3)—at 42°4' W, 19°6' S—about 700 m (2,310 feet) above sea level. There are two ways to reach these sites: From Ipatinga, travel 4 km east on BR 381 to a dirt road; turn south (right) and continue 14 km to Reves do Belem; then turn left (east) onto MG 425 (the Vargem Alegre–Caratinga Road indicated on the map) for an additional 10 km. A dirt road branches to the right, and may sometimes be traveled for 1 km by car, depending on conditions. It ends in a trail that can only be followed by foot or on horseback, up a steep and rocky mountain, for approximately 3 km. The climb to the top is treacherous during heavy rains.

The other access is from the city of Caratinga. Take BR 116 north 4 km to MG 425, turn west and continue past the town of Vargem Alegre; turn south onto the same dirt road noted above (on the left from this direction) after a total of 35 km from Caratinga. From here, follow the same directions given in the paragraph above.

Area C is accessible by four-wheel-drive vehicle via a dirt trail that runs roughly southwest from Vargem Alegre for 9 km to the site.

Figure 3. At Indaia, sapphires are recovered from alluvium in the hills that line this narrow valley as well as along the creek.

GEOLOGY

Although the precise origin of the Indaia sapphires is still under investigation, it is known that the general geology of the area is dominated by ancient Precambrian (older than 580 million years [My]) complexes of metamorphic basement rocks (DNPM, 1989), which outcrop over the entire area. In fact, the "iron quadrangle," just to the south of Indaia in Minas Gerais, is one of the world's classic areas of Precambrian geology.

These complexes include biotite gneisses, biotite hornblende garnet gneisses, and migmatites (banded rocks with both igneous and metamorphic portions). Radiometric dates for occurrences of these rock units in other areas are between 2.1 and 2.8 billion years old (Cordani, 1973; Hasui et al., 1976; Menezes Filho et al., 1977). Intrusive bodies, possibly associated with sapphire mineralization, have substantially younger ages: 550–600 My.

All presently known occurrences of sapphire here are alluvial (in recent gravels) or colluvial (on local hillsides). Even so, these Precambrian rocks are important, as they are the only likely source of the sapphire, either disseminated in the rocks themselves (in lenses or areas of variable composition within the unit) or associated with the intrusive bodies. In this respect, it is interesting that intrusive bodies of the "Granito Borrachudo" (Schorscher et al., 1982) were associated with gem mineralization in several other deposits within a 50-km radius, including the emerald deposit of Itabira (Souza, 1988), the Capoeirana emerald deposit (Epstein, 1989), and the Hematita alexandrite deposit (Proctor, 1989). It is not known whether one of the numerous intrusives that cross the region (Fontes, 1978) might be a factor in the mineralization of sapphire at Indaia. The intrusive granitoids of the region often resemble the ancient metamorphic rocks, with contacts between the two usually gradational and also weathered, making exact relations obscure. Note that any possible relation to intrusive activity in the Indaia area would be of a felsic-granitic type, unlike another known sapphire occurrence in South America—Mercaderes, Colombia (Keller et al., 1985)—which appears to have originated in alkaline basalts. Also note that the common accessory minerals normally found in alkaline basalts and/or heavy concentrates derived from them—such as at Mercaderes (black spinel, ilmenite, zircon, olivine, pyrope garnet, and augite)—are not present at Indaia. However, almandine garnet is, as are quartz gravels, white kaolinitic clay, very pale amethyst crystals, beryl, feldpsar, and muscovite.

It is possible that other ancient rocks, younger than the basement rocks and formerly overlying the

Figure 4. Nearly 2 m of clay-like material was removed with simple shovels to reach the sapphire-bearing gravels.

gneiss-migmatite complex, were the source of sapphires in the alluvium, but this is doubtful. The complex completely dominates the region, and any higher stratigraphic units that once existed have long since been eroded away, forming sedimentary beds older than and farther from the area of sapphire occurrence. The nature and occurrence of the sapphire indicates a closer source, which the mine operators hope to locate.

OCCURRENCE

The "diggings" are situated in an area of relatively high and very steep hills. Several small creeks merge to form streams, which run through the center of a narrow agricultural valley.

Although sapphires have been found on hillsides and in streambeds over more than 10 km^2, the first center of activity in 1990–1992 was an approximately 1-km stretch along Pedrosa Creek, extending as much as 50 m on either side of the stream (see area A on figure 2). The alluvium can be more than 5 m thick, but it averages 2–4 m (figure 4), with the gem-bearing gravel approximately 20–100 cm (8–40 inches) thick. There are two distinct gravel layers, usually separated by a horizon of predominantly white kaolinitic clay that grades into red and brown ferruginous clays. The upper layer is essentially barren, yielding only an occasional sapphire as the gravel is removed to reach the lower layer. Otherwise, the two layers are virtually the same, both composed of quartz gravels, white kaolinitic clay, and occasional small pieces of almandine garnet. The quartz, poorly sorted, varies from euhedral to subhedral and from sand size to fist size. Small, very pale amethyst crystals are frequently found. Other minerals found with the sapphires in sieve concentrates include beryl, feldspar, and muscovite.

Even when there is no kaolinitic horizon, the lower sapphire unit is easily recognized by the presence of sapphire itself, commonly numbering up to 200 small (0.5–2 ct) pieces per wheelbarrow load. The bottom of the sapphire unit is marked by a final layer of white clay, 20–30 cm (8–12 inches) thick, above the bedrock.

In late 1992 and early 1993, two new sites were identified at Indaia. Miners originally overlooked area B (see figure 2), adjacent to area A, apparently because the sapphire-bearing gravel layer is deeper (4–5 m). Initial efforts have produced slightly larger stones than at area A. Even more promising is area C, about 3 km to the southeast (see figure 2). Initial mining in this area has produced greater quantities of sapphires of a finer blue color and higher clarity than have been produced in either area A or B. Several fine, clear blue stones—weighing 5 to 7 ct—were recovered from a single prospect pit in area C. The occurrence of sapphire in these new areas appears to be the same as the occurrence in area A.

MINING

Several small "independent" operations have functioned sporadically in the past, but only Mr. dos Santos has a government-authorized exploration concession. This covers 42 km^2. Mineral rights are not in dispute, and access to areas A and B is limited by the 45-minute trail hike or mule ride over the mountain. The operators feel that these factors will inhibit large-scale unauthorized mining in the concession area.

In keeping with Brazilian law, the mine operators are working only at the "exploration level" of activity and they claim that they will continue at this level until the exploration concession can be upgraded to a mining concession (A. Nunes dos Santos, pers. comm., 1993). For this reason, the crew has been small—about five to 10 workers.

Even with the small crew, initial results have been promising, considering the primitive recovery methods. A washing system in area A includes a large (1 × 2 m) three-layer shaker screen and generator-operated electric water pumps. This is a significant improvement over the widely used circular hand screens, which are dipped in the nearest creek or water-filled pit. Miners use simple shovels to excavate down to the gem gravel layer (again, see figure 4). They then shovel the unsorted gem layer to the surface, cart it by wheelbarrow up a ramp, and dump it into the screening jig.

While one person directs water at the material from a pump-powered hose, another rocks the tilted top screen (which has a 2.5-cm [1-inch] mesh). Rocks and larger pebbles are discharged. The second screen (with a 1.25-cm mesh) catches the coarse gravel and pebble-size material. Fine gravel, and almost all sapphire, is retained by the third screen (0.3-cm mesh) and subsequently removed by hand (figure 5). Quality and quantity vary significantly from one pit to the next. Pits are widened or abandoned based on screening results.

Area C is worked using similar primitive mining and recovery methods. Unlike hard-to-access areas A and B, however, area C can be reached by a trail that is passable by four-wheel-drive vehicle. Although part of the approximately 9-km route from Vargem Alegre is tortuous and roundabout, the trail could be widened and improved.

PRODUCTION AND CUTTING

Production. Digging and washing operations are not conducted full-time at any of the specific areas, due to the emphasis on exploration and development of the entire mining claim. Nevertheless, at least some recovery operations take place regularly when the weather permits. According to the mine managers (A. Nunes dos Santos, pers. comm., 1993), area A has produced average weekly yields of 2–3 kg of corundum of a wide range of quality. Sapphire has been found scattered over area B, and sampling continues there. Almost every test pit in area C, each measuring about 2 × 2 m, has yielded sapphire. The yields of different pits range from a few hundred grams to about 2 kg. Total production of all grades of corundum from area C was about 50 kg in 1993.

The proportions of gem material appear to be about the same for all three mining areas. About 16% is cuttable and a marketable blue color; 4% is cuttable and purple to pink. Approximately 1%–3% of this cuttable material recovered to date is suitable for faceting, and the rest is suitable for carving or for cutting as cabochons and beads. Another 20% of the total is a nontransparent, "cloudy" blue that may be a candidate for heat treatment. The remaining 60% of the material is classified as "corundum gravel," which may also yield additional marketable sapphire with heat treatment. Experimentation with heat treatment is ongoing, and some color enhancement has been observed. Overall, however, the results remain inconclusive.

Particularly noteworthy is the high percentage—as much as 50% from some pits, and about 7% to 10% overall—of distinct color-change sapphire.

Given the small area being worked relative to the larger region over which sapphire has been confirmed, it would seem reasonable to expect that output will increase markedly when the government approves an upgrade to mining status, and the operators are ready to intensify efforts. Unknown factors affecting production include the quantity of sapphires present over the wider area and the feasibility of mechanizing an area of difficult access. Increasing the work force and retaining the hand methods currently in use is another option, and one that could be put into place quickly.

Figure 5. At Indaia, miners wash the sapphire-bearing gravels and then pick out the gems by hand.

Cutting. In general, cutting methods for Indaia sapphires are typical for corundum, but some of the rough requires special consideration for best results. Material with rounded color zoning must be cut so that the color is located in the culet of the gem and

Figure 6. The largest of these representative pieces of rough weighs 2.96 ct. Photo © GIA and Tino Hammid.

there is no window; the rounded color zone will then reflect off, and refract to, the pavilion facets. In most of the material, however, banding is slight and generally uniform in size and color throughout the stone. Most of the rough is broken pieces, which lend themselves more toward round shapes (melee) than toward the marquise and oval cuts commonly produced from well-formed crystals.

On lighter-toned goods, a brilliant cut is most effective, producing greater scintillation and making the tone sometimes a bit darker. In darker tones, the conventional mixed cut is recommended because the stepped pavilion facets move and divide the light less, minimizing any darkening effect. In overly dark stones, a window can be produced by cutting the pavilion facets below the critical angle.

DESCRIPTION OF THE MATERIAL

Materials and Methods. Twenty-seven rough Indaia sapphires, ranging in weight from 0.12 to 2.01 ct and in color from blue to purple and pink, were obtained at the locality. Using a Duplex II refractometer with a monochromatic sodium vapor light source, we determined refractive indices from two polished surfaces of sections cut from 19 of the rough samples. We determined specific gravity for 14 of the same sections with a 20-cm^3 pycnometer and an analytic balance. Twenty-four samples, each with at least one polished face, were examined with a Zeiss petrographic microscope. We also exposed the 27 rough specimens to standard long- and short-wave ultraviolet radiation. Three blue sapphires—0.12, 0.19, and 0.22 ct—were examined with a Beck prism spectroscope.

Visual Appearance. For the most part, the sapphires obtained at Indaia have been broken, subhedral pieces (figure 6), although we have seen some elongated hexagonal crystals. The predominant colors are medium to medium-dark tones of blue to violet- blue to purple. No hue approaching that of ruby has been found at the deposit to date, but there is an unusually high percentage of material showing color change—from a violet in day or fluorescent light to purple or saturated ("hot") pink in incandescent light.

It is interesting that a high percentage of sapphires with color change was also noted in the alluvial deposits of Mercaderes, Colombia (Keller et al., 1985). Color change also has been seen in some Australian (Coldham, 1985), Thai (Keller, 1982), Tanzanian (Dirlam et al., 1992), and Sri Lankan (Gübelin and Schmetzer, 1982) sapphires.

Refractive Index and Specific Gravity. We found that the refractive indices ranged from $n_\varepsilon = 1.760$ to 1.762 and $n_\omega = 1.768$ to 1.772; birefringence was 0.008–0.010. Analysis of 14 of the polished "sections" gave a specific gravity between 4.00 and 4.02.

Ultraviolet Fluorescence. None of the sapphires showed a reaction to short-wave U.V. radiation. However, 16 of the 27 stones tested exhibited a moderate to strong bright red fluorescence to long-wave U.V. This long-wave fluorescence, somewhat similar to that noted in sapphires from Mercaderes (Keller et al., 1985), also resembles that seen in some rubies. The other 11 stones displayed very weak or no fluorescence to long-wave U.V. A distinct correlation between fluorescence, body color, and color change was noted: "Purer" blue and/or stones with only a weak color change generally exhibited a weaker or no fluorescence; more violet to purple stones and those with a stronger color change generally showed at least moderate fluorescence; pinkish purple and purple stones with a strong color change to pink generally showed strong fluorescence. Five grayish blue low-grade stones (corundum gravel) were essentially inert. Note that the correlation between long-wave U.V. fluorescence and color was not perfect: One fine blue stone showed medium-strong red fluorescence, one stone with strong color change from violet blue to pinkish purple did not fluoresce, and one pinkish stone showed no fluorescence. No phosphorescence was seen in any of the sapphires tested.

Spectroscopy. All three stones tested with a hand-held type of spectroscope showed a faint band at approximately 450 nm. This is consistent with the spectra for iron-rich sapphires from other localities.

Internal Characteristics. We observed several features in the 24 Indaia sapphires examined. Evidence of lamellar twinning (figure 7) and fine hexagonal growth zoning was clearly visible. High magnification revealed that fingerprint-like inclusions (healed fractures) formed a network of irregular liquid-filled channels (figure 8). The most frequently seen crystalline inclusion appeared as groups of tiny crystals (possibly zircon) surrounded by a brownish stain, and showing typical strain halos (figure 9). Fine needles (apparently rutile) on the growth planes were visible with high magnification. We noted small reddish brown crystals of mica, probably biotite, in almost all of the stones (figure 10). Although we observed two- and three-phase primary inclusions only rarely (figure 11), we saw secondary liquid inclusions in all stones examined. All of these inclusions have been reported in sapphires from other localities; none appears to be distinctive of Indaia.

Figure 7. Growth lamellae are typical of Indaia sapphire. Photomicrograph by J. C. Mendes; magnified 100×.

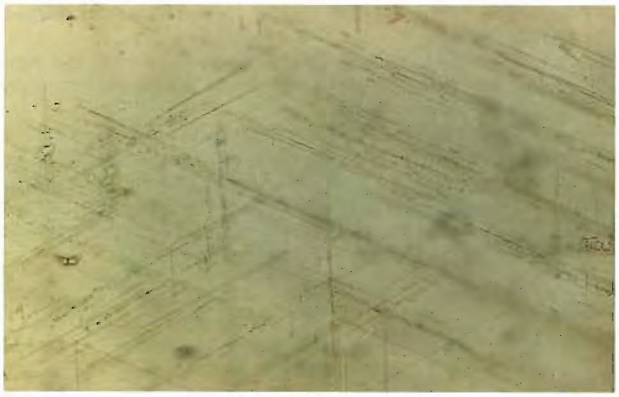

Figure 8. Most of the Indaia sapphires examined revealed networks of long, irregular liquid-filled channels, which are actually healed fractures. Photomicrograph by J. C. Mendes; magnified 200×.

Figure 9. This brown-stained inclusion looks like zircon. Note the tension halo associated with a healed fracture. Photomicrograph by J. C. Mendes; magnified 200×.

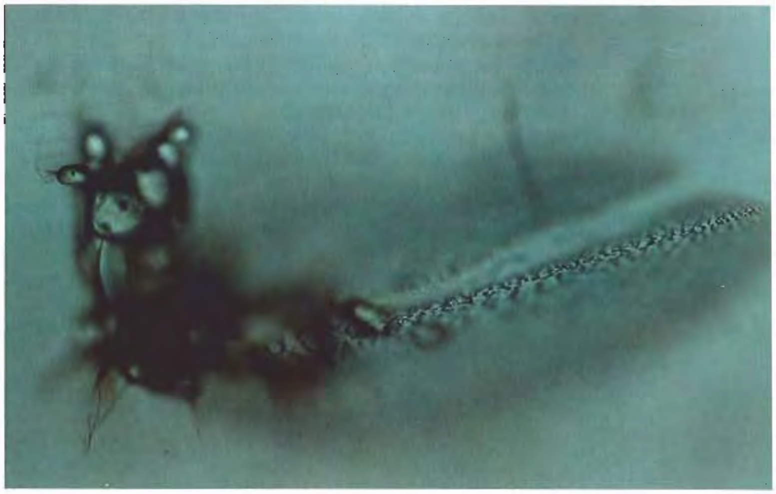

Figure 10. This reddish brown mica crystal, possibly biotite, shows strong pleochroism. Photomicrograph by J. C. Mendes; magnified 200×.

Figure 11. Only rarely were primary three-phase inclusions such as this observed in the Indaia sapphires. Photomicrograph by J. C. Mendes; magnified 200×.

CONCLUSION

The discovery of gem corundum in potentially commercial quantities is a significant development for Brazil. Also important is that a relatively large portion of the gem-quality material recovered to date shows color change. Although done at a very early stage, studies of recovery per square meter, and evaluation of quality and value of cut material, clearly show that some areas are potentially profitable, even with primitive mining methods. Yet to be determined, however, is how many areas can produce sapphire that matches or surpasses this quality and whether more sophisticated mining methods are practical and economical.

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FLUX-INDUCED FINGERPRINT PATTERNS IN SYNTHETIC RUBY: AN UPDATE

By K. Schmetzer and F.-J. Schupp

Chatham, Knischka, and Lechleitner, as well as other manufacturers, are known to have treated Verneuil flame-fusion synthetic rubies by immersion in a flux melt to induce patterns like the "fingerprints" seen in some natural rubies. Some of these products are on the market and may require careful microscopic examination for identification. Also seen marketed as natural is a synthetic ruby of unknown manufacture with a distinctly different flux-induced pattern. This pattern—a continuous, three-dimensional, honeycomb-like cellular structure of flux-filled fractures—is easily recognizable with a gemological microscope.

In the trade, we occasionally encounter synthetic rubies grown by the Verneuil flame-fusion method in which fingerprint-like patterns have been induced. Briefly, a "fingerprint" is a pattern of isolated dots and/or interconnected tubes that develops when a natural fluid or a synthetic flux is trapped by the healing of a fracture during growth. "Fingerprints" are induced in Verneuil synthetic corundum to imitate the fingerprint-like inclusions seen in natural rubies and to mask the curved growth striations that usually occur in flame-fusion synthetic rubies (Koivula, 1983).

In general, we do not know the names of the individuals and companies who commercially treat synthetic rubies by this process. Their products have appeared under trade names such as "Shinna," which we believe originated in Japan. However, we do know that three manufacturers familiar to gemologists—Chatham, Knischka, and Lechleitner—have treated Verneuil-grown synthetic rubies in this fashion. In personal communications since 1983, T. Chatham and P. O. Knischka have maintained that they have induced fingerprint-like inclusions in synthetic rubies primarily for growth studies rather than for commercial purposes. However, Lechleitner synthetic rubies with induced fingerprint patterns have been produced commercially and marketed in considerable quantities (Kane, 1985; Schmetzer, 1986a). In fact, samples from all three manufacturers have been encountered in the trade and could be submitted to a gemological laboratory for determination of origin. Other, unidentified products of similar or even identical growth and treatment methods undoubtedly exist.

We have a general idea of the methods by which these flame-fusion synthetic rubies are treated (Koivula, 1983; Kane, 1985; Schmetzer, 1986a and b, 1991), although experimental details such as the exact composition of the fluxes and the temperatures used are proprietary. The process

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Dr. Schmetzer is a research scientist residing in Petershausen, near Munich, Germany. Mr. Schupp is a gemstone dealer who resides in Pforzheim, Germany.

Acknowledgments: The authors are grateful to Prof. R. Guggenheim of the University of Basel and to Dr. H. A. Hänni, SSEF, Zürich, Switzerland, for performing the SEM-EDS and XRF analyses for this study.

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Figure 1. Induced fingerprint-like patterns of residual flux are seen here in a Verneuil-grown synthetic ruby treated by Chatham Created Gems. Photomicrograph by K. Schmetzer; immersion, magnified 40×.

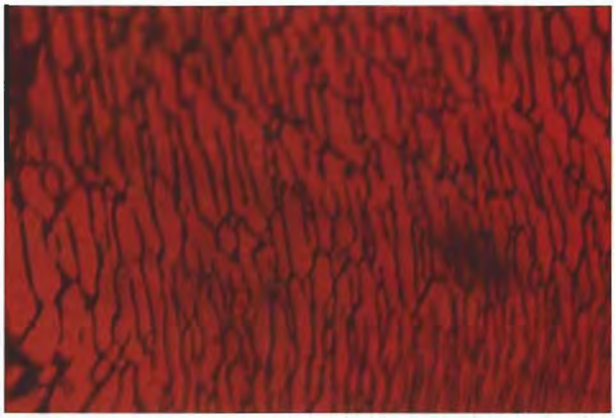


Figure 2. Healing fractures are commonly seen in natural ruby, like this stone from Sri Lanka. Photomicrograph by K. Schmetzer; immersion, magnified 60×.

usually begins with heat treatment, followed by rapid cooling by immersion in a liquid or melt (Koivula, 1983). This quenching process produces fractures and fissures within the synthetic ruby crystals, which are subsequently immersed for a time in a flux melt that typically contains dissolved aluminum oxide. The fractures become filled with flux and are partly healed by slow cooling of the flux during this last step, which causes the formation of "fingerprint" patterns of residual flux (figure 1). The result may somewhat resemble the healing fractures found in natural rubies (figure 2). Note that it has not been proved experimentally whether any of the commercially available Chatham, Knischka, or Lechleitner Verneuil-grown synthetic rubies with induced flux fingerprints were submitted to the initial heating and rapid cooling steps before immersion in flux. In at least some of these treated synthetic rubies, the "induced fingerprints" may actually be simple healing structures in fissure-bearing Verneuil material that was never submitted to quench crackling.

Figure 3. In several flux-treated synthetic rubies seen in the trade over the last few years, the healing fractures have a distinctive continuous, three-dimensional, honeycomb-like cellular structure. Photomicrograph by K. Schmetzer; transmitted light, magnified 40×.

Since 1989, the authors have also encountered about 60 synthetic rubies, usually set in mountings, that revealed a flux-induced pattern distinctly different from the flux-induced "fingerprints" typically seen in the Verneuil-grown synthetic rubies described above (figure 3). Some were identified from the stocks of several dealers in Germany, and about 20 others were submitted to the authors for gemological testing. Many were either labeled or represented as natural rubies from Afghanistan. Two such stones (see, e.g., figure 4) were purchased by one of the authors for more detailed study, including spectroscopy and chemistry.

This article reviews what is known about those synthetic rubies with flux-induced fingerprint-like inclusions that are typically seen on the market, and presents the results of our examination of the distinctly new flux-treated synthetic rubies.

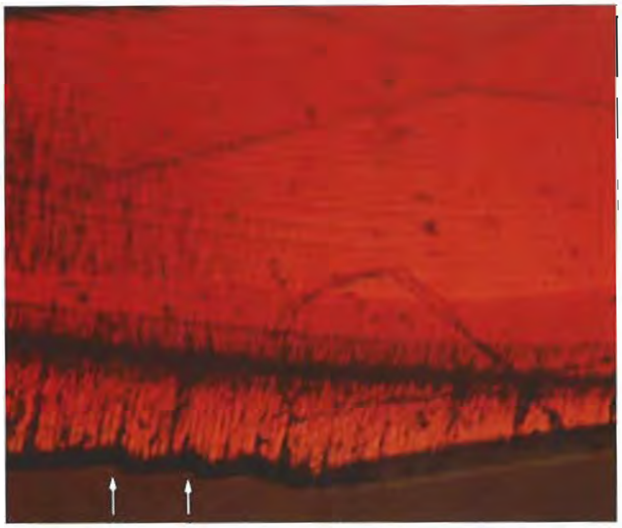
TYPICAL SYNTHETIC RUBIES WITH FLUX-INDUCED FINGERPRINT PATTERNS

Whether or not heat treatment is the first step, the process of inducing "fingerprints" usually involves placing small, irregularly shaped or preformed samples—or even complete boules—of Verneuil synthetic ruby in an aluminum oxide-bearing flux melt for days or weeks. This results in the formation of a layer of flux-grown synthetic ruby on the Verneuil

Figure 4. Flux-induced inclusions like those shown in figure 3 were seen throughout this 9.93-ct sample (approximately 10.3 × 14.8 mm) of a new type of treated synthetic ruby. Photo © GIA and Tino Hammid.

"seed". This skin of flux-grown synthetic ruby often contains parallel growth lines. In some cases, there occur distinct crystal faces that are typical of the flux used for growth (figure 5). After faceting, synthetic rubies treated by this process may actually retain some of the flux-grown synthetic ruby skin over the Verneuil core; more commonly, cutting and polishing removes the flux overgrowth, so that only the Verneuil seed remains.

Figure 5. A curved line marks the boundary between the Knischka Verneuil-grown synthetic ruby "seed" and the flux-grown synthetic ruby skin. Curved striae are visible in the core, and the skin reveals oscillating dipyramidal faces $n(22\bar{4}3)$ due to a tungsten-bearing flux. Photomicrograph by K. Schmetzer; immersion, magnified 60×.



In samples that retain the flux-grown synthetic ruby skin after cutting, a distinct boundary may still be seen between the Verneuil portion and the flux-grown skin, and may even extend to the surface of the polished stone (figure 6). The flux-grown layer may contain inclusions of relatively coarse residual flux material (figure 7). In some specimens, magnification reveals small, doubly refractive crystals confined to the boundary between the Verneuil and flux-grown components. The fact that the refractive indices of these included crystals approximate those of the host material indicates that they are synthetic corundum crystals

Figure 6. On the surface of this faceted Lechleitner synthetic ruby, the boundaries between the Verneuil-grown "seed" (center) and the partially removed flux-grown skin are readily apparent. Photomicrograph by K. Schmetzer; immersion, magnified 50×.

Figure 7. Note the coarseness of the residual flux in this overgrowth on a Lechleitner synthetic ruby. Photomicrograph by K. Schmetzer; immersion, magnified 100×.

that are oriented differently from the host material.

Whether or not the flux-grown layer of synthetic ruby remains after faceting, the Verneuil-grown seed material generally contains a variety of flux "fingerprint" inclusions that often resemble the patterns found in partly healed fractures in natural ruby (compare figures 1 and 2). When these occur, other diagnostic features may be needed to determine the natural or synthetic origin of a ruby. In most cases, Verneuil-grown synthetic ruby contains curved growth striations (figure 8), but these are sometimes difficult to resolve; occasionally, gas bubbles confined to curved growth layers provide conclusive evidence of synthesis (figure 9).

If magnification does not reveal any diagnostic features, trace-element analysis may provide conclusive results (Schmetzer, 1986a and b). Treated Chatham and Lechleitner synthetic rubies with Verneuil seeds contain traces of molybdenum and/or lead (from the flux) that can be detected by X-ray fluorescence spectroscopy. Similar material produced by Knischka is most often characterized by traces of tungsten and/or lead. Mo, Pb, and W are also found in treated flame-fusion synthetic rubies from unknown producers.

A NEW TYPE OF TREATED SYNTHETIC RUBY

Over the course of the last five years, the authors have observed distinctly different flux-induced inclusions in approximately 60 synthetic rubies that had been represented as natural in the gem trade (again, see figure 4). When viewed with magnification in reflected light, each stone revealed a net-like pattern of whitish to colorless material that reached the surfaces of these faceted samples (figure 10). In transmitted light, it can be seen that the included material forms a thin, continuous, three-dimensional, honeycomb-like cellular structure (again, see figure 3).

To characterize these new treated synthetic rubies, we tested 20 samples by standard gemological methods using a binocular gemological microscope, a standard gemological refractometer, and hydrostatic weighing. We then submitted two of these samples (1.99 ct and the 9.93 ct—shown in figure 4—both the intense red common to synthetic rubies) to energy-dispersive spectroscopy on a scanning electron microscope (SEM-EDS) for chemical analysis of the inclusions, and to energy-dispersive X-ray fluorescence (EDXRF) for qualitative chemical analysis of the whole sample.

Figure 8. In this Lechleitner flame-fusion synthetic ruby, both curved striae and the "fingerprint" patterns of residual flux are readily visible. Photomicrograph by K. Schmetzer; immersion, magnified 85×.

Figure 9. Gas bubbles follow the curved growth layers in this Chatham flux-treated flame-fusion synthetic ruby "seed," thus proving that it is a flame-fusion synthetic. Photomicrograph by K. Schmetzer; immersion, magnified 25×.

Gemological Properties. Refractive indices, specific gravities, and reactions to long- and short-wave ultraviolet radiation for the study samples (as well as for the other samples of this material previously encountered) are within the overlapping ranges for natural and synthetic rubies. We recorded refractive indices of n_o=1.770–1.771, n_e=1.762–1.763, with a birefringence of 0.008. Specific gravity was found to range from 3.99 to 4.01, and the stones fluoresced an intense orange-red to both long- and short-wave ultraviolet radiation. We noted that the absorption spectra of the two samples are typical for low-iron rubies—that is, with chromium-related features and without iron-related absorption bands. This is normal for most synthetic rubies.

Microscopy. As noted above, a net-like pattern of whitish to colorless material was observed with reflected light (again, see figure 10); in transmitted light, the included material appeared to form a thin, continuous, three-dimensional, honeycomb-like structure (again, see figure 3).

In one small area of the 1.99-ct sample, we observed a discontinuous pattern of included material that visually resembled the fingerprint pattern of a healing fracture in natural ruby. This feature is probably due to residual melt that was trapped during the primary synthetic growth process.

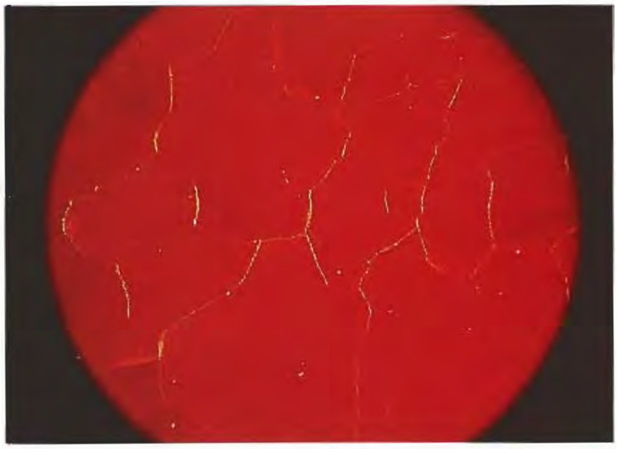
After intense examination with the microscope, we resolved extremely weak curved growth striae in a zone confined to the girdle area of the 9.93-ct sample. Because these striations are so weak, we cannot state conclusively that the original material submitted to flux treatment was Verneuil-grown synthetic ruby. It might be an example of the more expensive Czochralski-grown material that has been immersed in a flux melt.

Chemistry. SEM-EDS analysis of the colorless to white material that forms the cellular patterns in both samples revealed the presence of calcium and lead, and the absence of aluminum. One sample showed the presence of other impurity elements in some areas exposed to the surface, but these are probably residuals of the cutting and polishing process. EDXRF analysis of both samples revealed Ca and Pb from the included material as well as distinct amounts of chromium and small amounts of iron. The amounts of Ca and Pb can be related to the flux in which these synthetic rubies were treated. PbF_2 and/or PbO are the most commonly known components of fluxes (Schmetzer, 1986a and b), and CaF_2 has been used in the flux growth of ruby since the early work of Fremy and Verneuil in the late 19th century (Elwell and Scheel, 1975). Presumably, these synthetic rubies were treated by immersion in a flux composed of a mixture of PbF_2 and CaF_2 to induce the three-dimensional cellular pattern we observed.

COMPARISON OF GROWTH CONDITIONS

All previously reported Verneuil synthetic rubies with flux-induced fingerprint patterns appeared to

Figure 10. The flux-filled fissures in this new type of treated synthetic ruby form a distinctive cellular pattern. Photomicrograph by K. Schmetzer; reflected light, magnified 32×.



have passed through a step in which they were immersed in a flux containing dissolved aluminum oxide (Koivula, 1983; Schmetzer, 1986a and b). It is less certain whether all were also subjected to heat and subsequent rapid cooling (quench crackling) prior to immersion in the flux. However, the observable differences in the residual flux that is trapped in the healing fractures can most probably be attributed to differences in flux-melt composition and/or differences in temperature, time, and/or temperature cycling of the treatment.

In contrast to the discontinuous patterns of Mo-, Pb-, and tungsten-containing inclusions that are typical of flux-treated Verneuil synthetic rubies, the fissures in the new treated synthetic rubies described here are continuously filled with a flux material containing lead and calcium. Apparently, the flux melt used in the processing did not contain aluminum oxide, which usually promotes the healing process. This missing component may be one reason why the typical flux-induced fingerprint-like healing patterns (which resemble the partly healed "feathers" in natural ruby) did not form. Another possibility is that the seeds were not immersed in the melt long enough to cause partial healing of fissures or cracks. It is also possible that this represents a new treatment process, unlike any described to date.

CONCLUSION

Verneuil-grown synthetic rubies with flux-induced fingerprint-like inclusions continue to appear on the gem market, often misrepresented as natural rubies. In recent years, they have been joined by treated synthetic rubies with a distinctly different inclusion pattern—a continuous, three-dimensional, honeycomb-like cellular structure of fractures filled with flux material. Although the treatment process normally tends to obscure evidence of curved growth striae in the host synthetic, the distinctive inclusion pattern generally does not resemble inclusions in natural rubies or the fingerprint-like patterns previously induced in synthetic rubies. Therefore, this new type of treated synthetic ruby can be readily identified with a microscope or even a hand lens.

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GEM TRADE LAB NOTES

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DIAMOND

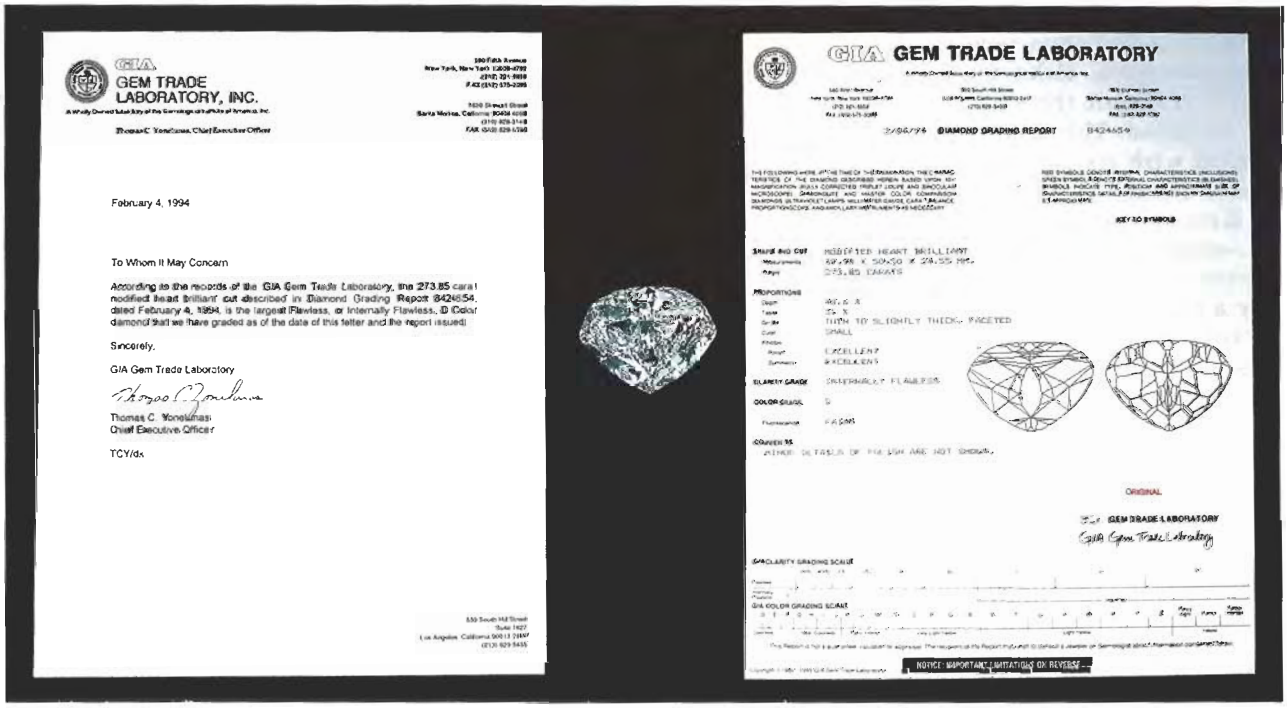
Centenary Diamond Graded

In early 1994, a special team of experienced senior staff members from both the East and West Coast labs traveled to London to grade, on-site, the Centenary diamond (figure 1). To ensure a grading environment consistent with that in the GIA Gem Trade Laboratory, specific requirements were forwarded in advance to the CSO Valuations AG, which prepared a room especially for the grading. To further ensure consistency, the grading team brought to the site a Minolta Chromameter, which was used to monitor both the ambient lighting conditions of the room and that of the grading equipment that was brought from New York by the team.

The Centenary was described on the grading report as a modified heart brilliant weighing 273.85 ct. It was graded "D" color, Internally Flawless, with polish and symmetry both graded as excellent, validating previously published information about this diamond. A letter was prepared which accompanied the grading report, stating that the diamond is the largest "D"-color, Flawless or Internally Flawless diamond graded by the GIA Gem Trade Laboratory as of the date of the grading report.

Tom Yonelunas, Ed Schwartz, and John M. King

Figure 1. The 273.85-ct Centenary diamond is the largest "D" color, Flawless or Internally Flawless diamond graded by the GIA Gem Trade Laboratory to date.



GIA
GEM TRADE
LABORATORY, INC.

February 4, 1994

To Whom It May Concern

According to the records of the GIA Gem Trade Laboratory, the 273.85 carat modified heart brilliant cut described in Diamond Grading Report 8424654, dated February 4, 1994, is the largest Flawless, or Internally Flawless, D Color diamond that we have graded as of the date of this letter and the report issued.

Sincerely,

GIA Gem Trade Laboratory

Thomas C. Yonelunas
Chief Executive Officer

TCY/dx

GIA GEM TRADE LABORATORY

DIAMOND GRADING REPORT

SHAPE AND CUT: MODIFIED HEART BRILLIANT
273.85 CARATS

PROPORTIONS
THIN TO SLIGHTLY THICK, FACETED
SMALL
EXCELLENT
EXCELLENT

CLARITY GRADE: INTERNALLY FLAWLESS

COLOR GRADE: D

COMMENTS
MINOR DETAILS OF FINISH ARE NOT SHOWN.

ORIGINAL

GEM TRADE LABORATORY
GIA Gem Trade Laboratory

Color Origin, "Unnamed Brown"

A second purpose of the recent trip to London by GIA Gem Trade Laboratory staff members was to examine and issue an Identification

Figure 2. The largest diamond on which the GIA Gem Trade Laboratory has reported to date is the 545.65-ct natural-color, fancy yellow-brown "Unnamed Brown" diamond.

and Origin of Color report on the 545.65-ct diamond known as the "Unnamed Brown" (figure 2). This provided a unique opportunity to document the properties of this important diamond and to authenticate the origin of color.

Examination of the diamond with magnification revealed characteristic brown planar graining alternating with near-colorless zones in some areas. The diamond was inert to both long- and short-wave ultraviolet radiation, although it did weakly transmit the short-wave U.V. radiation. This latter feature, coupled with its ultraviolet and infrared absorption spectra, showed the diamond to be a type IIa. The U.V.–visible spectrum was essentially devoid of sharp features, showing only a gradual rise in absorption toward the shorter wavelengths. These combined properties provided proof of natural color.

The shape of the diamond was described on the report as a modified cushion brilliant, and the color was graded Fancy Yellow-Brown, Natural Color. This report was accompanied by a letter stating that it was the largest diamond on which the GIA Gem Trade Laboratory had issued a report as of the date of testing.

TM and John M. King

Fancy-Colored Rough

In most fancy orange-to-brown diamonds, the color is distributed along graining throughout much—if not all—of the stone. Thus, a New York diamond dealer was surprised—and disappointed—when the cutting of an apparently "fancy" orangy brown piece of rough (as illustrated by the remnant in figure 3—right) produced a near-colorless stone (figure 3—left).

Although this dealer was thoroughly familiar with the green and/or brown irradiation stains seen on the surface of some near-colorless rough, which are usually removed during cutting, he had never observed this kind of color distribution in an orangy brown diamond. Therefore, he brought the cut stone and remnant to the East Coast laboratory for examination, noting that the original rough had been purchased in Bangui, Central African Republic.

When we examined the remnant with a gemological microscope and diffused transmitted light, we noted brown irradiation stains covering the entire surface. Although some darker stains were readily apparent at high magnification, most of the stains were pale brown with poorly defined edges, which contributed to the impression that the skin was evenly brown (figure 4). Almost all of these stains were extremely shallow; even the darkest ones did not appear to penetrate the surface more than 0.05 mm. We

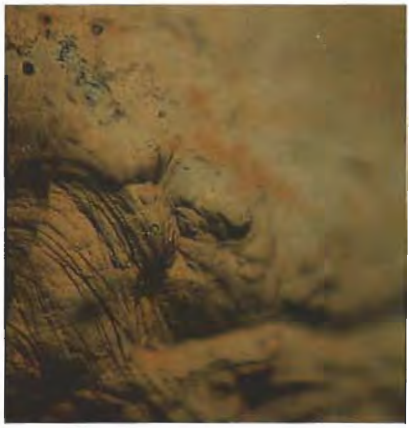
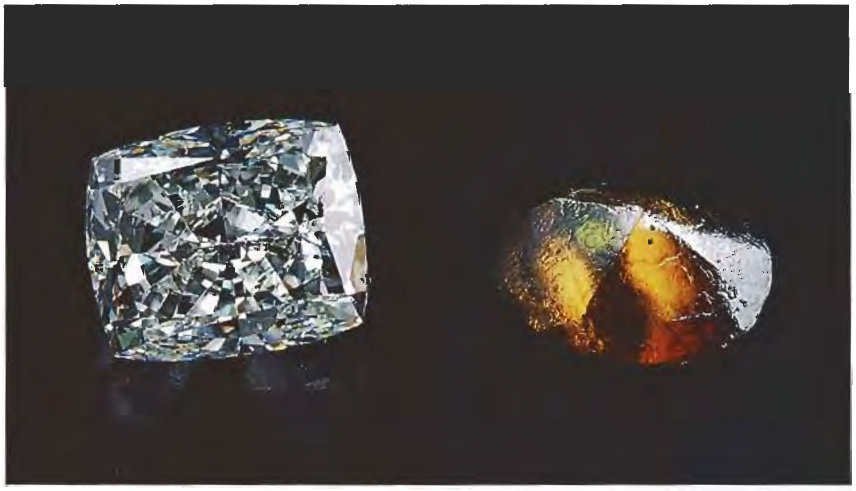


Figure 4. The color of the rough shown in figure 3 was due to the brown natural irradiation stains that cover its entire surface. Note also the green irradiation stain toward the top left of the photo. Magnified 126×.

Figure 3. The dark orangy brown rough diamond on the right is a remnant of the piece from which the 1.18-ct rectangular modified brilliant, of I to J range in color, was cut.



noted one green irradiation stain as well (again, see figure 4).

The visible absorption spectrum of this rough piece, measured at low temperature with a Pye-Unicam SP8-400 spectrophotometer, revealed a weak line (due to irradiation) at 741 nm and a moderate absorption at 595 nm. The latter was strong enough to be clearly visible with a desk-model spectroscope at room temperature. The cut stone, of I to J range in color, also showed an extremely weak 741-nm line in the spectrum, but not the 595-nm absorption line. We detected no residual radioactivity from the shallow surface stains on the rough remnant, one of the properties occasionally encountered in laboratory-treated stones.

It appears that this stone was exposed to both alpha radiation and moderate heating in nature. In 1943, B. W. Anderson noted similar characteristics in brown, surface-colored rough also from the Central African Republic (see, for example, *Gems & Gemology*, Summer 1982, p. 76). Laboratory experiments have shown that heat treating a diamond to 500°–550°C will turn green irradiation stains brown while developing a 595-nm absorption peak. However, some researchers speculate that similar effects may occur in nature at lower temperatures maintained over much longer periods. The green stain on this piece of rough suggests that exposure to radiation continued after heating had stopped.

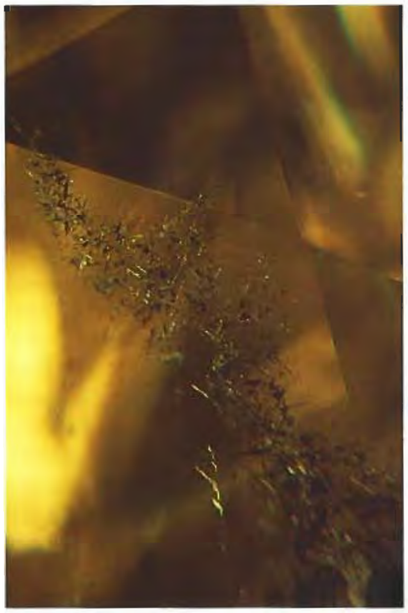
While the GIA Gem Trade Laboratory has seen many rough diamonds with brown and green irradiation stains contributing to the color, this is our first encounter with a stone where the dark brown stains completely disguised the inherent near-colorless body color of the diamond crystal. It also adds to the documentation of rare naturally occurring 595- and 741-nm absorption features; the former was once considered to be evidence of laboratory irradiation and heat treatment in all cases. *Ilene Reinitz and TM*

Characteristic Inclusions in Fancy-Color Diamonds

Gemologists can identify some gemstones with moderate certainty by their characteristic inclusions. For instance, demantoid garnet is well known for its "horsetail" inclusions, and natural spinel for its inclusions of octahedral crystals. The low-relief, rounded crystal inclusions and roiled appearance of hessonite garnet also come to mind, as do emerald's very frequently encountered "three-phase" inclusions.

As we continue our research into the problems of determining the origin of color in colored diamonds, we now routinely establish the diamond type of the stone under examination. This usually requires the use of an infrared spectrometer to study the mid-range infrared spectrum of each stone. (See the article by E. Fritsch and K. Scarratt, in the Spring 1992 *Gems & Gemology*, pp. 38–39, for an excellent discussion of different diamond types.) One type—the rare type-Ib diamond—is noted for producing one of the most commercially desirable fancy colors, called a "true canary" by some in the trade. Here, the nitrogen impurities are dispersed throughout the crystal, replacing some carbon atoms rather than clustering in aggregates. We study such stones in detail when they appear in the lab, because of both their rarity and their intensity of color. Note that type-Ib stones do not show the "Cape" spectrum commonly seen in type-Ia diamonds with a hand spectroscope.

Figure 5. Needle-like inclusions such as these are often found in type-Ib fancy intense yellow diamonds. Magnified 63×.



Over the past few years, as more information has become available on diamond types, researchers and laboratory gemologists have been able to establish correlations between some of the inclusions in a diamond and its type. By extension, these inclusions can be used as indications of the origin of color in fancy-colored diamonds. One feature noted in nearly all predominantly type-Ib diamonds, but not in other types, are clusters of fine dark needles of unknown composition. On the basis of the presence of such clusters (figure 5), we surmised that the 1.01-ct fancy intense yellow diamond in figure 6 was a type Ib. The mid-range infrared spectrum proved that our thoughts were correct.

Some fancy intense yellow diamonds have another distinctive inclusion—oriented platelets—that is even rarer than the dark needles in type-Ib stones. We saw numerous such platelets (figure 7) in another fancy yellow diamond examined in the East Coast lab. These inclusions are reminiscent of those seen in some East African rubies and sapphires. Again, on the basis of the inclusions and the characteristic color, one experienced staff member predicted that the stone would prove to be a type-IaA diamond. The mid-range infrared spectrum showed it to

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

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Figure 6. This 1.01-ct fancy intense yellow, pear-shaped brilliant cut—in which the inclusions shown in figure 5 were found—is a type-Ib diamond.

be type IaA>>B, plus minor Ib (to which the intense yellow color is attributed). However, because of the type-Ia component, such a stone may also show a weak 415-nm line of the "Cape series" (as was the case with the sample described above).

Observation of such needles or platelets helps establish that an intense yellow diamond is both natural and naturally colored.

GRC

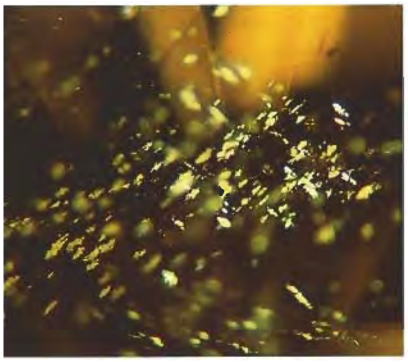


Figure 7. These oriented platelets appear to be unique to type-IaA fancy yellow diamonds. Magnified 63×.

FELDSPAR and GARNET Snuff Bottle

Carvings are among the most interesting and challenging items submitted for identification to the GIA Gem Trade Laboratory. Often, their size prevents determination of specific gravity and the typically curved surfaces limit refractometer testing to spot readings (with even less accuracy if the polish is poor). Furthermore, some carved materials consist of more than one distinct mineral, or they represent a mineral that is only rarely seen in carved form. The list of such ornamental materials reported in Lab Notes includes: pinite (Fall 1983, pp. 175–176); a rock consisting of serpentine and other minerals (Winter 1983, pp. 233–234); a rock containing plagioclase feldspar and muscovite mica as major components (Fall 1985; pp. 173–174); clinochlore IIb (Winter 1991, p. 248); massive grossular garnet (Spring 1985, p. 44, and Winter 1991, pp. 248–249); and orthopyroxene (Winter 1993, p. 282).

The latest such novelty to be submitted to the West Coast lab for identification was a snuff bottle, reportedly from China, that was carved from a translucent mottled white-and-green material. It measured approximately 55.0 × 56.1 × 11.6 mm (figure 8). With magnification, we noted that the white areas were similar in appearance to jadeite, and the green component along one side of the bottle consisted of numerous green platelets and mossy-appearing inclusions. Spot refractometer testing of the white area produced a 1.57 value, but the green platelets were too disseminated within the white area to give a separate reading. The specific gravity (determined hydrostatically) was 2.76. The white areas fluoresced a weak, dull gray to long-wave U.V. radiation, but strong red to short-wave U.V. The green areas were inert to both wavelengths.

Figure 8. This 56-mm-high carved bottle is composed primarily of plagioclase feldspar, with garnet of the grossular-andradite-uvarovite series.

On the basis of the gemological properties, we determined that the white component was a plagioclase feldspar. However, X-ray diffraction analysis was needed to identify the green component. Analysis of a minute powder sample from one such area produced a pattern that was very close to our standard reference pattern for uvarovite garnet [$Ca_3Cr_2(SiO_4)_3$]. However, a similar pattern could result from a mixture of grossular [$Ca_3Al_2(SiO_4)_3$] and andradite [$Ca_3Fe_2(SiO_4)_3$], with only a small amount of chromium causing the green color. Therefore, we felt this pattern was insufficient to identify the green component specifically as uvarovite.

Energy dispersive X-ray fluorescence (EDXRF) analysis performed by GIA Research revealed significant aluminum and iron components, in addition to calcium and chromium. This chemistry shows that the mineral in the green areas is actually composed of grossular, andradite, *and* uvarovite, all members of the garnet group. Thus, the snuff bottle was identified as a rock consisting primarily of plagioclase feldspar, plus garnet in the grossular-andradite-uvarovite series, with the possibility of additional minerals. We also noted on the report that petrographic testing (a destructive process) would be necessary to characterize the material fully. *RCK*

Magnetic HERCYNITE, a Warning About Magnetic Cards

Over the past several months, a number of samples of a black spinel-group mineral have come through the West Coast laboratory (see, e.g., Gem News, Fall 1993, pp. 212–213). The spinel group of minerals contains the transparent gem species spinel ($MgAl_2O_4$), as well as the opaque black species hercynite ($FeAl_2O_4$), magnetite (Fe_3O_4), and magnesiochromite ($MgCr_2O_4$), among others. Solid-solution mixtures may occur between two or more members of the spinel mineral group, with the resulting materials exhibiting physical properties—sometimes unexpected—between those of their end-member components.

The East Coast lab received an 8.94-ct black stone for identification. Although the R.I. was over the limits of the standard refractometer (1.80+), the material was similar in appearance to stones from the spinel group that we had tested. The gemological properties and X-ray diffraction results indicated that the stone was an intermediate spinel (about 75% hercynite and 25% spinel). The fact that it was attracted to a pocket magnet suggests that it probably contained some magnetite.

An additional feature of this stone was discovered by accident. After inadvertently placing the stone in contact with a pass card that contained an embedded magnetic strip, we noticed that the key code was no longer valid, rendering the card useless. Although the next two hercynites that we examined were not as magnetic, other magnetic gem materials might also affect magnetic strips on pass cards. Such materials include slag imitations of hematite (used for cameos) and pyrite-rich shale, which has recently been cut for jewelry (G. H. Dick, *American Jewelry Manufacturer,* February 1993, pp. 14–15). Although this is our first experience with a gemstone affecting a magnetic card, it will probably not be the last. Readers are warned to take heed of the potential risks involved in handling such materials. *Mary L. Johnson*

Lavender JADEITE, Impregnated

The article titled "Identification of Bleached and Polymer-Impregnated Jadeite" (E. Fritsch et al., *Gems & Gemology,* Fall 1992, pp. 176–187) focused on predominantly green and white jadeite that has been bleached to remove undesirable brown staining and then is polymer impregnated to improve the stone's transparency and overall appearance. Such treated jadeite, often referred to in the trade as "B jade", has become a major concern to those dealing in jade.

However, polymer impregnation is not limited to green jadeite, as the West Coast lab recently discovered. Standard gemological testing of a 15.86-ct lavender oval cabochon (figure 9) determined that it was jadeite. Examination with magnification provided the first evidence of treatment—small cavities containing a transparent, essentially colorless filling material. Infrared (FTIR) spectroscopy confirmed these initial observations. A strong absorption at about 2900 cm^{-1} confirmed the presence of a synthetic resin similar to that detected in some of the jadeite described in the above-referenced article and in other samples submitted to the East and West Coast labs for identification.

Figure 9. Infrared spectroscopy confirmed that this 15.86-ct lavender jadeite cabochon had been polymer impregnated.

As is done with polymer-impregnated green jadeite, the laboratory report identified this lavender jadeite cabochon as "impregnated jadeite jade." Because we could not definitively determine the origin of the color in this stone (which is typically the case with lavender jadeite), the conclusion also included a note to that effect.

RCK, SFM, and Emmanuel Fritsch

OPAL, Translucent Greenish Blue

Turquoise is probably the best known of the nontransparent greenish blue gemstones. Chalcedony colored by finely disseminated inclusions of the mineral chrysocolla has a color reminiscent of the best turquoise, but typically with a higher degree of diaphaneity. A Mexican locality has produced commercial quantities of this chalcedony, which has been seen in the U.S. market for the past few years (see, e.g., the chalcedony entries in the Spring 1991 Lab Notes, p. 40, and in the Spring 1992 Gem News, pp. 59–60). Occasionally we have seen opal in this color, but that material typically lacked the color saturation that we associate with the finest chrysocolla-colored chalcedony. Such opal is reportedly mined in the Andes Mountains of Peru (see "Fine Greenish Blue Opal," Summer 1991 Gem News, pp. 120–121).

Last fall, the West Coast lab was asked to identify four items—three carved, pierced pendants (see, e.g., figure 10) and one cabochon—that were all translucent and looked very much like the finest Mexican chalcedony. However, gemological testing revealed properties consistent

Figure 10. This 72.69-ct carved opal (approximately 52.65 × 27.65 × 11.53 mm) strongly resembles chrysocolla-colored chalcedony.

with opal, including spot R.I.'s ranging from 1.45 to 1.47 and S.G.'s from 2.15 to 2.17. Magnification revealed a texture that closely resembled that of the Mexican chrysocolla in chalcedony, but was also similar to the structure seen in a reference sample of blue opal from Peru. Because of the unusual appearance of the material, the slightly elevated R.I. (at the high end of values for opal), and the ambiguous structure, we decided to perform X-ray powder diffraction analysis. This produced a very weak cristobalite pattern, which is typical for many opals. The specimens were therefore identified as opal.

RCK

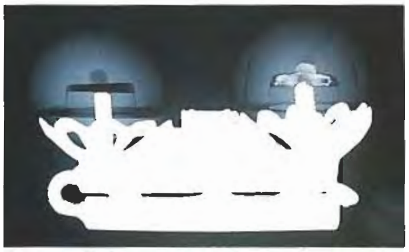
PEARLS

Early Japanese Assembled Cultured Blister Pearls

Only twice in the Lab Notes section's long history have we mentioned so-called "Japanese pearls," the first products of Japan's pearl-culturing efforts. One mention was about a latticework necklace in the Summer 1983 issue (p. 116): A lovely "pearl" appeared at each intersection of the white enameled bars making up the lattice. At that time we had many questions about the formation of these "pearls." The second mention was in Spring 1988 (p. 49), when the lab examined a pair of earrings set with similar "pearls." By then, we had learned enough about these gems to report that they were made before the secret of culturing solid round pearls was discovered.

Figure 11. Each of these early assembled cultured pearls is about 6.8 mm in diameter. Magnified 10×.

Figure 12. This X-radiograph of the pearls in figure 11 shows rectangular inserts similar to the one illustrated in the Spring 1988 issue of Gems & Gemology.



Within the past few months, the East Coast lab has identified these assembled cultured blister pearls in two pieces of jewelry. Figure 11 shows a necklace clasp with two "Japanese pearls" that were readily identified by the cement plane visible in each. Although not needed for the identification, an X-radiograph (figure 12) was taken to show their typical assemblage: a blister pearl top with a cement backing, sometimes with a shell cube or other insert for support.

The Edwardian ring in figure 13 at first glance appeared to contain colored freshwater pearls, which were popular at the turn of the century. These colors and shapes are typical of American pearls available at that time. Therefore, we were surprised to discover from the X-radiograph (figure 14) that at least the two outer "pearls" were early assembled cultured blisters (i.e., with the rectangular saltwater-shell insert characteristic of this material—again, see the Spring 1988 issue of *Gems & Gemology*, p. 49, for a detailed discussion). Although the center "pearl" showed no evidence on the X-radiograph of the characteristic dark shadow line between the bead implant and the nacreous overgrowth, visual examination from the side showed that it, too, was assembled.

Another surprise was the discovery that all three cultured blister pearls had been dyed, evidently to imitate American freshwater pearls.

Figure 13. These three assembled cultured blister pearls (6.6–7 mm) have been dyed, perhaps to imitate American freshwater pearls.

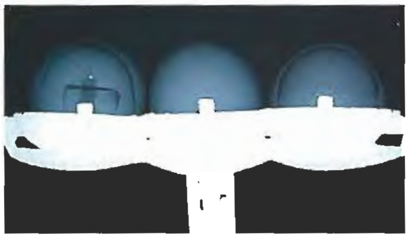


Figure 14. This X-radiograph shows a rectangular insert in one of the assembled cultured pearls illustrated in figure 13.

If, as we surmise, these are "Japanese pearls" and were dyed prior to setting, they would be the oldest dyed cultured pearl product of which we have knowledge. Figure 15 shows the bubble-like separations in the dye layer of the center black "pearl." We had been told that dyed black natural pearls were not routinely produced until the 1920s.

GRC

Experimental Nucleus in a Cultured Pearl

Following work done by Mikimoto in the early 1900s, it was generally agreed that a nucleus of white freshwater mother-of-pearl shell provided the best culturing results. Thus, testing of bead-nucleated ("Akoya") cultured pearls today usually reveals shell nuclei. However, we do rarely encounter whole cultured pearls with other nuclei, including wax (*Gems & Gemology*, Summer 1988, pp. 114–115) and plastic, used as the irritant. When something other than shell is used, the purpose is usually to create a specific effect on the color, as was the case with the green composite nuclei reported in *Gems & Gemology*, Fall 1990, pp. 222–223. Historically, dyed blue shell cores have been used to impart a gray-to-black color to the finished product.

Figure 15. Bubble-like separations can be seen in the dye layer of the gray pearl illustrated in figure 13. Magnified 15×.

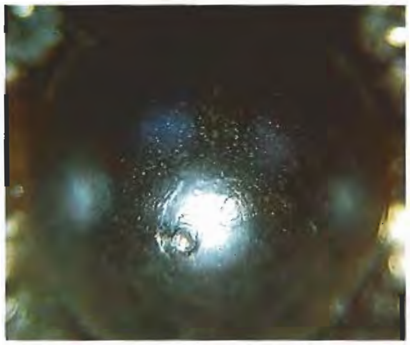


Figure 16. Notice the darker appearance of one of the cultured pearls (approximately 8 mm in diameter) in the center strand.

A necklace recently submitted to the East Coast lab for identification was found to consist of cultured pearls that ranged from 3.75 to 8.50 mm in diameter. One bead had a distinctly different, darker appearance than the rest (figure 16).

An X-radiograph (figure 17) revealed that the nucleus of this cultured pearl was considerably more transparent to X-rays than the typical shell nucleus. Because of this, we took a small scraping from the nucleus and exposed the shavings to a thermal reaction tester. The relative hardness of the material (as determined during the scraping process), and the fact that the shavings did not readily melt, indicate that this was some type of plastic rather than a wax.

On the basis of the unusual nucleus in the one bead, the shape of the cultured pearls, and the thickness of their nacre, we speculate that this necklace was probably produced in the 1920s or '30s, when experimentation with different nuclei was more prevalent.

TM

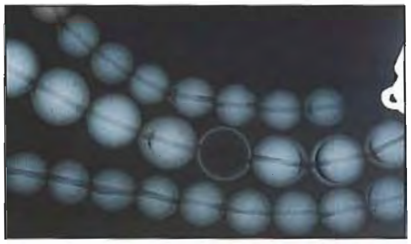


Figure 17. The difference in X-ray transparency of one cultured pearl clearly shows that its nucleus is not the same as that of the other cultured pearls, which appear to have shell-bead nuclei.

Star SAPPHIRE, with a Buff-Top Cut

Generally, most gems fall into one of three broad fashioning categories: faceted, cabochon cut, or engraved. However, there are exceptions, as in the "fantasy cuts" that have received considerable attention over the past several years. Another hybrid style, one that predates fantasy cuts, is known as the buff-top. This features a convex top—like a cabochon—and a faceted pavilion. It is a fashioning style employed most frequently with flame-fusion synthetic corundums and synthetic spinels that are used in class rings and similar types of popular jewelry.

As this cut is most often associated with mass-produced, nonphenomenal synthetic gem materials, it was with interest that the West Coast lab received for identification the stone shown in figure 18. Standard gemological tests proved it to be a natural star sapphire. In addition to exhibiting a star of moderate

Figure 18. Face up, this 11.66-ct blue star sapphire displays asterism, as well as some brilliancy that is not usually seen when a standard cabochon cut is used for such material.

intensity on its domed top surface, this fairly transparent stone also displayed some brilliancy, caused by reflections from its step-cut pavilion facets (figure 19). It is possible that the decision to use this cutting style, which is not common for natural material, was based on the desire to obtain good weight retention from the rough, while at the same time producing an unusual fashioned natural gem. *RCK*

Figure 20. Face up, this 15.80-mm color-change synthetic sapphire appears redder than is typical for this material because of a coating on the pavilion facets.

SYNTHETIC SAPPHIRE, Color-Change with Unusual Backing

The GIA Gem Trade Laboratory periodically receives color-change stones that are subsequently identified as synthetic sapphires. The color change is typically from grayish greenish blue in day or fluorescent lighting to purple-pink under incandescent light.

Recently, the West Coast lab received for identification a ring mounted with a reddish purple round brilliant (figure 20). Standard gemological testing revealed properties consistent with those for corundum, and the presence of curved striae proved that it was synthetic. The spectrum was typical of the color-change synthetic sapphires that are colored by vanadium. What was unusual about this specimen was that in both incandescent and fluorescent lighting it had an atypical red component. Although the closed-back nature of the mounting made it impossible to examine the stone from the pavilion, examination with a microscope through the crown revealed that the unusual color was due to the presence of a red foil or paint-like coating on the pavilion facets. We speculated that this backing was applied to add red to the face-up color of the stone in an attempt to approximate more closely the color of alexandrite, rather than the more purple hue of color-change synthetic sapphires, in incandescent light.

We have seen foil-backed synthetic color-change sapphires in the trade (again, often in class rings), but this is the first we recall receiving in the laboratory for identification. Note that usually the backing is not colored and is used to increase apparent brilliance. *RCK*

Figure 19. A side view of the star sapphire shown in figure 18 reveals the cabochon top and faceted pavilion characteristic of the cutting style known as a buff top.

PHOTO CREDITS

Figures 1 and 2 are courtesy of CSO Valuations AG. Nicholas DelRe took the photos used in figures 3–7, and 11–17. Shane F. McClure provided figures 8–10, and 20. Figures 18 and 19 are by Maha DeMaggio.

GEMNEWS

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

DIAMONDS

Cubic zirconia misrepresented as diamond. Two attempts to pass off cubic zirconia (CZ) as diamond were reported in International Colored Stone Association (ICA) Alert No. 73, dated August 13, 1993, and authored by K. T. Ramchandran and Dr. Jayshree Panjikara, of the Gemmological Institute of India. In the first, a parcel of rough diamonds included one CZ that was fashioned to imitate an octahedral diamond crystal, complete with "trigons" etched on the octahedral faces (although these ersatz etch markings were oriented incorrectly). In the other episode, CZ baguettes and round brilliants were salted into parcels of diamonds of similar shapes and dimensions.

On a related note, a major research project commissioned by De Beers revealed that India may have the highest ownership of CZ-set jewelry in the world. This was attributed in part to deceptive advertising. According to the study, some large Indian firms advertise jewelry as being set with "American diamonds," usually without disclosing the true nature of the material. (*Jewellery News Asia*, No. 108, August 1993, p. 172).

COLORED STONES

Jade-cutting factory on the Myanmar-Thai border. One of the Gem News editors (RCK) visited the northern Thai town of Mae Sai on the Myanmar border last fall to observe the trading in rubies from the Monghsu area (see Winter 1993 Gem News, pp. 286–287). This is not, however, the only gem-related business in that town. A number of firms have set up cutting factories in Mae Sai to take advantage of both the easy availability of rough and the relatively low cost of doing business as compared to Bangkok.

The editor visited one such facility, a jade-cutting firm. As with other such factories (see, e.g., the Fall 1989 Gem News entry on a similar factory in Guangzhou, China), jade is not the only ornamental material fashioned. At the time of the editor's visit, no Burmese jadeite was being cut, although both carvings and cabochons of jadeite were plentiful in the factory store. Instead, nephrite jade from the Canadian province of British Columbia was being fashioned into small Buddhist amulets, while white marble—from a quarry north of Mandalay, Myanmar—was being carved into statuettes of Buddha and other items (figure 1). When the editor remarked that this marble was visually similar to the host marble in which corundum is found in the Mogok Stone Tract, the factory owner produced a carved marble apple in which several large (approximately 1 cm in diameter), opaque red crystals were plainly visible. However, the piece from which this was cut was reportedly the only one his cutters had come across to date.

Figure 1. A quarry in the Sagyin Hills, north of Mandalay, Myanmar, was probably the source of this marble being fashioned at a "jade"-cutting factory in Mae Sai, northern Thailand. Photo by Robert C. Kammerling.

A subsequent check of the gemological literature suggested that the marble quarry in question is located in the Sagyin Hills, on the east bank of the Irrawaddy River, about 26 km (15.6 miles) north of Mandalay. In the May 1987 *Gemmological Review* ("Gem Occurrences in Burma," pp. 2–7), A. Chikayama stated that ruby, spinel, and occasionally sapphire are mined at this deposit as a by-product of quarrying marble.

ENHANCEMENTS

Instability of diamond filling. Although initial testing of filled diamonds indicated that the first commercially

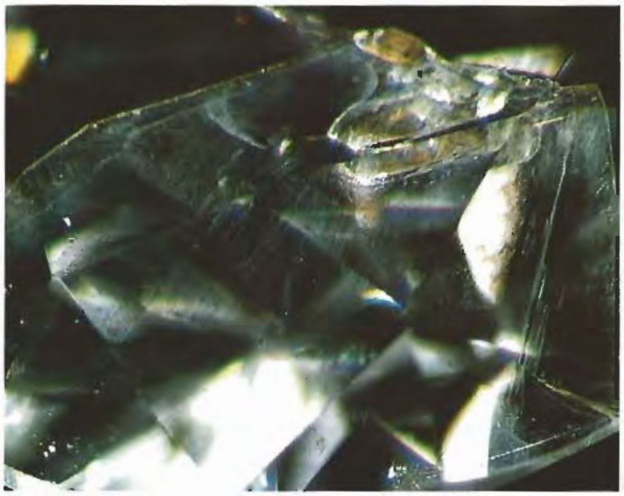


Figure 2. Discoloration of the filling material is clearly evident in this 0.27-ct fracture-filled diamond. It was subjected to a total of 101 hours under a short-wave U.V. lamp. Photomicrograph by John I. Koivula.

Figure 3. This approximately 1-ct sapphire, represented as diffusion treated, was found to be surface coated. Photo by Tony Laughter.

produced material was fairly durable and stable, the passage of time—and entrance of new treaters into the market—has shown that greater caution is needed. In addition to the early-documented damage to the filling material caused by jewelry-repair procedures involving heat (for example, in the retipping of prongs) and repolishing, we have since learned that prolonged ultrasonic cleaning can damage or partially remove the filling material from a diamond.

Another potential stability problem has been documented by gemologist Sharon Wakefield of the Northwest Gemological Laboratory in Boise, Idaho. Ms. Wakefield took a heavily fractured 0.27-ct diamond that she had purchased from the Koss firm as a filled diamond and exposed it to a 4-watt short-wave U.V. lamp at a distance of approximately 10 mm. The first visible degradation of the filling material—noted as a darkening of its color near the surface entry points—was seen at 40× magnification after only 1.5 hours of exposure. After a total exposure of 10.2 hours, the degradation of the filler had progressed so deep in the stone that it could be seen at only 10× magnification. After a total U.V. exposure of 18.2 hours, the discoloration could be seen clearly using only 2.5× magnification; further exposure—to a total of 101 hours—caused additional discoloration (figure 2). Another stone, which had only minor filled fractures, was similarly tested. Although the time for noticeable visible degradation of the filler increased to about 34.5 hours exposure, this was not unexpected inasmuch as there was less filling material.

Coated sapphires misrepresented as diffusion treated. Tony Laughter, manager of the School of Gemological Sciences in Bangkok, told the editors about an interesting incident involving treated sapphires. Mr. Laughter was asked by a local dealer to examine a parcel of four small sapphires (see, e.g., figure 3). According to the dealer, the stones had been color enhanced by a new, "electric blue" diffusion process. Initial visual examination was consistent with diffusion treatment, as one of the stones had a large broken surface that revealed an essentially colorless stone with color confined to a shallow surface area.

When the stone was immersed in methylene iodide and examined with a microscope, however, there was no dark color outlining the facet junctions, a feature characteristic of blue diffusion-treated sapphires (figure 4). Also noted was a dimpled appearance on the surfaces, and a very slight repolishing of some facets very rapidly removed the color layer. When the dealer was told that the stones were coated rather than diffusion treated, he admitted that this was the case. He did not, however, offer any information as to how or where the treatment took place.

TUCSON '94

As is the case every February, the Gem News editors joined thousands in the gem and jewelry industry from around the world in attending the many gem and mineral shows held throughout Tucson, Arizona. According to the guide published by *Colored Stone* magazine, the various shows were held at 23 different venues, including the Convention Center and various hotels and motels. This number does not include the many roadside "shows" that sprout up around the city—many little more than small card tables covered with wares.

The Gem News editors thank all the participants and representatives of the various firms mentioned in the

Figure 4. When the stone shown in figure 3 was immersed in methylene iodide, color concentrations along facet junctions were noticeably absent but the facets revealed a dimpled appearance. Photo by Tony Laughter.

following entries for sharing their time to provide information. In addition, the editors thank Dr. Mary Johnson and Sam Muhlmeister of GIA Research and Dino DeGhionno, Patricia Maddison, Shane F. McClure, and Cheryl Wentzell of the GIA Gem Trade Laboratory, who provided information or helped test materials.

COLORED STONES

Arizona gem materials. The gem materials of Arizona, the host state, are always well represented at the Tucson shows. Turquoise from several mining areas, including the well-known Kingman region, was available in rough and fashioned form, as well as set in Native-American style silver jewelry. Chrysocolla chalcedony was also available. In addition to the sought-after bright greenish blue material some local dealers call "gumdrop blue," the editors saw some cabochons consisting of randomly disseminated bluish green "plumes" of chrysocolla in a near-colorless chalcedony groundmass. Azurite, another copper mineral, was being offered as drusy specimens and cabochons. We also saw some exceptional carvings that were fashioned in China from azurite mined from the famous copper-mining area at Morenci. Both rough and cut peridot from San Carlos was readily available. Some dealers were offering small chrome pyropes, sometimes referred to as "anthill garnets" because they are excavated by these insects and deposited on the mounds around their burrows.

Emeralds from Brazil. Emeralds from the Nova Era area of Minas Gerais, Brazil, were being offered by several dealers. James T. Drew, Jr., of Star Gem, reported that some relatively large stones have recently been recovered at this source. His firm had several stones over 10 ct, with the largest slightly over 20 ct. The medium-dark tone of these stones, combined with their sizes, make them very reminiscent of commercial-grade Colombian emeralds. Nova Era emeralds were also offered at a booth from the Cooperativa dos Garimpeiros de Nova Era (COOPNERA). In April 1993, this cooperative of independent miners was licensed by the state of Minas Gerais to prospect and work a total area of 27,365 hectares (67,591 acres) in the area of the Capoeirana mine at Nova Era.

Emeralds were also available from the Carnaíba mining area in Bahia State, where recently there has been a resurgence of activity. Roughly 1,000 *garimpeiros* arrived from Santa Terezinha de Goiás in late November 1993, according to Hugo Mol of FGH-Pedrabras Ltda., Belo Horizonte. The move was reportedly prompted by a slowdown in activity at the Campos Verdes mine in Santa Terezinha, due to a combination of restrictions on independent mining and difficulties caused by the great depths at which they are operating. The *garimpeiros,* who are working what are described as "new" areas at Carnaíba, timed their move so their children could transfer to public schools in Bahia at the beginning of the next school period.

When one of the editors noted a pleasing aroma emanating from the surfaces of Carnaíba rough (see, e.g., figure 5), Mr. Mol stated that it was a natural oil from the peroba tree that is indigenous to the area. This substance, which is also used locally as wood polish, is typically applied to emerald rough from Bahia. Mr. Mol noted that Opticon, which is popular at Santa Terezinha, is not presently used at Carnaíba.

We also saw phenomenal stones. These included some cat's-eye emeralds and green beryls from Santa Terezinha, which ranged from pale to dark green and

Figure 5. This 7.70-ct emerald crystal is typical of recent production from the Carnaíba mining area of Bahia State, Brazil. Such material is commonly treated with oil from a local tree. Photo by Maha DeMaggio.

Figure 6. Madagascar is the reported source of these gemstones. Back, left to right: 1.28-ct rhodolite, 1.86-ct hessonite, and 1.36-ct rhodolite; front: 0.84-ct pyrope-almandine and 2.14-ct "rainbow moonstone." Garnets courtesy of Allerton Cushman & Co.; "rainbow moonstone" courtesy of Gem Reflections of California. Photo by Maha DeMaggio.

from melee sizes up to a stone of 5.80 ct. The vendor, David Kaassamani, reported that some of these stones were of recent production, from sites known as "Mine 66" and (currently the largest producer of cat's-eye emeralds in the area) the "Vienna mine." Mr. Kaassamani also had a medium-toned 5.93-ct emerald from Santa Terezinha that exhibited a weak but fairly complete six-rayed star.

"Jurassic Park" gems and carvings. The box-office success of the film "Jurassic Park" had a definite impact on Tucson this year. Amber from both the Dominican Republic and the Baltic region was available at almost all the shows visited by the editors. In addition, it appeared that more dealers than in past years were offering "inclusion specimens." One Russian dealer offered his specimens with small, descriptive fact sheets about each of the insect types they contained. Another dealer was selling amber cabochons, both loose and mounted in earrings and pendants, that had dinosaur images carved into their bases, producing a three-dimensional effect when viewed from the top. (See figure 3, p. 200, of the Fall 1992 Gem News section for an example of this type of carving in amber.) On a related note, for the first time we saw a polishing compound developed specifically for use with amber. Named "Amber-Sheen," the product was being promoted both for use in the final polishing stage and for restoring the polish on fashioned material with worn or scratched surfaces.

Although carved gem materials are a regular fixture of the Tucson shows, the editors noted what appeared to be more materials carved in the form of dinosaurs this year, including amethyst-citrine, massive azurite, and a fossil marble from China. Carvings from this last material were labeled "fossil fossils."

Gems from Madagascar. The island nation of Madagascar, off the southeast coast of Africa, is a well-known gem source, and we saw a number of Madagascar materials offered. Tom Cushman of Allerton Cushman & Co., Sun Valley, Idaho, had emeralds from the areas of Mananjara on the east of the island and Tulear on the west. The Mananjara emeralds were predominantly medium toned and, according to Mr. Cushman, have a negative reaction when viewed through a Chelsea color filter. The Tulear emeralds are darker in tone and appear red when viewed through the Chelsea filter. Most of the emeralds seen by the editors were relatively small—under 1 ct; the largest, of very good color, was about 1.5 ct.

We also saw small quantities of Madagascar aquamarine and morganite. The aquamarines ranged from slightly greenish blue to almost pure light to medium blue; Tom Cushman reported that all were of natural color. In hue, they most resembled some of the fine Mozambique material that is sometimes called "Santa Maria Africana" in the trade. We were also shown some reportedly natural-color morganites of a deeper, purer pink than is typical of.the material coming from Brazil.

In the Summer 1991 Gem News column, we mentioned large carvings of labradorite from Madagascar. This year we saw a feldspar from Madagascar that was fashioned as small (roughly 1 ct) cabochons and offered as "rainbow moonstone" (figure 6)—a trade name typically used to describe an essentially colorless phenomenal bytownite from India that lacks the dark ilmenite inclusions seen in labradorite from other sources, such as Canada and Finland. The Madagascar material that we saw had a slightly gray body color and eye-visible dark inclusions, although these did not appear to be as heavily concentrated as in labradorite from the other sources mentioned above.

Mark H. Smith of Bangkok had 500 carats of faceted colorless phenakite in the 1- to 10-ct range, as well as two faceted stones weighing 36.34 and 171.12 ct.

Apatite from Madagascar in a slightly greenish blue to bluish green color similar to that of some tourmaline from Paraíba, Brazil, has been available at the Tucson shows for several years now. Mr. Cushman informed one of the editors (RCK) that all this material is heat treated at the mines, on large circular steel plates placed over open fires. The untreated material is described as having a rather unattractive "olive" green color.

Madagascar garnets were also being offered. The firm of Michael Couch, Ft. Wayne, Indiana, had about two dozen spessartines, ranging from under 1 ct to 7.89 ct and from brownish orange to a very pure orange. According to Tom Cushman, garnets of a predominantly red color are mined at Marlambo, in the central eastern part of the island, while hessonite comes from an area near Antsirabe in central Madagascar and pink to purple rhodolites come from a region near the central eastern coast.

Mr. Cushman provided the editors with four stones (again, see figure 6) for gemological characterization in accordance with the criteria established by C. M. Stockton and D. V. Manson ("A Proposed New Classification for Gem-Quality Garnets," *Gems & Gemology*, Winter 1985, pp. 205–218). A 0.84-ct dark orangy red square modified brilliant—R.I. 1.758; S.G. 3.87; absorption bands at 420, 435, 465, 500, 525, and 575 nm—was identified as pyrope-almandine. A 1.28-ct medium purple-pink round modified brilliant—R.I. 1.750; S.G. 3.84; absorption bands at 465, 500, 525, 565, and 610 nm—was identified as rhodolite. A 1.36-ct dark reddish purple triangular modified brilliant—R.I. 1.756; S.G. 3.87; absorption bands at 435, 465, 500, 525, 575, and 610 nm—was also identified as rhodolite. The fourth stone, a 1.86-ct medium-dark brownish orange oval cabochon—spot R.I. 1.74; S.G. 3.65; absorption bands at 440 and 500 nm—was identified as hessonite.

Also seen was an attractive 0.73-ct faceted oval ruby that, according to Mr. Cushman, was cut from rough recovered from a streambed near Antsirabe. He reported that this alluvial material is typically very small (under 1 ct) and usually cuts stones of only about 3 mm in diameter. While larger, flat hexagonal ruby prisms are found near Tulear, this material is typically opaque and unsuitable for fashioning, even as cabochons.

Myanmar gems. Rubies from the new mining area of Monghsu in Myanmar were available from many dealers at this year's show. These stones are notable for their bright, consistent color, which makes them very easy to match for use in jewelry. This material was most readily available in calibrated melee sizes and stones up to about 1 ct (figure 7), with stones in the range of 0.50 to 0.75 ct most prevalent. There were far fewer larger stones, and these were often fairly highly included; stones over 2 ct seen by the editors generally contained eye-visible inclusions.

The ready availability of this material, especially in small sizes, apparently has led to its being marketed in some of the less traditional cutting styles. Omni Gems of Los Angeles was offering calibrated Monghsu rubies in trilliant and princess cuts.

Other Myanmar gems (again, see figure 7) were more abundant than in years past. In particular, many dealers offered good selections of very fine red spinels, which were once considered scarce, especially in larger sizes. Blue sapphires were also easier to find, especially asteriated stones. (See also the note on peridot in this section.)

Figure 7. This suite is representative of some of the fine Myanmar gems available at Tucson this year. Front, left to right: 4.88-ct blue spinel, 1.87-ct pink spinel, 1.39-ct red spinel, and 1.13-ct ruby from Monghsu. Back: 13.32-ct peridot and 5.43-ct star sapphire. Courtesy of Gemstones Import, Seattle, Washington; photo by Robert Weldon.

More on obsidian. The Summer 1993 Gem News section reported on an obsidian from Mexico with striking iridescent colors. This material was available in greater quantities this year, both as rough and as fashioned gems and carvings. According to P. Damian Quinn of Talisman Trading Co., San Diego, California, his material came from this same Mexican source.

Among the more unusual carvings seen at Tucson was an intertwined "rope" of obsidian, accented by sugilite and opal (figure 8). Arthur Anderson, of Speira Gems in Ashland, Oregon, carved the intricate piece—which measures 45 mm long by 25 mm deep—from a single

Figure 8. This 45 × 25 mm "rope" was carved from a single piece of obsidian and then accented with sugilite and opal. Photo by Robert Weldon.

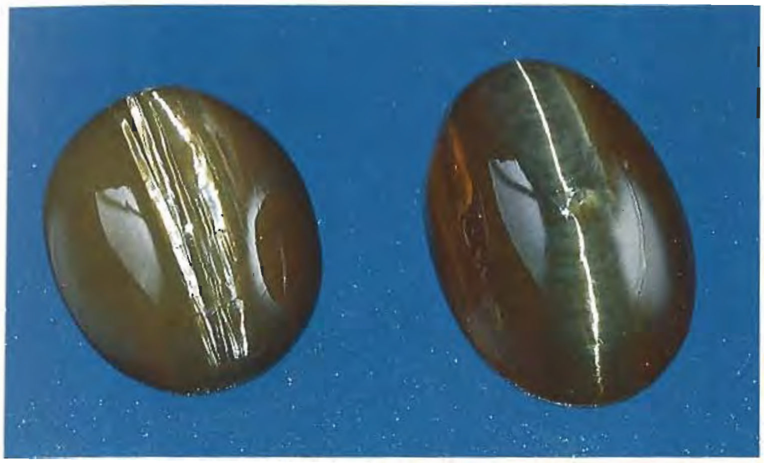


Figure 9. Before it was soaked in water for several minutes, the 1.74-ct cat's-eye opal on the right looked almost identical to the 1.40-ct untreated stone on the left. Stones courtesy of Jean-Claude Nydegger; photo by Shane F. McClure.

chunk of obsidian. He used a point carver for the actual carving, and then finished the work with a Foredom hand piece. He is currently experimenting with similar types of carvings using different, softer materials.

Cat's-eye opal from Brazil. The Fall 1990 Gem News section and the Fall 1992 Gem Trade Lab Notes reported on examples of cat's-eye opal. According to the owner of the latter stone (a 2.76-ct greenish yellow cabochon), the material originated in northern Brazil.

This year at Tucson, a considerable amount of cat's-eye opal was available from De Wal Brazil Ltda. of Teófilo Otoni, Minas Gerais. According to Jean-Claude Nydegger, his firm is involved in mining the material from the northern part of Bahia. At Tucson, they had approximately 6,000 ct of cabochons from less than 1 ct to as large as 57.6 ct, with the average about 5 ct.

The material, which sometimes contains dendritic inclusions, ranges from yellowish green to yellowish brown; it is generally greener than the Brazilian cat's-eye opal reported previously. All of it is very fibrous; material with finer fibers has proved relatively easy to cut, whereas material with relatively thick fibers has a tendency to split during fashioning. The material is also very porous. An average-size cabochon placed in water will absorb the liquid in a matter of minutes. (As an example, one stone weighed 1.74 ct when dry and 1.88 ct after it was soaked in water.) Although immersion produces a dramatic improvement in apparent transparency as well as a shift to a browner body color (figure 9), these changes are temporary: A water-soaked stone left in air will return to its original appearance in several minutes. Mr. Nydegger is experimenting with possible methods to "stabilize" the material so that it retains the more attractive appearance exhibited after soaking in water.

At Tucson, we saw another unusual specimen from Brazil, a 25.83-ct matrix opal. This had a dark grayish brown matrix and exhibited a good play-of-color. Although matrix opal from Australia is commonly seen in the trade, this is the first such example we have seen from Brazil.

Opal from Ethiopia. Ethiopia is one of the more recent East African countries to join the club of gem-producing nations. As noted in the Spring 1993 Gem News section, peridot from this country made its Tucson debut last year. Now opal from Ethiopia has entered the market. According to a report by Dr. N. R. Barot in the February 1994 issue of the *ICA Gazette*, lots of rough Ethiopian opal ranging up to several hundred grams have appeared in the Nairobi market since mid-1993. These lots include some complete nodules ranging from 20 mm/15 grams to 55 mm/300 grams; 70%–90% of each is opal. Approximately 65% of this is opaque common opal, 5%–7% displays play-of-color (see, e.g., figure 10), and the remainder is transparent gemmy material without play-of-color.

Dr. Barot showed the editors some representative samples of Ethiopian opal at Tucson (figure 11). The more transparent material occurs in pale yellow, orange, and brown with either weak or no play-of-color. This material is visually similar to Mexican fire opal. More unusual is a dark brown to reddish brown body color with strong play-of-color in a mosaic pattern of rectangu-

Figure 10. This 63.4-gram nodule of dark brown opal with strong play-of-color is from Ethiopia. Photo courtesy of N. R. Barot.

Figure 11. These specimens (approximately 1.5–3 ct) are representative of the range of gem-quality opals coming from a source in Ethiopia. Photo by Robert Weldon.

lar to rounded patches. This material was more reminiscent of fire agate than any opal the editors had previously seen.

Miscellaneous notes on peridot. The San Carlos Apache Reservation, just east of Globe, Arizona, was the source of most of the peridot seen this year. Good-quality stones (i.e., with no secondary brown hue) in sizes up to about 4–5 ct were available from several dealers. Chinese peridot was also available, both as calibrated melee and in stones of a few carats.

Rudi Cullmann of the firm Karl August Cullman, Idar-Oberstein, Germany, had 5,000 grams of rough peridot from Ethiopia and stated that a regular supply of Ethiopian rough has been available this past year in Nairobi; this was corroborated by Dr. N. R. Barot.

Of particular interest was the number of fairly large (approximately 15–25 ct) peridots reportedly of Myanmar origin being offered, more than the editors had seen at any show in the past. Most of this material was a lighter, more yellowish green than what we typically associate with large Myanmar peridots. One dealer volunteered that at least some of this material may have been cut from large Chinese rough that was being passed off as from Myanmar. This was independently confirmed by another dealer well-versed in the gem materials being recovered and cut in China. Apparently mining at depth in China is producing larger stones of a slightly darker color than what has been found in the past. This material was described as being visually identical to material from San Carlos and "regularly" available in sizes that would cut 15- to 20-ct stones. We did not, however, see any stones over 10 ct among those claimed to be from China.

A small amount of the typically light-toned peridot from Norway was being offered. Rough and Ready Gems of Denver, Colorado, had a selection of about 50 stones in the 0.5- to1.5-ct range, plus a few around 2.25 ct. Finally, Robert Haag Meteorites was again offering a few very small peridots that were faceted from material taken from the Esquel pallasitic meteorite (see J. Sinkankas et al., "Peridot as an Interplanetary Gem," *Gems & Gemology,* Spring 1992, pp. 43-51).

Russian uvarovite garnet . . . With Russia's recent opening to world markets, it has become an increasingly important source of gem materials, both natural and synthetic. At Tucson this year, many dealers were offering Russian goods.

One of the more noteworthy materials was drusy uvarovite garnet on a chromite matrix. We saw numerous irregular matrix specimens that had uvarovite crystals ranging from microscopic size to no more than 4 mm in diameter (one dealer even advertised uvarovite on a billboard along the freeway). A few dealers, such as Bill Heher of Trumbull, Connecticut, had attractive matched tablets for use in earrings. Another dealer, Maxam Magnata, also showed the material set in jewelry (see, e.g., figure 12).

Figure 12. This 14k gold pendant is set with drusy uvarovite garnet on a chromite matrix, accented by a colorless zircon. The pendant, designed and fabricated by Laura Tremaine of Maxam Magnata, measures 27 mm wide × 42 mm long; photo by Robert Weldon.

Figure 13. These stones are representative of some of the gem materials currently being mined in the Indian state of Orissa: (back, left to right) 1.22-ct ruby, 1.08-ct iolite, 3.62-ct purple sapphire; (front) 0.59- and 1.38-ct rhodolites. Iolite courtesy of Amar J. Jain Fine Gems, New York; garnets courtesy of Orissa Gems, Jaipur; ruby and purple sapphire courtesy of Gem Reflections of California. Photo by Maha DeMaggio.

Mr. Magnata and Abigail Harris, of Fairfax, California, provided the following additional information. One of the least known of the green garnets, uvarovite is quite new to the West as a gem material. Its matrix of metallic chromite provides a strong black contrast to the garnet's saturated green color. Just as the alexandrite variety of chrysoberyl was named after Czar Alexander, uvarovite was named after another notable Russian, the mineralogist Count Uvarov.

The Russian uvarovite is mined in the Ural Mountains, near the town of Ekaterinburg (named after Katherine the Great). Reflecting the radical changes that have taken place in the 20th century, the town was renamed Sverdlovsk in 1917, then changed back to Ekatirinburg in 1990. The mine has steadily produced material since the mid-1800s, albeit in limited quantities, but the outlook for future availability appears good.

For most gem materials, larger generally equates with more desirable, but Russian uvarovite does not occur as individual crystals large enough for faceting. Over the past few years, however, there has been a sustained interest in drusy gem materials (see, e.g., the Tucson Report in the Spring 1991 Gem News). This interest comes at a time when the major source of Russian uvarovite has become available to the international market.

Specimens composed of relatively small, closely packed individual crystals usually have the best overall appearance. With magnification, the surface looks as if it has been pavé set with minute crystals. In the best specimens, the entire surface that would be exposed when set in jewelry is totally and uniformly covered with uvarovite crystals—with no areas of exposed matrix. In addition, the smaller the individual uvarovite crystals, the more durable the piece, that is, the less likely the crystals are to separate from the matrix.

. . . and other Russian materials. Small amounts of a drusy pale brown-orange garnet in matrix that was labeled "Russian peach garnet" were also on hand at Tucson; similar matrix specimens with garnets of a slightly darker tone were labeled "hessonite garnet" by another vendor of Russian goods.

We also saw a number of demantoid garnets from Russia, all reportedly "new production." Most of the stones were small—no larger than 1.5–2 ct—and light to medium-light in tone. Because of the light body colors, the strong dispersion (0.057) of this gem was readily apparent even in the smaller (2–3 mm) sizes. Chrome diopside was available from several dealers, both rough and fashioned. Gem Reflections of California, from San Anselmo, had a selection that was fairly typical of what was available: faceted stones ranging from 4.2 mm rounds to gems as large as 26 ct, and 4-mm round cabochons. The smaller stones tend to show the color to best advantage, as larger stones can be overly dark.

Several ornamental gems of Russian origin were being offered. Bartky Minerals of Livingstone, New Jersey, for example, displayed vases and small jewelry boxes assembled from materials including rhodonite, charoite, nephrite, and jasper. We also saw some ammonite specimens from a locality identified only as "Mihaelovich near Moscow," as well as purple sapphire in matrix from the Karelia area.

Rubies and other gems from Orissa. The firm of Orissa Gems, with headquarters in Jaipur, India, was marketing a number of gem materials from the state of Orissa. These included bright brownish orange hessonite garnets (3–5 ct) and rhodolite garnets of a very purple hue (3–15 ct). Also being offered were some slightly greenish yellow nonphenomenal chrysoberyls, near-colorless faceted sillimanites, dark red to purple zircons, greenish blue to violetish blue sapphires (which had a fair number of inclusions), and iolites.

Amar J. Jain Fine Gems of New York also had a number of good-quality iolites, in a wide range of calibrated sizes and cutting styles (including cabochons). Mr. Jain told one of the editors (RCK) that Orissa is the source of the vast majority of iolite coming from India today; little is being produced from the former major sources in the state of Madras.

Gem Reflections of California, in San Anselmo, was offering a selection of rubies and pink to purple sapphires from Orissa. According to firm representative Michael Randall, Orissa ruby rough only rarely produces cut gems

Figure 14. "Bleeding" of diffused color can clearly be seen in this 0.15-ct sapphire cabochon. The stone had been "salted" into a parcel of natural sapphires from Kanchanaburi and was subsequently repolished. Courtesy of Mark H. Smith, Bangkok; photomicrograph by John I. Koivula, magnified 10×.

over 1 ct, but some of the pink to purple rough can be cut to gems as large as 8 ct. Mr. Randall also noted that he saw considerably more rough when he visited the locality in November of 1993 than during his August visit only a few months earlier. Typically, the Orissa rubies contain numerous small, colorless zircon inclusions. A suite of gemstones from Orissa is shown in figure 13.

Miscellaneous notes on tourmaline. Particularly scarce at Tucson this year were the saturated-color cuprian tourmalines from the state of Paraíba, Brazil. Most of the stones in the small amounts being offered were under 1 ct. Some attention seems to have shifted to attractive greenish blue to bluish green tourmalines from Bahia, Brazil. While this material occurs in hues similar to those of some of the Paraíba material, the color is significantly less saturated. Also from Brazil—specifically, the Governador Valadares area of Minas Gerais—were some brownish pink to pinkish brown tourmalines that were being marketed as "salmon" and "cinnamon" tourmalines by the firm Braz-G-Can of Rio de Janeiro. According to firm representative Fernando Otavio da Silveira, some of the more atypical colors were produced by cutting the stones from the central portions of watermelon tourmaline crystals, incorporating various amounts of the green "rind" into the edges of the faceted stones.

Bright green "chrome" tourmaline from Tanzania, in tones ranging from medium dark to very dark, appeared to be more available than in recent years. Affro Gems of New York offered half-moon cuts of this tourmaline matched with light yellow scapolite, also from Tanzania. Amoroko International, based in Los Angeles, had about 50 bright orangy yellow tourmalines from Kenya, in the 1- to 3-ct range. They reported, however, that this material was mined several years ago.

Tourmalines from the Nuristan region of Afghanistan were again available. This year, however, there appeared to be more lighter-toned material, including pink as well as bicolored (pink-and-blue and pink-and-green) crystals. Afghan-Basar-Gems, of Idar-Oberstein and Los Angeles, was also offering about 700 grams of a very saturated, medium-toned greenish blue tourmaline.

ENHANCEMENTS

Update on diffusion treatment. Diffusion-treated sapphires were less prominent this year than in any of the past three years. None of the editors came across any vendor specializing in or prominently displaying this type of material. One exhibitor, who asked to remain anonymous, stated that he was experimenting with the production of red diffusion-treated stones and showed one of the editors some material that was similar in outward appearance to that described in the article "Update on Diffusion-Treated Corundum: Red and Other Colors" (by McClure et al.) in the Spring 1993 *Gems & Gemology.*

According to Mark H. Smith of Bangkok, diffusion-treated sapphires regularly appear on the market in that city, salted into parcels of stones from Kanchanaburi. Mr. Smith estimated that perhaps 1%–2% of the stones he sees in parcels from this source have been diffusion treated. He showed the editors about a dozen small cabochons from such a parcel, which he had subsequently repolished. The characteristic "bleeding" of diffused color can be clearly seen in surface-reaching pits and fractures (figure 14).

One new diffusion-treatment product was being offered by the firm HRI International Corp. of Middletown, New York. These small (about 0.60–0.75 ct), pale blue synthetic sapphires had been diffusion treated with a cobalt compound; thus, the color was more reminiscent of blue synthetic spinel or the rare natural "cobalt" blue spinel than of natural or synthetic sapphire (figure 15). Examination with a desk-model spectroscope revealed three diffused bands centered at about 545, 580, and 620 nm. The stones were inert to long-

Figure 15. The cabochons on the far left (0.67 ct) and far right (0.71 ct) are flame-fusion synthetic sapphires, typical of material that was cobalt-diffused to produce stones like the 0.66-ct (left) and 0.69-ct (right) examples in the center. Photo by Maha DeMaggio.

Figure 16. This 9.76-ct beryl triplet cameo (approximately 18.23 × 14.01 mm) is one of the more unusual assembled stones seen at Tucson this year. Courtesy of Hermann Grimm; photo by Bart Curren, courtesy of ICA.

wave U.V. radiation and fluoresced a weak, chalky bluish green to short-wave U.V. They appeared a saturated dark red through the Chelsea color filter. All these features are consistent with those reported for the cobalt-doped blue diffusion-treated natural sapphire preforms described on page 123 of the article "The Identification of Blue Diffusion-Treated Sapphires" (by R. E. Kane et al.) in the Summer 1990 *Gems & Gemology*. Magnification revealed gas bubbles and/or curved color banding in each of the four diffusion-treated stones examined, which confirmed that the starting material was a melt-grown synthetic.

The editors were also shown cobalt-diffused synthetic sapphires for which the starting material was reportedly light pink. According to Professor Vladimir S. Balitsky, who serves as vice-president and gemologist for HRI, he produced these stones for use as a tanzanite simulant, as they exhibit a "cobalt" blue color in fluorescent light and a violet to purple color under incandescent light.

SYNTHETICS AND SIMULANTS

Beryl triplets. Assembled stones are still widely used as emerald substitutes, because synthetic emeralds are produced by two of the more expensive methods of gemstone synthesis—flux and hydrothermal growth—and because neither flame-fusion synthetic corundum nor synthetic spinel can be manufactured in a realistic "emerald" color. Although the synthetic spinel triplet—two sections of colorless synthetic spinel joined by a green cement—is the type of assemblage most often encountered as an emerald simulant, we occasionally see quartz triplets and beryl triplets as well. The last can present a problem to the careless gemologist, because the refractive indices of this material (typically near-colorless beryl or very pale aquamarine) are very close to those of emerald, another beryl variety.

This year at Tucson, the firm Hermann Grimm of Idar-Oberstein, Germany, was offering several dozen beryl triplets in a very convincing "emerald" color, using beryl that was suitably included to add to the effectiveness of the pieces. While most of these were faceted in styles typically used for emerald, two were carved as cameos (see, e.g., figure 16). As noted in the article "Emeralds and Green Beryls of Upper Egypt" (by Jennings et al.) in the Summer 1993 *Gems & Gemology*, the carving of emeralds for use as ring stones dates back to the days of ancient Rome (see, e.g., figure 3 of that article).

This firm also had several dozen beryl triplets with a saturated, slightly greenish blue color for use as substitutes for Paraíba tourmaline.

Chatham flux-grown pink synthetic sapphires. At the 1994 Tucson show, Tom Chatham introduced his firm's new pink synthetic sapphires (figure 17). This flux-grown material shows a consistently saturated pink hue that ranges from light to medium light in tone. The lower chromium content (0.06 to 0.2 wt.% Cr_2O_3, compared to

Figure 17. This 884-ct crystal and three faceted stones (the largest weighs 13.35 ct) are representative of the new flux-grown pink synthetic sapphires being produced by Chatham Created Gems, San Francisco. Photo by Robert Weldon.

Figure 18. This 7.37-ct crystal and 1.89-ct faceted synthetic ruby are typical of the new "Douros" product from Piraeus, Greece. Courtesy of Melinda Adducci, Plymouth, Michigan; photo by Robert Weldon.

0.5 to 2.0 wt.% Cr_2O_3 for ruby) is responsible for the pink color. We examined in detail five faceted stones ranging from 1.81 to 13.35 ct and found that the gemological characteristics are generally consistent with those previously reported for Chatham flux-grown synthetic ruby (see, e.g., Gem Trade Lab Notes, *Gems & Gemology,* Fall 1981, pp. 163–165). One exception is that the pink material's slightly orangy red fluorescence to short-wave U.V. radiation is of roughly the same intensity as its red fluorescence to long-wave U.V., whereas Chatham synthetic rubies generally fluoresce a weaker red to short-wave than to long-wave U.V. radiation. The material is being marketed in one quality, which the firm refers to as "clean."

We also examined a large (884 ct) crystal of this new synthetic sapphire (again, see figure 17), which shows the same morphology we have observed on large Chatham synthetic ruby crystals. It also contains elongated flux inclusions that are parallel to the striations observed on the crystal. These inclusions show a green fluorescence to short-wave U.V. radiation only, which may appear yellow if combined with the red emission from the sapphire itself.

Douros synthetic rubies. Another flux-grown synthetic to enter the gem trade recently is a product of Created Gems of Piraeus, Greece, that is being referred to colloquially as the "Douros" synthetic ruby after the family name of the brothers who developed it (see the relevant abstract from the 24th International Gemmological Conference, published in the Winter 1993 Gem News). One of these gentlemen, John Douros, was in Tucson this year to learn first-hand about the market for laboratory-grown gem materials and to show samples of his product (see, e.g., figure 18). A detailed report on this synthetic ruby will be published in an upcoming issue of *Gems & Gemology.*

More on Russian synthetics and simulants. Gem News has had several entries in recent years about synthetics and simulants from Russia that were being marketed at the Tucson shows. This year proved to be no exception.

Figure 19. This 8.29-ct synthetic malachite and the 3.95-ct synthetic turquoise were produced in Russia. Photo by Maha DeMaggio.

In fact, Rafi Dagan, president of New York–based Yael Importers, reported that his firm has begun marketing a number of synthetic products being provided by Pinky Trading Company of Bangkok. Pinky Trading, in turn, has a joint-venture—"Tairus"—with the Siberian branch of the Russian Academy of Sciences for the production and marketing of materials produced in Novosibirsk. Walter Barshai, president of Pinky Trading, subsequently confirmed that he had signed an agreement with Yael giving that firm exclusive distribution rights for materials produced by Tairus.

Among the faceted materials on display at Yael's booth were hydrothermal synthetic emeralds; synthetic rubies produced by three methods--hydrothermal, "horizontal crystallization" (a floating-zone technique), and a modified flame-fusion process; flux-grown red and blue synthetic spinel; flame-fusion synthetic sapphire; and Czochralski- pulled synthetic alexandrite.

Flux-grown synthetic emerald from Russia was again being marketed in Tucson by the Crystural firm (see the entry in the Summer 1993 Gem News). Russian hydrothermal synthetic quartzes seen include amethyst, citrine, a medium-dark blue, and a dark green, the latter two without natural counterpart (see, e.g., Winter 1992 Gem Trade Lab Notes, p. 265, for information on the green). HRI International Corp. of Middletown, New York, had a new, Russian-grown, pink synthetic quartz. A report on this material will appear in an upcoming Gem News section. This firm also had a small selection of Russian synthetic turquoise and synthetic malachite (figure 19).

Cubic zirconia from Russia was available in many colors, including a yellow-green that would make an effective simulant for peridot. A 20.70-ct emerald cut purchased for examination was inert to long-wave U.V. radiation, fluoresced a weak chalky yellowish green to short-wave U.V., and appeared greenish gray through the Chelsea color filter. Examination with a desk-model spectroscope revealed lines of varying intensity at 484, 514, 528, 535, 537, 541, 569, 572, 575, 577, 580, 582, 587, 591, 595, and 600 nm.

Gems & Gemology
CHALLENGE

As technological advances have joined political developments in removing communication barriers all over the world, *Gems & Gemology* has brought together gemologists and researchers from Russia, China, Finland, Sri Lanka, and South Africa, as well as the United States. We challenged them to bring you the best information on topics as wide ranging as antique jewelry, treated synthetic diamonds, and opal mining in Queensland. Now once again, in conjunction with GIA's continuing education program, we challenge *you.*

Based on information from the four 1993 issues of *Gems & Gemology,* the following 25 questions call on you to demonstrate your knowledge and understanding of these developments in the field. Refer to the feature articles and Notes and New Techniques in these issues to find the *single best answer* for each question, then mark your letter choice on the response card provided in this issue (photocopies or facsimiles will not be accepted). Mail the card to us by Friday, August 19, 1994. Be sure to include your name and address—all entries will be acknowledged with a letter and an answer key.

Score 75% or better and you will receive a GIA Continuing Education Certificate in recognition of your achievement. Earn a perfect score of 100% and your name will also be featured in the Fall 1994 issue of *Gems & Gemology.*

Gemological Institute of America

This Letter of Completion is presented to

Robert T. Jeweler

for participation in

GIA Gems & Gemology Challenge

Note: Questions are taken from only the four 1993 issues. Choose the single best answer for each question.

1. A formerly diagnostic feature of synthetic diamonds eliminated by the new Russian synthetic diamonds is
   - A. the presence of magnetic metallic inclusions.
   - B. the absence of long-wave U.V. luminescence.
   - C. an octagonal pattern of color zoning.
   - D. differences in the optical absorption spectra.

2. One of the most valuable and consistent tests for detecting diffusion treatment is
   - A. magnification.
   - B. specific gravity.
   - C. absorption spectra.
   - D. Chelsea color filter.

3. The oldest known source of emerald is
   - A. India.
   - B. Egypt.
   - C. Persia.
   - D. Russia.

4. Blue coloration in De Beers experimental gem-quality synthetic diamonds is attributed to the presence of
   - A. boron.
   - B. cobalt
   - C. nitrogen.
   - D. nickel.

5. The most common impurity in sapphire is probably
   - A. iron.
   - B. titanium.
   - C. chromium.
   - D. magnesium.

6. Heat treatment in blue sapphires from Rock Creek, Montana, can be identified by the presence of
   - A. deep blue plate-like fractures.
   - B. a saturated blue color.
   - C. hercynite precipitation.
   - D. both a and c.

7. In this century, significant quantities of Queensland boulder opal did not appear on the gem market until the
   - A. 1930s.
   - B. 1940s.
   - C. 1960s.
   - D. 1970s.

8. Compared to the R.I. values for natural red spinel, the R.I.'s of the red flux-grown synthetic spinels from Russia are
   - A. slightly higher than the range for natural spinels.
   - B. very much higher.

C. consistently lower.
D. within the same range.

9. A style of Edwardian jewelry characterized by a light and lacy look that was both majestic and intricate in its use of diamonds and pearls is known as
A. Art Nouveau.
B. Belle Époque.
C. the garland style.
D. the Imperial style.

10. A feature of the new Russian synthetic gem-quality diamonds that distinguishes them from natural and other synthetic gem-quality yellow diamonds is
A. blue fluorescence to long-wave U.V. radiation.
B. nickel-related sharp absorption bands in the optical spectrum.
C. graining patterns related to the arrangements of internal growth sectors.
D. characteristic metallic inclusions.

11. Experiments in the heat treatment of sapphires from Rock Creek, Montana, indicate that in most of the material tested
A. the color could not be improved.
B. the color was improved, but the finished product had poor clarity.
C. both color and clarity were better than the natural material.
D. neither color nor clarity could be improved.

12. In the case of red flux-grown synthetic spinel from Russia, the only diagnostic gemological properties are
A. flux or metallic inclusions.
B. organ pipe luminescence lines.
C. red ultraviolet luminescence.
D. refractive index and specific gravity.

13. When subjected to treatment by irradiation and annealing, yellow-to-brown type Ib diamonds, whether natural or synthetic, will turn
A. blue.
B. green.
C. pink to red.
D. green to blue.

14. The color of diffusion-treated sapphires is generally stable as long as one avoids
A. repolishing.
B. steam cleaning.
C. ultrasonic cleaning.
D. boiling in a detergent solution.

15. Edwardian jewelry is chiefly characterized by the extensive use of
A. Art Nouveau styling.
B. diamonds and pearls.
C. gold and silver settings.
D. colored stones such as sapphire, ruby, and emerald.

16. Before it is sold, green topaz should always be tested for
A. color stability.
B. fluorescence.
C. chemical stability.
D. residual radioactivity.

17. The most useful properties for identifying near-colorless GE synthetic diamonds include short-wave U.V. fluorescence, X-ray luminescence, and
A. graining.
B. metallic inclusions.
C. electrical conductivity.
D. the presence of anomalous birefringence.

18. Which of the following terms is used to describe gem-quality opal that, when fashioned, retains some portion of the ironstone in which it occurs?
A. boulder opal
B. ironstone matrix
C. Queensland opal
D. sandstone boulder opal

19. In terms of the total value of minerals exported from Sri Lanka, gems represent
A. 57%.
B. 65%.
C. 84%.
D. 91%.

20. The split-sphere apparatus for producing gem-quality synthetic diamonds is known to be used in
A. South Africa.
B. Japan.
C. the United States.
D. Russia.

21. Of the several tons of grossular garnet that have been recovered from Cocoktau (near Altay, China) since 1980, the percentage that is gem quality is approximately
A. 10%.
B. 20%.
C. 40%.
D. 50%.

22. Compared to their flux-grown synthetic counterparts, red and blue natural spinels both contain significantly more
A. chromium.
B. zinc.
C. nickel.
D. titanium.

23. All of the Egyptian emeralds examined with magnification were found to contain
A. unhealed fractures stained by a yellowish brown substance.
B. partially healed fractures composed of two-phase inclusions.
C. phlogopite incisions.
D. ubiquitous oxidized amphibole "stalks."

24. Before major opal deposits were discovered in Australia in the 1870s, the principal source of opal had been in what is now known as
A. Egypt.
B. Russia.
C. New Zealand.
D. Czechoslovakia.

25. Most gem beryl from Luumäki, Finland is
A. pale blue to pale green.
B. medium green.
C. bright golden yellow.
D. pale yellow to yellowish green.

BOOK Reviews

SUSAN B. JOHNSON AND JANA E. MIYAHIRA, EDITORS

GEMSTONE AND CHEMICALS: HOW TO CREATE COLOR AND INCLUSIONS

By George W. Fischer, Ph.D., 74 pp., illus., publ. by the author, Shelton, WA, 1991. US$24.00

The bulk of this book is devoted to 35 processes, many with variants, for coloring porous cabochon materials with inorganic substances, some by means of precipitation reactions and some by heating. Included are some well-known "oldies," such as the honey-acid process.

There are many good aspects and some very bad ones to this book. The principal bad one first: While the author gives suitable precautionary warnings and disclaimers about the chemicals he recommends using, the same is not true about the end products. Some of his colored cabochons contain soluble salts of nickel, chromium, cobalt, and so on, which could be dissolved by perspiration to irritate the skin. Don't even think about what would happen if a child were to put one of them in his or her mouth! Anyone who does not know enough chemistry to distinguish the safe from the unsafe among the many processes described by Dr. Fischer should not consider performing any of them.

Yet there are many interesting features in this book. It is well written (except for the occasional awkwardness in phrasing, as in the title), is nicely reproduced from a cleanly typed original (spiral bound with plastic covers), and is illustrated by 16 full-page color plates.

The book, however, contains additional omissions and inconsistencies. Dr. Fischer's knowledge of chemistry appears to be minimal. He gives elaborate details on how to mix hydrochloric acid with water, which needs few precautions. Yet he deals with the very important (both in terms of personal safety and environmental concerns) issue of how to dispose of concentrated sulfuric acid by saying merely to "discard" it.

For him, apparently there are few certainties in even the most basic mineralogy: "Granite is said to be composed of. . . ." Although he apologizes, he also uses improper locality agate names, such as *moabite* and *panautchite.* And he claims that the colors he produces are "natural."

The final and most interesting section contains several ways of forming dendritic copper and tin inclusions in porous agates, which produces very attractive "moss" and "plume" effects. Yet here, too, the soluble salts used are not removed.

Overall, this is an interesting book. In this reviewer's opinion, however, it should not be used by anyone who does not have adequate knowledge of chemistry to evaluate the processes described.

KURT NASSAU
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THE PROPERTIES OF NATURAL AND SYNTHETIC DIAMOND

*Edited by John E. Field, 710 pp., illus., publ. by Academic Press, London, England, 1992, US$195.00**

This imposing textbook is the much-awaited revision of *The Properties of Diamond*, published in 1979 by the same editor (itself the successor of a 1965 book edited by R. Berman). Written at a technical level, it reviews the current knowledge and understanding of diamond's physical properties, growth, and technological applications. The contributing authors are all experts in their respective fields. Although the book contains few references to gem diamonds, it is a fascinating compilation that includes extensive bibliographic references, and is particularly useful to the research gemologist. Also, this new version is overall more "user friendly" and easier to read than the previous one.

Certainly, interest in diamond as a material has increased considerably since 1979. New methods for the low-pressure synthesis of diamond have already found a number of industrial applications. High-pressure synthesis techniques have also received considerable attention, especially since Sumitomo made its large single-crystal synthetic diamonds commercially available in 1985. This book generally does an excellent job of reporting both old and new knowledge in a single source.

The book has four main sections: Solid State, Geology and Growth, Mechanical, and Industrial. The first section includes chapters on recent advances in theory, absorption and luminescence spectroscopy, nuclear probes (100 pages!), surface properties, diffraction and imaging, aggregation of nitrogen, thermal conductivity, and ion implantation. The geology-and-growth section has chapters on diamond geology, growth of synthetic diamond, and synthesis of diamond from the vapor phase (the only truly new chapter in the book). The mechanical section discusses strength, fracture and erosion properties, indentation hardness, plasticity and creep, friction, and wear and polishing. The industrial section reports on high-technology applications of diamond, as well as on applications of diamond grits and components. The book ends with various property tables.

The change in title, emphasizing the differences between natural and synthetic diamonds, is certainly welcome by gemologists. Particularly recommended for gemologists is the

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

chapter on absorption and luminescence spectroscopy by C. D. Clark, A. T. Collins, and G. S. Woods (the two latter authors occasionally publish in gemological journals), which contains details useful for the separation both of natural from synthetic diamonds and natural from treated-color diamonds. A. R. Lang, M. Moore, and J. C. Walmsley's chapter on diffraction and imaging contains a wealth of information on microscopic and macroscopic growth features and defects of natural and synthetic diamonds; these are revealed by techniques not generally available to study gems. Diamond geologist extraordinaire Jeff Harris presents new details on the age of diamonds and their formation, and also some data previously presented in the "inclusions in diamonds" chapter, which no longer exists. Gemologists interested in synthetic diamonds grown at high pressure will find the chapter by R. C. Burns and G. J. Davies most informative, with a welcome section on the separation of natural from synthetic crystals. Y. Sato and M. Kamo provide a useful review of the relatively new synthesis of diamond from the vapor phase (also known as CVD diamond, or diamond thin films). Finally, M. Seal provides a short but eye-opening chapter on industrial applications for large gem-quality synthetic diamond crystals.

Given the stated purpose of this book, there are really few criticisms. The fact that the present work is designed to supplement, rather than replace, previous work is sometimes detrimental to clarity. For example, table 18.11, which purportedly lists bands observed in diamonds, does not list such common ones as the N2 and N3 (responsible for the "Cape lines") and the GR (responsible for green color in many instances), since these features were discussed in G. J. Davies' 1977 work. Not only is the convenience of a single reference lost, but Davies' 1977 paper is hard to come by for most gemologists, and even for some scientists.

In conclusion, this work is an authoritative resource on the properties of natural and synthetic diamonds. Although many of the chapters are very technical, with considerable scientific jargon, those of our readers who are curious about the scientific aspects of diamond will find this book a "must have," well worth its hefty price. John Field did a truly remarkable job of condensing and organizing an extremely large body of knowledge.

EMMANUEL FRITSCH
Manager, GIA Research
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OTHER BOOKS RECEIVED

Mineral Reference Manual, *by Ernest H. Nickel and Monte C. Nichols, 250 pp., illus., publ. by Van Nostrand Reinhold, New York, 1991. US$18.95.** Since 1971, when the first edition of Michael Fleischer's *Glossary of Mineral Species* appeared (it is now in its sixth, 1991, edition, with J. A. Mandarino as co-author), the gemological and mineralogical communities have depended on the *Glossary* as the gospel on mineral nomenclature and chemical composition. Now, there is another excellent entry into the field, Nickel and Nichols' *Manual.*

Both books have an alphabetical listing of mineral names, along with chemical formula, crystal system, and color for each of the minerals. Each contains about the same small number of selected well-known chemical varieties (e.g., amazonite, but not rhodolite) and recently discredited minerals. The book under review (the *Manual*) contains up to three references (first description, mineral description, and crystal structure) for each entry compared to a single reference in the *Glossary.* The *Manual* gives some additional physical properties, such as hardness, luster, and density. In addition, it gives the type locality and the "status ruling" of the International Mineralogical Association.

Both books are authored by experts in the field of mineralogical (but not gemological) nomenclature. Both books are about the same size and (very reasonable) price. The serious gemologist will eventually realize that both are essential references for a good library.

A. A. LEVINSON
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Calgary, Alberta, Canada

A Special Report from JPR on the Bold Retro 1940s Jewelry, *edited by Nina Woolford, introduction by Lael Hagan, 117 pp., illus., publ. by JPR, Nina Woolford, and Gail Levine, Rockville, VA, 1992, US$35.00.* This informative work incorporates worthwhile information in a deceptively modest-looking paperback. Lael Hagan's short, comprehensive introduction notes the origin of this flamboyant style of jewelry and how certain stylistic concepts can identify a piece as being from the Retro era. The introduction also contains brief but invaluable biographies of obscure as well as well-known designers who were influential during this period.

Although the narrative is a bit wordy for my taste (e.g., "Four hollow, open plaques designed as two puffed yellow gold squares atop each other topped and bottomed with two similar squares beside each other facing out"), it does include valuable data—description of the item, auction house through which it sold, pre-auction estimate, actual sale price, and buyer (dealer, private individual, etc.). Also noted are signs of wear, damage, obvious repair to a piece, metal type and karat content, weight of the piece, size (if applicable), and description of major and accent stones.

The report is plagued with spelling and punctuation errors, but these are minor irritations considering the amount of work involved in compiling so much information.

JO ELLEN COLE
Richard T. Liddicoat Library
and Information Center

GEMOLOGICAL ABSTRACTS

C. W. FRYER, EDITOR

COLORED STONES AND ORGANIC MATERIALS

Check-list for rare gemstones: Vlasovite. W. Wight, *Canadian Gemmologist,* Vol. 14, No. 4, 1993, pp. 110–113.

Vlasovite, a sodium zirconium silicate with a Mohs scale hardness of 6, is a very rare collectors' species. Facetable material comes from the Kipawa region of Quebec. Susan Robinson's pencil drawing shows a specimen collected in 1987 by staff of the Canadian Museum of Nature, as well as their 1.43-ct stone faceted by Art Grant. The checklist gives all the information that a gemologist needs to make an identification, including the pertinent properties of gem minerals that might be confused with vlasovite. The section ends with a list of references for additional research. *Michael Gray*

Foitite, $[Fe^{2+}_2(Al,Fe^{3+})]Al_6Si_6O_{18}(Bo_3)_3(OH)_4$, a new alkali-deficient tourmaline: Description and crystal structure. D. J. MacDonald, F. C. Hawthorne, and J. D. Grice, *American Mineralogist,* Vol. 78, No. 11/12, pp. 1299-1303.

Tourmalines are among the most important of colored gemstones. Because of a wide range of compositional variability, this mineral group consists of a number of end-member species, including feruvite, liddicoatite, and uvite. The gemological properties are sufficiently similar, and the colors sufficiently varied, that most gem tourmalines are often not gemologically identified by mineral species.

This article reports on a recently discovered tourmaline end-member. Foitite was found in the mineral collection of the Department of Geology, Dalhousie University, Halifax, Nova Scotia. The label on the material indicated that it came from an unspecified locality in southern California (presumably from one of the many granitic pegmatites).

Only two small foitite crystals are currently known from the university's collection. Foitite is bluish black, has indices of refraction of $\omega = 1.664$ and $\varepsilon = 1.642$, and a measured density of 3.17 g/cm^3. Chemical analysis reveals that it is an iron-aluminum tourmaline with a crystal-structure site that is vacant due to the lack of an alkali component. The authors describe the crystal structure of this new tourmaline, and then discuss the relationship between this and other tourmaline species. Foitite is similar to schorl, which is also an iron-aluminum tourmaline. However, schorl contains sodium, while foitite lacks an alkali component. *JES*

This section is designed to provide as complete a record as practical of the recent literature on gems and gemology. Articles are selected for abstracting solely at the discretion of the section editor and his reviewers, and space limitations may require that we include only those articles that we feel will be of greatest interest to our readership.

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

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

FM-TGMS-MSA Symposium on Garnets. *Mineralogical Record,* Vol. 24, No. 1, 1993, pp. 61–68.

The 1993 Tucson Mineralogical Symposium on garnet was sponsored by the Friends of Mineralogy, the Tucson Gem and Mineral Society, and the Mineralogical Society of America. The symposium was held in conjunction with the February 1993 Tucson Gem and Mineral Show. The *Mineralogical Record* published a compilation of 11 abstracts authored by the presenters. The topics and authors include: "Nomenclature and Classification of Gem Garnets," J. Shigley and D. V. Manson; "Crystal Structures, Chemistry, and Properties of Garnets," P. Ribbe and S. Eriksson; "The Causes of Color in Garnets," E. Fritsch and G. Rossman; "Inclusions in Garnets," J. Koivula; "Geologic Occurrence of Minerals in the Garnet Group," P. Modreski; "Chemical and Physical Properties of Vanadium- Chromium- and Iron-Bearing Gem Grossular Garnets," W. Simmons, A. Falster, K. Webber, and S. Hansen; "Garnets in Architectural Paints—A Historical Perspective," L. Solebello; "Garnets in the Gem-Bearing Pegmatite Dikes of San Diego County, California," E. Foord and W. Kleck; "Garnets of Magnet Cove, Arkansas," J. Howard; "A New Garnet Locality in Connecticut," R. Behnke, F. Schuster and B. Jarnot; and "The McBride Property," J. Van Velthuizen and W. Wight. Fourteen crystal diagrams, four photographs, a table, and a graph accompany the abstracts. *LBL*

DIAMONDS

Argyle diamonds. *Swiss Watch & Jewelry Journal Export* 5/93, October/November 1993, pp. 761, 762.

This brief article features information on the Argyle diamond mine in Kimberley, Northwest Australia, including a summary of the recovery processes used. According to the article, the Argyle pipe measures about 1,600 m long and varies in width from 150 to 600 m. Much of the recovery from both the primary and secondary deposits is done by large mechanized equipment. After diamonds have been removed from the ore, sterile rock is immediately used to fill the excavation. Mined-out areas are later planted with greenery. At the treatment plant, the lamproite is washed and sieved several times. Diamonds are finally separated out using X-rays. Argyle diamonds have a coating of iron oxide that makes sorting by grease tables unreliable. The CSO markets 75% of the diamonds; the remaining crystals are cut and sold through Argyle Diamonds. Included are photos of the Argyle mine.

JEM

Crystallization of diamond from a silicate melt of kimberlite composition in high-pressure and high-temperature experiments. M. Arima, K. Nakayama, M. Akaishi, S. Yamaoka, and H. Kanda, *Geology,* Vol. 21, No. 11, 1993, pp. 968–970.

It is widely accepted that kimberlite is the transporting medium that brings diamonds to the surface after they have crystallized in peridotite and/or eclogite in the mantle. However, fluid-inclusion studies of natural diamonds suggest a genetic link between diamond formation and fluids (melts) that are broadly similar to kimberlite in composition. Further, there is the nagging problem of the origin of microdiamonds, that is, small (<1 mm) diamonds, frequently with sharp edges, that show little or no sign of the resorption that is common in larger diamonds of clearly peridotitic or eclogitic origin.

This paper shows that it is possible to grow diamonds from a kimberlite melt, which the authors produced by melting powdered natural kimberlite from the Wesselton mine, South Africa. The powdered kimberlite was placed in a graphite (source of C) capsule. Experiments were run from 20 to 900 minutes. A modified belt-type high-pressure apparatus was used at high temperatures (1800–2200°C) and high pressures (7.0–7.7 GPa); these temperature and pressure conditions are considerably higher than those generally attributed to the growth of natural diamonds. The diamonds produced (up to 100 μm in diameter) had well-developed {111} faces, typical for natural diamonds and atypical for synthetic diamonds, which are usually cubo-octahedral.

The authors conclude that kimberlite melt has a strong solvent-catalytic effect on natural diamond formation, supporting the view that at least some diamonds (e.g., microdiamonds) crystallized from upper-mantle, volatile-rich melts that are distinctly different from those of peridotitic or eclogitic affinity. *A. A. Levinson*

Diamonds show resilience. M. Cockle, *Jewellery International,* No. 18, December/January 1993/1994, pp. 85–86.

This short article offers an optimistic outlook for diamond sales in 1994. Sales, especially that of jewelry commemorating life's "important chapters" and higher-end jewelry ($5,000 plus), were up in 1993—1%-3% over 1992's $40 billion total. Japan and the U.S., which make up about 60% of the market, are spending more despite bad economies in both countries. Personal consumption seems likely to go down in the U.S. in 1994, but up in Japan. Overall, most forecasts suggest good things for the year to come, including more diamond jewelry consumption by developing markets in China, Mexico, and South America. *Elizabeth A. Keller*

Nano-structures on polished diamond surfaces. W. J. P. Van Enckevort, M. S. Couto, and M. Seal, *Industrial Diamond Review,* Vol. 53, No. 6, 1993, pp. 323–327.

Despite many debates in the past, the actual mechanism of diamond polishing is still unclear. To obtain more information on this, the morphologies of polished surfaces of several semiconducting diamonds were examined by scanning tunnelling microscopy. The results of this topographic study are presented and provide essential new insights into the process of diamond polishing, but further questions arise. Abrasion along the hard directions proceeds via fracture and chipping on a nanometer scale; material removal in the softer directions seems to take place by single-pass grooving by diamond particles at supercritical loads followed by a polishing action by particles at subcritical loads. Problems to be solved include the actual mechanism of "plastic" grooving and how the extreme dependence of polishing rate on crystal orientation can be explained—now that the Tolkowsky cleavage model must be abandoned. *RAH*

Russians adapt know-how for enhancement of rough. V. Teslenko, *Diamond World Review*, No. 75, June-July 1993, pp. 50, 52, 54.

In addition to being a producer of rough diamonds, Russian is a leader in the development of technologies used in advanced weapons, nuclear, and aerospace industries. Subsequently these have been adapted for use in other industrial sectors. For almost 25 years, programs have been in operation that aim to enhance gem-quality rough and to raise the grade of near-gem-quality stones. The current changes in political climate have increased frankness on the part of the scientists and diamond industry members about this work.

A number of industry leaders—including Igor V. Gorbunov, general director of Almazjuvelirexport; Pavel K. Kovylin, head of the export department of Almazy Rossii-Sakha; and Yuri A. Dudinkov, director of the Diamond Center—confirmed that no enhanced rough is being released on the open market. They assure that any enhanced diamond sold will include a certificate that clearly outlines any procedure used.

The article lists some technologies that Russians are using to enhance rough diamond, including annealing, thermobaric treatment, laser irradiation, surface dissolution, thermodiffusion of inclusions, and diamond deposition.

Annealing entails heating at atmospheric pressure in an inert environment to remove green or yellow spots from rough stones. A negative effect of the process, as reported by a research team from the Gemological Center of Ginalmazzolto, was "graphitization in an extremely inert environment."

Thermobaric treatment (a high-temperature and high-pressure process) was carried out at two locations, including the Institute for Synthetics and Raw Materials at Aleksandrov in the Vladimir region. Like annealing, it is used to decolor diamonds. It was difficult to maintain isothermic and isobaric conditions across masses of crystals, making it too expensive for mass treatment of small rough. Using "original equipment," another research team was able to improve the color of brown diamonds by three to four grades. Negotiations regarding future development of the latter process have been conducted with several foreign companies.

At the Gemological Center of Ginalmazzolto, another enhancement technique—laser irradiation—is used to heal microcracks and relax inner stresses for cutting and polishing.

Three basic techniques of surface dissolution—yet another enhancement method—have been reported. Plasma etching, a thermochemical process, and laser etching are used by three different institutes to dissolve or etch the surface of a diamond to enhance frosted or coated diamonds.

Little is known about techniques involving thermodiffusion of inclusions. It has been suggested that diffusion is achieved by "moving through a thermogradient enhanced by a fine electromagnetic field."

In a sidebar, "Firms Rush for CVD Technology," the Gulf War's role in spurring development of carbon vapor deposition is explained. About 200 companies and labs, including Norton Diamond Film and De Beers Industrial Diamond Division, are investigating the technology, a process that came out of early research by Russian scientists. None of their work is covered by patents.

NDC

Solid carbon dioxide in a natural diamond. M. Schrauder and O. Navon, *Nature*, Vol. 365, September 2, 1993, pp. 42–44.

Solid carbon dioxide (CO_2; "dry ice") has been discovered by infrared spectroscopy in a small, unpolished natural diamond. The 9.2-mg diamond (which was purchased in Israel but is of unknown origin) consisted of two intergrown crystals. The larger was brownish yellow and color zoned; the smaller was colorless. CO_2 was present only in the colored zones and was submicroscopic (no inclusions visible with high optical magnification). Because of the shift of certain CO_2 infrared bands from their expected position at one atmosphere of pressure (i.e., at the earth's surface), CO_2 was determined to be in the diamond crystal at a pressure of about 5 GPa (50 kbar; 50,000 atmospheres). However, the authors conclude that the CO_2-containing fluids from which the solid CO_2 formed must have been trapped at even greater pressures in the hot mantle, corresponding to depths of about 220–270 km. Diamond is one of the few minerals with the strength to contain materials (gases) under such great pressures, bring them to the surface, and keep them trapped; thus, it is an effective "sampling device" for fluids deep within the earth.

These results also have implications for the petrological processes operating in the mantle because, for example, free CO_2 at these pressures should have reacted with silicates such as olivine and pyroxene to form magnesite ($MgCO_3$). The source of the trapped CO_2 could not be determined, but the authors have several theories. These include: release from high-pressure fluids (degassing) as they ascended through the mantle; and subduction of carbonaceous sediments from the surface.

A. A. Levinson

Hydrous and carbonatitic mantle fluids in fibrous diamonds from Jwaneng, Botswana. M. Schrauder and O. Navon, *Geochimica et Cosmochimica Acta,* Vol. 58, No. 2, 1994, pp. 761–771.

Fibrous diamonds have an opaque-to-translucent outer coat composed of nearly parallel diamond fibers that appear as outward-growing columns; the inner core may be transparent and of good quality. The diamonds are usually of cubic morphology and are commonly from Zaire, Sierra Leone, Siberia, and Botswana.

When the fibers grow, they trap very small amounts of high-temperature, high-pressure mantle fluid, from which some solid minerals may crystallize as the diamond cools on its way to the surface. The remaining fluid—although modified—is trapped under high pressure because of diamond's great strength. This paper shows how information on the chemistry of the original crystallizing fluids can be obtained, and how these data can be used to interpret the composition of fluids in the earth's mantle.

The fluid inclusions of 13 diamonds (cubic morphology) from Jwaneng were studied by means of transmission electron microscopy, infrared spectroscopy, and optical microscopy. Mineral phases identified included silicates, carbonates, and apatite; fluids (gases) included water and CO_2. By assuming that the original fluids were homogeneous at depth, their original compositions can be determined from the chemistry of the identified solids and the composition of the modified fluids still in the inclusions. On this basis, the authors determined that, although there is wide compositional variation in the fluids within inclusions in these coated diamonds, there are two end-member compositions: carbonatitic and hydrous. The carbonatitic fluid is rich in carbonates, CaO, FeO, MgO, and P_2O_5. The hydrous fluid is rich in water, SiO_2, and Al_2O_3. Both end-members are high in K_2O.

Fluid inclusions in fibrous diamonds have been analyzed by other researchers. However, this is the first time that the end-member compositions have been determined. By extrapolation of published experimental data, it is suggested that these fluids existed in the diamond stability field deep within the mantle at temperatures of about 1100°C and pressures of about 4.5 GPa (45 kbar). Further, there is an implied genetic link between these fluids and diamond formation. Three possible models for the formation and evolution of the two types of fluids within the earth's mantle are presented. All are compatible with the experimental data. *A. A. Levinson*

Three generations of diamonds from old continental mantle. S. H. Richardson, J. W. Harris, and J. J. Gurney, *Nature,* Vol. 366, November 18, 1993, pp. 256–258.

Diamonds form within two rock types, peridotite and eclogite, each of which has a distinct assemblage of minerals that can be represented by minute inclusions within diamonds. Diamonds cannot be age dated. However, their minute inclusions, particularly garnet and pyroxene, can be. They contain measurable quantities of radioactive elements. Because the inclusions formed at the same time as the diamond, the age of the inclusions is also the age of the host diamond.

Diamonds from several kimberlites in southern Africa have been dated previously at about 3,300 My and 1,150 My. The older diamonds have peridotitic (variety harzburgite, clinopyroxene-free) inclusions; younger ones have eclogitic inclusions. This paper reports that diamonds of another age group, 1,930 My, have been found. These contain inclusions of another variety of peridotite, lherzolite, which is characterized by the presence of clinopyroxene. (Most peridotitic diamonds are of the harzburgite variety.) Diamonds of all three ages are found in the Premier mine in South Africa.

A. A. Levinson

GEM LOCALITIES

The emerald mines of Madagascar. A. Thomas, *South African Gemmologist,* Vol. 7, No. 3, pp. 3–11.

The author visited nine emerald mines (Ambodirofia, Ambodibonary, Ambadamanino, Ambodibakoly, Mororano, Ambodifandrika, Ambodizainana, Ambilanifitorana, and Mohotsana II) in the Mananjary District of Madagascar. He vividly describes the difficulties involved in reaching this district; the mines employ over 1,000 people, and some heavy machinery is used.

Like emeralds from other sources (Brazil, Zambia), the Malagasy stones are found in dark schist, which is composed of blackish brown biotite with quartz lenses and minor plagioclase. The author tentatively identifies cubic, high-R.I. inclusions in some emeralds as rhodizite. The coexistence of rhodizite with emerald would be unique to Madagascar. Thus, when found, rhodizite inclusions would provide a definitive identification for this source of the emeralds.

Physical properties are given for stones from three Madagascar mining districts (Ankadilalana, Mananjary, and Morafeno). Refractive indices vary between $\omega = 1.580–1.581$ and $\varepsilon = 1.586–1.589$, with birefringence between 0.006–0.008; the specific gravities range from 2.72 to 2.74. For comparison, values are also given for emeralds from Mozambique, South Africa, Tanzania, Zambia, and Zimbabwe. Stones from the three districts are also described in terms of their appearance through the Chelsea filter and absorption bands seen in a hand spectroscope. Their mineral inclusions and fractures are also described. The author notes that he saw no tremolite or actinolite needles in the emeralds he examined (or in the working faces of the mines he saw), unlike the observations of earlier researchers.

There are two photographs of emerald mining, and one cover illustration of an emerald crystal, but no photomicrographs. *Mary L. Johnson*

Mineralogy of the Sanford vesuvianite deposit. D. L. Leavitt and N. J. Leavitt, *Mineralogical Record,* Vol. 24, No. 5, 1993, pp. 359–364.

The Sanford (Maine) vesuvianite deposit has produced collector-quality specimens of vesuvianite, grossular garnet, scapolite, scheelite, and other species for over 140 years. The site is still open for collecting, and this article provides location maps along with a synopsis of mining activity and the general geology of the deposit. Accompanying the many photographs is a table listing the sizes and other pertinent information of the various minerals that have been positively identified from the deposit. *LBL*

Montana sapphires. S. Voynick, *Rock & Gem,* Vol. 23, No. 8, August 1993, pp. 42–48.

This article is primarily a retrospective of sapphire-mining activity at the Yogo dike in Montana. Although sapphire from this location was first discovered in 1895, the overall working of the site has been moderately low. Based on geologic studies done in the early 1980s, and the recent discovery of a western extension of the dike, it appears that the economic potential of the dike could far exceed all previous estimates. With the announcement of a new lease on the main section of the dike by one of the world's leading mineral-resource-development corporations—AMAX Explorations of Golden, Colorado—the author speculates on the probability of greatly increased mining activity and production of gem-quality material in the near future. *LBL*

A quartz discovery at the Sally Ann claim. T. Bleck, *Mineral News,* Vol. 10, No. 2, February 1994, p. 8.

From late 1992 to Spring 1993, the author dug out a pocket containing 300 amethyst-tipped smoky quartzes on the Helena Mineral Society's claim along Sally Ann Creek in Powell County, Montana. Faceting material was also found; the largest amethyst faceted from this locality weighs 45 ct. Only hand tools are allowed at this claim, and commercial digging is forbidden. *Michael Gray*

INSTRUMENTS AND TECHNIQUES

Microscopic estimation of refractive index using a dial test indicator and a personal equation. T. Farrimond, *Journal of Gemmology,* Vol. 23, No. 7, 1993, pp. 418–421.

The refractive index of a gemstone can be estimated from the ratio of its actual depth to its apparent depth, as viewed through its table with a microscope. The author describes how a dial-test indicator can be used to facilitate this process. Since the sample must be carefully manipulated (so that its vertical position does not change during the analysis), a microscope with a mechanical stage is recommended. If one is not available, a slide mount—like the one illustrated in this article—can be used. Ten values were determined by this method for a 0.52-ct pyrope garnet; they ranged from 1.756 to 1.787—with the lowest value matching the stone's actual R.I. The author suggests that this probably represents a personal bias, which can be included in the calculation following initial trial tests. Although only useful for estimations, the test has distinct advantages: It can be performed on most mounted stones, on gems with refractive indices exceeding 1.81, and in the absence of a refractometer. *CMS*

Towards a mathematical gemmology. Thinking in terms of ratios makes a difference. M. A. Schell, *Journal of Gemmology,* Vol. 23, No. 7, 1993, pp. 422–426.

This article is intended to provide gemologists with a better understanding of the relationship of doubling to birefringence and dispersion. Although doubling is related to birefringence, it is also affected by R.I.; that is, it is more apparent (all else being equal) in stones of low R.I. For example, calcite's birefringence is less than that of synthetic rutile, but its doubling appears greater. Since most gemologists do not attempt to estimate birefringence or perform identifications based on doubling, this report initially appears to be of primarily academic interest. However, the author's discussion leads to his development of a new index, which he calls "dispersing strength." This may be of value (particularly to lapidaries) in quantifying the visual effects based on divergent light rays. This article concludes with a discussion of color fringes at the shadow edge when obtaining refractive indices with white light. By using a comparison of the critical angle in red to that in violet light, rather than dispersion, refractometer readings could be sharpened. This could point the way toward the development of a better refractometer. Gemologists with an interest in the theory and application of gemology will enjoy this well-written—if somewhat technical—article. Fair warning: Trigonometry is involved, as well as the optics we all know and love. *CMS*

JEWELRY HISTORY

The opal—Louis Comfort Tiffany's lens to a world of color. J. Zapata, *Antiques,* Vol. 144, No. 5, 1993, pp. 318–327.

This sumptuous article probes the use of opal in jewelry by renowned American artist, Louis Comfort Tiffany. Well known for his peacock art glass and innovative stained glass lamps, Mr. Tiffany was fascinated by the ever-changing mosaic of color inherent in opal. This article looks at the history of Mr. Tiffany as it relates to the inspired use of opal in his jewelry designs. Ms. Zapata, a respected jewelry historian, does justice to her subject, recording minutely the historic partnership of Mr. Tiffany with opals and jewelry. For example, she describes slight changes made to an opal necklace after it was shown at the Louisiana Purchase Exposition in St.

Louis in 1904. This article precedes a new book by Ms. Zapata, *The Jewelry and Enamels of Louis Comfort Tiffany,* published by Harry N. Abrams. Supplementing the article's well-written text are splendid photographs of Tiffany's opal jewelry. *JEC*

The Straits Chinese and their jewelry. E. Chin, *Arts of Asia,* Vol. 23, No. 4, 1993, pp. 100–108.

This article describes an exhibition of the same name that was held from April to September 1993 in the National Museum of Singapore. The Straits Chinese (also called Peranakans) were a loosely organized group of early Chinese immigrants to the British and Dutch East Indies. By the late 19th century, they had developed a distinctive culture—with some variation from area to area—and established a reputation as the leading artistic patrons of the era. Over 300 examples of their rare jewelry were gathered for this display, many exhibited for the first time. The importance of this show is underscored by an increasing interest in Straits Chinese decorative arts that has spurred the production of many fakes and reproductions. Although of obviously inferior craftsmanship, the fakes are still very effective, as little of the original jewelry had been available for study before this exhibition.

Various types of jewelry are described, from everyday wear to fantastically ornate wedding jewels, including breastplates and crowns for both bride and groom. A mixed culture, the Straits Chinese were reasonably open to foreign influence in their artwork, dress, and customs. This cultural affability resulted in some amazing creations. Because the Straits Chinese loved glitter and brightness, jade is rarely found in their ornamentation, but diamonds are very prominent. Faceted granulation was combined with intricate details to create dramatic family treasures that were handed down from one generation to the next. *JEC*

JEWELRY MANUFACTURING

Advances in gem designing by computer. B. Atwell and M. Hunt, *Canadian Gemmologist,* Vol. 14, No. 4, 1993, pp. 104–109.

This article discusses the performance of several types of gemstone-design software available to the gem and jewelry industry, and then outlines why appraisers should use these programs. Discussion is lengthy on the use of these programs by gem cutters, going so far as to suggest that the programs be used to test new facet designs for brilliance and dispersion before actually cutting the stone. Arguments are made for using this software as a marketing device to sell well-cut gems to the public, and for jewelry designers to create new gemstone cuts to accent their creations. *Michael Gray*

JEWELRY RETAILING

New jewels for the new Russians. J. Helmer, *Jewellery International,* No. 18, December/January 1993/1994, pp. 29–32.

This article tells of a new breed of Russian jewelers who are emerging onto the world market with fresh ideas and new respect for the work of pre-revolutionary Russian masters. These designers and manufacturers, however, have encountered many obstacles in their quest for a free market. For example, the supply of gems and precious metals remains restricted. In order to escape these limitations, jewelers resort to "connections and patronage," which has produced corruption and chaos in the domestic manufacturing market. Nevertheless, new companies such as Karat, Ascor, Sirin, and Juvelirprom are thriving. They employ fewer people than the "old" traditionalist companies that dominated jewelry making under the Soviets, yet they have an annual turnover of between $1 billion and $2.5 billion. Many have offices in the U.S. and western Europe. These companies, the "new" traditionalists, are creating jewelry reminiscent of well-respected predecessors like Fabergé and Khlebnikov, or they take their inspiration from ancient Byzantine art. While demand grows for their work, they also realize that Russia cannot continue to trade solely on the reputation of the pre-revolutionary masters.

Elizabeth A. Keller

Saleroom report: Sotheby's sets sale [sic] **world record.** *Retail Jeweller,* December 2, 1993, p. 9.

Sotheby's set a world auction record for any jewelry sale with its $78,142,350 Geneva event on November 16–17, 1993. The highlight of the auction was a 100.36-ct D-flawless diamond which sold for $13,247,194, "the second highest price in dollars for any jewel."

Meanwhile, Christie's claimed a rival success with its $46.3 million jewelry sale on November 18, 1993. Top pieces included the historic Archduke Joseph diamond, sold for $7 million to the American Ishaia Trading Corporation. Laurence Graff of London acquired a pear-shaped purplish-pink diamond of 10.83 ct for $4.6 million and named it the Graff Pink. *MD*

Tenth annual ultimate gift guide. *Robb Report,* Vol. 17, No. 12, December 1993, pp. 51, 58, 79, 81.

Unsure of what to get that certain someone who already has everything? Is price no object? Consult the 10th Annual Ultimate Gift Guide in the *Robb Report,* the magazine "for the affluent lifestyle."

For the serious scribe, consider the Solitaire Royal fountain pen by Montblanc, billed as the world's most expensive writing instrument. The cap and barrel of this $100,000 pen are covered with 4,200 pavé-set diamonds (totaling 24 ct), which form a continuous and absolutely smooth surface. Order now for Christmas. Each pen takes nine months to assemble.

Clicking their heels three times might not whisk you to Kansas, but just wearing them will undoubtedly make you the talk of Kansas—or any state for that matter. The size-5$^1/_2$, $3-million ruby slippers—made by Harry Winston to commemorate the 50th anniversary of

The Wizard of Oz—are embedded with 4,600 rubies and trimmed with 50 ct of diamonds.

A limited-edition Colisée Kilim wristwatch by Cartier sparkles with 530 diamonds weighing 20.63 ct, 12 emeralds weighing 1.97 ct, two rubies weighing 0.70 ct, and two sapphires weighing 0.35 ct. Plan ahead. Each watch takes 10 months to a year to complete. If you have to ask, you can't afford it. Price is available *only* on request.

Also described are $20,000-a-set, 24k gold-plated wire rims to dress up your car and a $60,000 pool cue with malachite/lapis lazuli inlays depicting the Taj Mahal and environs.

With the exception of the pool cue, one color photo illustrates each item. *Irv Dierdorff*

Two for one. S. Biallôt, *Town & Country,* Vol. 147, No. 5163, December 1993, pp. 78, 80.

Each month, various contributors write *Town & Country*'s section on jewelry. In this issue, Suzanne Biallôt explores convertible jewelry's recent resurgence. Convertible jewelry is intricate and versatile, manufactured so that it can be worn in a variety of ways (e.g., a brooch with sections that can be detached and worn as earrings). The author briefly notes current trends and designers, being sure to mention that "convertible jewelry is not a novelty," dating its origins to the mid-1800s. Color photographs of convertible jewelry from leading international jewelry houses and designers accompany the article. *Juli Cook-Golden*

PRECIOUS METALS

MetalsNews: Demand for platinum rises. *National Jeweler,* Vol. 2, No. 2, January 1, 1994, p. 41.

Total platinum demand in the "Western world" grew 6% to 4.02 million ounces in 1993, while supply rose 10% to 4.21 million ounces, according to the Johnson Matthey semiannual Platinum Interim Review. Johnson Matthey is a London-based leading refiner and supplier of platinum-group metals.

These increases were tempered by a 16.2% drop—to 685,000 ounces—in industrial demand. Jewelry demand for platinum was expected to rise 80,000 ounces, or 5%, to a record 1.50 million ounces by year end. Platinum-jewelry consumption in Japan rose an estimated 3.9% to 1.34 million ounces, despite a poor economy.

The number of jewelry designers and manufacturers working in platinum in the United States is "now more than 150," triple the figure in the 1980s. Platinum-jewelry sales in the U.S., which only totaled 20,000 ounces in 1991, reached an estimated 45,000 ounces in 1993.

Johnson Matthey predicted a 17.6% rise in platinum-jewelry consumption in western Europe, and a modest 5% increase for the rest of the Western world.

From January through September 1993, the price of platinum averaged $374 an ounce, compared to $360 for the same period in 1992. A steep late-November drop in the Nikkei index in Tokyo, and the prolonged slump in the Japanese economy, caused platinum to dip below gold's price on November 23. Platinum prices were expected to remain in the $350- to $390-per-ounce range through Spring 1994. *MD*

SYNTHETICS AND SIMULANTS

Chic and cheap. B. Greysmith, *Jewellery International,* No. 13, 1993, pp. 74–76.

This article looks at the "major players" who influence the costume-jewelry market. The article opens suggesting that, although costume jewelry is nothing more than imitation, this market is enjoying a boom, thanks to consumers and collectors. To support this notion, Ms. Greysmith mentions costume-jewelry auctions held by Christie's; the dates of these auctions are somewhat vague. She also claims that some pieces have sold for prices close to what the "real thing" would fetch. Accomplishments of major costume-jewelry designers past and present (Chanel, Dior, Swarovski, and Monet, among others) are reviewed. Also noted are how historic events have influenced these designers. Ms. Greysmith also describes basic material used in making costume jewelry, such as lead glass, bakelite, plastic, and rhodium plating. She concludes that the popularity of costume jewelry will remain strong as professional women choose to accessorize their wardrobes. *Juli Cook-Golden*

Flux-grown synthetic rubies from Russia. U. Henn and H. Bank, *Journal of Gemmology,* Vol. 23, No. 7, 1993, pp. 393–396.

Characteristics are reported for two crystals of flux synthetic ruby manufactured in Russia. The two specimens represent two types of material: one that grows in a tabular prismatic form, and the other that is rhombohedral. On the basis of SEM-EDS analyses, the authors report Al_2O_3 and Cr_2O_3 as the main components. The rhombohedral crystal revealed significantly more chromium (about 1.5 wt.% Cr_2O_3) than did the tabular sample (about 0.3 wt.%), which is consistent with the color descriptions of dark red for the former and pale red for the latter. Other reported properties are typical for flux synthetic ruby. Inclusions were found to be tungsten-bearing flux and triangular residues of crucible material (probably platinum), both also typical of flux rubies. The producer reports growth conditions of 1100°C in a lithium-tungstate melt. EDS analysis, used to determine composition of the inclusions, would detect tungsten, but not the light element lithium. This succinct report is well illustrated with color macro- and micro-photographs and a table of the measured properties. *CMS*

Imitation lapis lazuli, charoite and azurite-malachite. D. Bennett, *Australian Gemmologist,* Vol. 18, No. 3, 1992, pp. 83-84. Part II, J. L. Keeling, pp. 84–85.

Despite different outward appearances, all three types of this new range of imitations were determined to have similar gemological properties: Mohs hardness under 5; dull luster; 1.54 spot R.I.; S.G. within the range of 2.53-2.61; inert to U.V. radiation (except for the charoite imitation, which fluoresced a weak gray to long-wave U.V.); and a slight burnt-rubber smell when tested with a "hot point." None of the three was a very convincing imitation. Their gemological properties were sufficiently different from their natural counterparts to make the separations straightforward.

In Part II of this report, the materials were further studied to determine composition and structure. SEM-EDS analysis revealed two types of fine-grained powder in an organic cement. One type consisted of approximately equal amounts of barium and sulphur, and was tentatively identified as barite; the other consisted mostly of aluminum, and—with the help of infrared spectroscopy—was identified as gibbsite. Infrared spectroscopy indicated that the organic cement contained polymers similar in composition to butyl phthalate or methyl benzoate. *RCK*

TREATMENTS

Unpleasant truth behind jade treating and bleaching. R. Milburn, *Asia Precious*, September 1993, pp. 72-75.

The Hong Kong tourist association warns the jade-buying public to demand that the type of jade be described in writing on the invoice when making a major purchase. This has been prompted in part by the abundance of bleached and polymer-impregnated jadeite on the market there. Perhaps as much as 70% of the jadeite sold in Hong Kong and 90% of that sold in Taiwan is treated. China treats much of its output, too.

The "inexact" classification used by jade dealers includes three types of jade: Type A, basically untreated; Type B, bleached and polymer-impregnated; and Type C, dyed (B and C can occur together).

Recent advances in the bleaching treatment have made it difficult to detect by standard gemological methods alone. With early treatment procedures, the jade often contained a large percentage of the relatively light resin, which made its specific gravity significantly lower than the untreated material. Also, the resin commonly fluoresced a chalky blue to long-wave ultraviolet radiation. Apparently, treaters now put less polymer in the bleached jadeite and use a resin that does not fluoresce.

B jade has durability problems. Eventually, the iron oxides that have been reduced oxidize again and darken the piece. The translucency caused by the polymer also will become duller as the polymer slowly degrades over time.

This situation has created a major problem for the jade trade, as challenges in identification make proper disclosure even more difficult. This is especially true in the case of medium-quality jade, which is usually not expensive enough to justify a laboratory report. However, proper testing is necessary if the jade market is to survive. In Japan, jade sales dropped 50% in 1991 due to concerns over B jade. *EF*

Testing jadeite to protect the trade and consumers. R. Milburn, *Asia Precious*, October 1993, pp. 60–63.

Due to widespread bleaching and polymer impregnation, a new classification system for jadeite—to clearly indicate treated pieces—has been deemed necessary in Hong Kong. Many Hong Kong organizations are expected to sit on the standard-making body, including representatives of the government, trade organizations, and gemological associations. Authorities might make this standard mandatory. This raises the difficult question of who will be authorized to issue certificates, and how that will be done. It has been suggested that only qualified gemologists with an understanding of infrared spectroscopy (the only sure way to identify polymer impregnation) should be involved. Other details still need to be worked out, too. These include whether to indicate the degree of polymer impregnation and whether the cost of testing should be limited to 5% of the cost of the jadeite piece.

The rest of the article describes methods used to identify treated jadeite. The information is mostly correct. However, several mistakes in the layout could be confusing. For example, figure captions describing the infrared spectra of untreated and treated jadeite have been mistakenly switched. In addition, a number of items in the table are not matched to the appropriate discussion. *EF*

MISCELLANEOUS

The first annual Phony Awards. T. Laughter, *JewelSiam*, Vol. 4, No. 6, 1994, pp. 31–39.

Mr. Laughter has put together an informative and entertaining article that summarizes some "outstanding" synthetic and treated stones seen at Bangkok's School of Gemological Sciences in 1993. The reader might be amazed at the lengths that some of the "award winners" went to in order to deceive a customer. The Phony Awards remind us that even the best can be fooled if caution is forgotten even for a moment. Highlights include the "Best Celestial Sham," a synthetic star ruby that looked natural to the unaided eye. The cut was bottom-heavy, atypical for synthetic stars, and sported a pavilion cavity that was cut to look natural; a less distinct but more natural-looking star was the result of a low concentration of rutile needles. However, a microscope revealed curved striae, proof that it was a synthetic ruby.

The "Best Hidden Curves" featured a flame-fusion synthetic ruby that had been heat treated to reduce the appearance of curved striae and to induce inclusions that resembled natural fingerprints. The "Best Fused Flux Fusion" was a flame-fusion synthetic boule that had been given an overgrowth of flux ruby. The overgrowth made curved striae difficult to identify, while the flux inclusions in the overgrowth were much easier to locate. The motivation behind the creation of this piece is clear when one remembers that flux synthetics are 300 times more costly than flame-fusion synthetics. The winner of the "Hardest" award (as in Mohs scale) was a yellow synthetic diamond. This section included information on how the stone was identified as synthetic, as well as a portion of a conversation that then took place between the submitting company and the school's lab. Photos of each of the 17 award winners are included, with text on how each identification was made. *JEM*

1993: The geosciences in review. *Geotimes*, Vol. 39, No. 2, February 1994, pp. 10–37.

This lengthy article has 40 sections, each written by an expert in a particular field, that summarize trends seen in earth sciences in 1993.

The geosciences as a whole have been affected by the economy, ecology, and zeitgeist of the '90s. Research must be relevant, not esoteric; development must be sustainable, not just exploitive; waste-disposal problems are likely to be considered as important as extraction problems. A significant trend for individuals is the increased access to computers as a form of international communication (consider, for instance, GIA-Net and the recently announced GemLink). The successful earth scientist of the '90s will be nothing if not versatile.

In the United States and Latin America, extractive mining continues to be important for only two metals: copper and gold. Current mining techniques make it unlikely that mineral specimens (much less gems) will be recovered using modern gold-mining techniques, but copper mines are producing (for example) azurite, malachite, drusy quartz with chrysocolla, and turquoise.

Exploration geophysics continues to be of primary importance for oil producers, but exploration geochemistry is gaining further emphasis. The Geological Survey of Canada, for instance, is working on stream-sediment and heavy-mineral surveys for a national geochemical data base, with special emphasis on kimberlites. Regional mapping is also being undertaken by Greenland, Finland, Sweden, Norway, Great Britain, and Poland. Australia, New Guinea, and Fiji are searching for new gold deposits. UNESCO is sponsoring a project to systematically map geochemical regions worldwide.

Analytical techniques continue to measure smaller and smaller concentrations of more and more substances. ICP (inductively coupled plasma) emission spectrometers and mass spectrometers can measure minute amounts of elements and organic compounds; laser ablation mass spectrometry and ion microprobes measure isotopes, for example, as in the zoning patterns in individual garnets. Unfortunately, all these techniques are destructive, at least on the scale of tenths of millimeters. However, another new technique, the atomic force microscope, can look nondestructively at the positions of individual atoms on a surface. Fluid inclusions tell petrologists about formation conditions and water/rock interactions.

Diamonds are of interest to mineralogists and petrologists alike because they provide information about conditions in the Earth's deep interior. The (recently discovered) occurrence of solid carbon dioxide in diamonds suggests that the composition of the Earth's mantle may be less uniform than previously thought. High-pressure mineralogy continues to be an important field. Mineralogists are also becoming more interested in exploring the health effects of mineral-rich dusts, a subject with possible implications for the faceter and lapidary.

Mary L. Johnson

Minerals, mineralogy, and mineralogists: Past, present, *and future.* *F. C. Hawthorne, Canadian Mineralogist*, Vol. 31, No. 2, 1993, pp. 253–296.

Several fundamental concepts used in gemology come from the field of mineralogy. Good examples include much of gemological nomenclature, certain methods of gem identification, and ideas on topics, such as crystal growth and the causes of color in some gemstones. Thus, an understanding of mineralogy's past and its possible future directions should be of interest to gemologists.

In this article, Dr. Frank Hawthorne, a mineralogy professor at the University of Manitoba and a recent past president of the Mineralogical Association of Canada, presents a condensed but thorough overview of mineralogy. Starting with the earliest key publications on minerals, he traces the major developments, first in the classification and then in the characterization of minerals. All the major analytical techniques now used to study minerals are briefly reviewed. Future directions that research on minerals may take are highlighted. The author concludes with a plea for retaining classical mineralogical education and mineralogical research in a period of shrinking funding for both science and scientific education. *JES*

Perren Gem and Gold Room opens at Royal Ontario Museum. *Canadian Gemmologist*, Vol. 14, No. 3, 1993, pp. 86–87.

This exhibit is named for the late gemologist and gem dealer, Richard Perren. Six photographs show examples of the displays, which feature interactive videos, gold specimens, and gemstone groupings.

Michael Gray