GEMS & GEMOLOGY

VOLUME XXVII FALL 1991

THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA

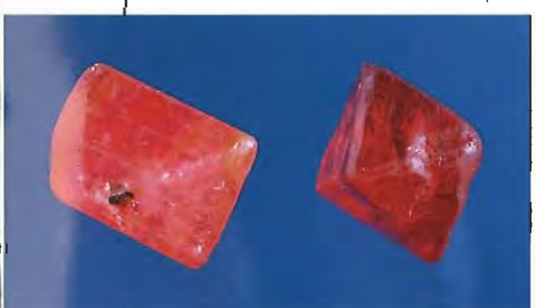
GEMS & GEMOLOGY

FALL 1991 Volume 27 No. 3

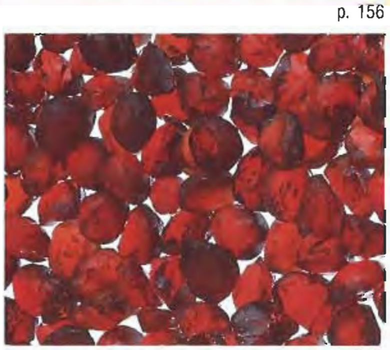
TABLE OF CONTENTS

p. 136

p. 136



p. 156



p. 168

ABOUT THE COVER: Historically, the most highly prized rubies have come from the Mogok deposits of Burma (now called Myanmar). Their deep rich color is well represented by this necklace of reportedly Burmese rubies (a total of 46.05 ct; the largest stone is 6.22 ct) provided courtesy of R. Esmerian, Inc., New York. In recent years, rubies have emerged from new deposits in Tanzania and Vietnam that closely resemble Burmese stones and probably originate from geologic conditions similar to those at Mogok. The lead article in this issue provides a comprehensive description of the major occurrences and key gemological characteristics of Vietnamese rubies, while the other main article examines similar material that has recently emerged from the Morogoro area of Tanzania. The loose rubies and fancy sapphires illustrated here, all reported to be from Vietnam, are representative of some of the fine material from that nation. The 5.18-ct and 7.94-ct pink sapphires are courtesy of Andrew Sarosi, Los Angeles, CA; the 1.69-ct ruby is courtesy of Evan Caplan & Co., Los Angeles, CA; the remaining stones (0.32–0.50 ct) are courtesy of FIMO Gemstone S.A., Chiasso, Switzerland.

Photo of the loose gems © Harold & Erica Van Pelt – Photographers, Los Angeles, CA. Photo of the necklace courtesy of R. Esmerian, Inc., New York.

Typesetting for Gems & Gemology *is by Scientific Composition, Los Angeles, CA. Color separations are by Effective Graphics, Compton, CA. Printing is by Waverly Press, Easton, MD.*

 ISSN 0016-626X

GEMS & GEMOLOGY

SUBSCRIPTIONS

Subscriptions in the U.S.A. are priced as follows: $49.95 for one year (4 issues), $119.95 for three years (12 issues). Subscriptions sent elsewhere are $59.00 for one year, $149.00 for three years.

Special annual subscription rates are available for all students actively involved in a GIA program. $39.95 U.S.A., $49.00 elsewhere. Your student number *must* be listed at the time your subscription is entered.

Single issues may be purchased for $12.50 in the U.S.A., $16.00 elsewhere. Discounts are given for bulk orders of 10 or more of any one issue. A limited number of back issues of G&G are also available for purchase.

Please address all inquiries regarding subscriptions and the purchase of single copies or back issues to the Subscriptions Department.

For subscriptions and back issues in Italy, please contact Istituto Gemmologico Mediterraneo, Via Marmolaia #14, I-38033, Cavalese TN, Italy.

To obtain a Japanese translation of *Gems & Gemology,* contact the Association of Japan Gem Trust, Okachimachi Cy Bldg, 5-15-14 Ueno, Taito-ku, Tokyo 110, Japan.

MANUSCRIPT SUBMISSIONS

Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in this issue of the journal, or contact the editor for a copy. Letters on articles published in *Gems & Gemology* and other relevant matters are also welcome.

Gems & Gemology is published quarterly by the Gemological Institute of America, a nonprofit educational organization for the jewelry industry, 1660 Stewart St., Santa Monica, CA 90404.

Postmaster: Return undeliverable copies of *Gems & Gemology* to 1660 Stewart St., Santa Monica, CA 90404.

New Sources Bring New Opportunities

Recent world events are having a dramatic impact on the gem and jewelry industry. We all remember how the "opening" of China a decade ago stimulated exploration at countless potential diamond and colored stone localities. Now, the more recent opening of political borders in the USSR, as well as the changing economic outlook of countries such as Vietnam and Tanzania, promises both new markets and new gem materials. Certainly, as economic needs increase and political climates relax, formerly isolated gem-producing countries will seek further cooperative ventures for exploration, mining, and distribution of their gem riches. The additional goods that reach the international marketplace present new opportunities for the gem community, both in renewing supplies depleted elsewhere and in stimulating the demands of a growing consumer market.

For example, in the Summer 1991 issue of *Gems & Gemology*, we featured an article on a new production of emeralds from the Ural Mountains of Russia. Historically, the Urals have been the source of many fine gem materials; with modern exploration techniques and the infusion of capital, they could again produce beautiful gems in significant quantities. As we learned from Dr. Vladimir Balitsky at the International Gemological Symposium in June, hundreds of other areas in the USSR are also being explored for their gem potential—from diamond and demantoid deposits in Siberia to jadeite and malachite occurrences in Kazakhstan.

The current issue of *Gems & Gemology* chronicles further developments in countries that are reemerging in the world economy. Czechoslovakia maintains a jewelry industry based on renewed mining for pyrope garnets from the historic deposits in the Bohemian Hills. In Tanzania, we have seen mining expanded, leading to the discovery of a new ruby occurrence. In Vietnam, we are seeing the identification of major deposits of fine rubies and fancy sapphires—with three million carats produced from one deposit alone over a five-month period. It is especially exciting that these new Tanzanian and Vietnamese rubies are remarkably similar to rubies from the classic Mogok deposit in Burma (now Myanmar). Even Myanmar shows signs of reaching out to world markets; our Gem News section notes that government's renewed interest in working with foreign gem dealers. Reports in the literature and by our colleagues also indicate that fine rubies have recently been found in Laos and China. After many years during which fine rubies were in short supply, significant amounts may soon become available, from many diverse localities.

In the 1980s, massive amounts of irradiated blue topaz entered the market, heat treatment significantly boosted the supply of inexpensive blue sapphires, and large quantities of lower-quality diamond melee started to come out of Australia. These increased supplies of affordable gems helped broaden the customer base for gems and jewelry worldwide. Relatively inexpensive gem-set goods could now be mass marketed to lower-income groups that once considered jewelry beyond their means. Now, in the 1990s, the discovery of significant quantities of fine rubies and other gems is accelerating. If the challenges in mining and distribution can be met, this trend promises greater opportunities to market to that broader consumer base. With the opening of economic and political borders, the decade of the '90s could well be the most productive in the history of our industry.

Alice S. Keller
Editor

RUBIES AND FANCY SAPPHIRES FROM VIETNAM

By Robert E. Kane, Shane F. McClure, Robert C. Kammerling, Nguyen Dang Khoa, Carlo Mora, Saverio Repetto, Nguyen Duc Khai, and John I. Koivula

Gem-quality rubies and pink to purple sapphires are being recovered from the Luc Yen and Quy Chau mining regions of Vietnam. This article briefly reviews the history and geology of these areas, as well as the mining methods used. The gemological characteristics of more than 100 of these stones are described in detail. The most notable internal features are blue color zones, swirl-like and angular growth features, bluish "clouds," and inclusions of rod-like calcite and pyrrhotite as well as the rare mineral nordstrandite.

ABOUT THE AUTHORS

Mr. Kane is manager of identification, and Mr. McClure is a senior gemologist, in the GIA Gem Trade Laboratory, Inc., Santa Monica, California. Mr. Kammerling is director of technical development, and Mr. Koivula is chief gemologist, at the Gemological Institute of America, Santa Monica. Mr. Khoa is a consulting geologist in Hanoi, Vietnam. Mr. Mora is a gemologist at Tecno-Resource, Turin, Italy. Mr. Repetto is manager for Europe and Vietnam of FIMO Gemstone S.A., Chiasso, Switzerland. Mr. Khai is senior geologist of the Council of Ministers, Hanoi.

Acknowledgments: The authors are grateful to the vice-chairman of the Council of Ministers, Socialist Republic of Vietnam, H. E. Tran Duc Luong, and to Dr. Nguyen Chu, Department of Foreign Economic Relations, Office of the Council of Ministers, for their assistance and encouragement during the preparation of this article. Dr. James Shigley, of GIA Research, provided the information on chemistry and other helpful comments.

Gems & Gemology, Vol. 27, No. 3, pp. 136–155.

Until recently, little was known about the gem potential of Vietnam, in spite of the fact that it is surrounded by countries with significant gem riches. In 1983, however, corundum was reported near the towns of Ham Yen and An Phu, north of Hanoi. Major exploration began in 1987, when geologists brought to the attention of the local government their discovery of rubies near the town of Luc Yen, 28 km west of Ham Yen, in Yen Bai (formerly Hoang Lien Son) Province.

In a five-month period, from November 1989 through March 1990, one deposit in the Luc Yen district produced more than three million carats of rough pink sapphire and ruby. Several other deposits are currently being worked in this gem-rich district. According to various trade sources, the finest rubies from this locality rival the finest stones from Myanmar (formerly Burma; see, e.g., "Vietnam Claims Major Ruby Find," 1990; Hughes and Sersen, 1991; and Weldon, 1991). In December of 1990, rudimentary mining operations began at Quy Chau in Nghe An (formerly Nghe Tinh) Province, south of Hanoi. Stones examined thus far from this latter deposit compare favorably with those mined at Luc Yen (figure 1).

Two of the authors, Messrs. Khai and Khoa, have been involved in the geologic study of the gem deposits of Vietnam and the marketing of the stones recovered. Messrs. Mora and Repetto are participating in a joint venture between the Italian firm Tecno-Resource (a subsidiary of FIMO Inc., of Switzerland) and the Vietnamese government to establish a cutting operation and gemological laboratory in Vietnam. They provided GIA with numerous samples of rubies and pink to purple sapphires obtained in Vietnam, which formed the basis of the current research. This article reviews the Luc Yen and Quy Chau mining regions, and provides a gemological characterization of the rubies and fancy sapphires found there.

Vietnamese geologists believe that there is consider-

Figure 1. Fine rubies and fancy sapphires, some comparable in quality to fine Burmese stones, are now emerging from the Luc Yen and Quy Chau districts of Vietnam. The stones shown here, all of which were obtained in Vietnam, range from 0.33 to 1.94 ct. Jewelry provided by the Gold Rush, Northridge, CA; photo by Shane McClure.

able potential for ruby and sapphire elsewhere in Vietnam. Currently, however, the Di Linh/Binh Dien sapphire mine, in the Lam Dong Province of southern Vietnam, is the only other active operation.

Reports in the trade press indicate that very small quantities of pink and violet spinels, blue sapphires, yellow and green tourmalines, and yellowish green chrysoberyl have reached the gem market ("Vietnam: An Important Potential New Source of Fine Ruby," 1990). Local geologists have also identified potentially gem-quality zircon, garnet, aquamarine, and topaz. Future prospects for some of these other gem materials in Vietnam are also briefly discussed.

HISTORY

Following the discovery of ruby at Luc Yen in February 1987, the government began geologic prospecting of this area in northern Vietnam. In March 1988, the government set up Vinagemco, a state-owned company devoted to the exploration, mining, cutting, processing, and distribution of gem materials in Vietnam. That same year, Vinagemco entered into a joint venture with B. H. Mining Co., of Bangkok, to work the Khoan Thong

Figure 2. This map of Vietnam shows the major localities where rubies are currently being mined (together with spinels, garnets, and some tourmaline), as well as known deposits of blue sapphire and other gem materials. The numbers are keyed to specific localities discussed in the text and listed in the key. Artwork by Carol Silver.

deposit at Luc Yen. In November 1989, the B. H. Mining/Vinagemco joint venture opened Vietnam's first commercial gem-mining operation. During the period November 1989 through March 1990, they recovered approximately 244 kg of potentially gem-quality corundum. At the height of exploitation at Khoan Thong, there were approximately 70 workers. Since March 1990, however, management problems have led to reconsideration of the joint venture and organized mining has come to a virtual halt. In October 1990, a law was enacted that prohibits foreigners from traveling to the mine area.

Also in 1988, Savimex Cie. of Ho Chi Minh City entered into a joint venture, called Savitech, with the Italian firm Tecno-Resource to develop a faceting industry and gemological laboratory in Vietnam. Originally, this joint venture was set up to analyze and facet rough material from the Bo Pailin ruby and sapphire district in Kampuchea (Cambodia); however, heavy fighting in that region has made the supply of such material very erratic. With the successful mining of rubies and fancy sapphires at Luc Yen—and, more recently, Quy Chau—Savitech became involved in the evaluation and cutting of this material as well.

Although mining in the Luc Yen area is officially under the direct control of the Yen Bai Province People's Committee, most of the activity is by local "smugglers." During some periods, thousands of these independent miners have swarmed over the area. It is likely, then, that actual production considerably exceeds official figures.

Mining is known to have started at Quy Chau as early as December 1990, by local peasants. In July 1991, authorities of the Nghe An Province People's Committee established four mining enterprises to control and exploit gem deposits in the Quy Chau area. As at Luc Yen, the number of official workers is relatively small—50 in this case—but during some periods more than 10,000 independent miners, from all over Vietnam, have worked illegally throughout the area. Although the most recent statistics on official production at Quy Chau are the equivalent of US$20,000 per month, actual production undoubtedly is several times larger.

LUC YEN

Location and Access. The Luc Yen mining region is located approximately 270 km northwest of Hanoi, just 75 km from the border with China.

Figure 3. Rubies are being mined in the valleys and foothills of the imposing Bac Bo Mountains of northern Vietnam.

Seven deposits are currently being worked in the area – at Khoan Thong, Nuoc Ngap, Nuoc Lanh, Hin Om, Phai Chep, Khau Sum, and Lung Thin – all within 8 km south, southeast, and south-southwest of the town of Luc Yen (figure 2). To date, the rubies and fancy sapphires have been found in secondary, largely alluvial deposits in the lush tropical valleys and foothills of the Bac Bo (previously, Tonkin) Mountains (figure 3). For the most part, roads in the region are not paved, but the area is readily accessible from Hanoi except during the rainy season (approximately May to November), when the mud becomes too deep to allow passage by vehicle.

Geology and Description of the Gem-Bearing Deposits. Exploration has identified rubies and fancy sapphires in secondary deposits that occur over a surface area of approximately 50 km^2, with evidence of an even larger area of some 300 km^2. The deposits are located in small valleys within the Bac Bo Mountain Range, on the sides of surrounding hills, in rice paddies at the base of the mountains, and along the rivers that cross the area.

The placer deposits are found in Quaternary sediments lying in a karst-like terrain of depressions and valley terraces within a 130 km $\times$ 2–5 km northeast-southwest trending belt of Upper Proterozoic–Lower Cambrian marbleized limestones and crystalline schists and quartzites (see figure 4). The gem-bearing valleys are often narrow, small depressions ranging from 0.5 to 7.0 km^2 but most commonly 2–3 km^2. They are part of the Vietbac formation (Phan Cu Tien, 1989). It has been suggested that the mineralized marble belt in which the Luc Yen stones have been found is similar to the geologic conditions in which rubies occur in the Mogok area of Myanmar and the Hunza Valley of Pakistan (Bank and Henn, 1990; Henn and Bank, 1991; H. Hänni, as reported in Koivula and Kammerling, 1990). The gem-bearing sedimentary beds average 2–3 m thick; the overburden ranges from less than a meter in some areas to as deep as 5 m in others. To date, no corundum has been recovered in situ, but local geologists have found some corundum samples still embedded in matrix (figure 5). Local geologists believe that the rubies are formed in association with pegmatites.

Associated gem minerals include red, pink, and pale blue spinels (which may represent from 70% to 90% of the gem material in a particular site), as well as potentially gem-quality (but small) yellow and green tourmalines and garnets. All of the corundum found here to date has been pink to purple to red.

Mining Methods. Open-pit mining is the dominant method used. Several pits, 1.5–3 m in diameter and 3–7 m deep, have been dug using backhoes and by hand throughout the Luc Yen district. In the most sophisticated operation, at Khoan Thong, the

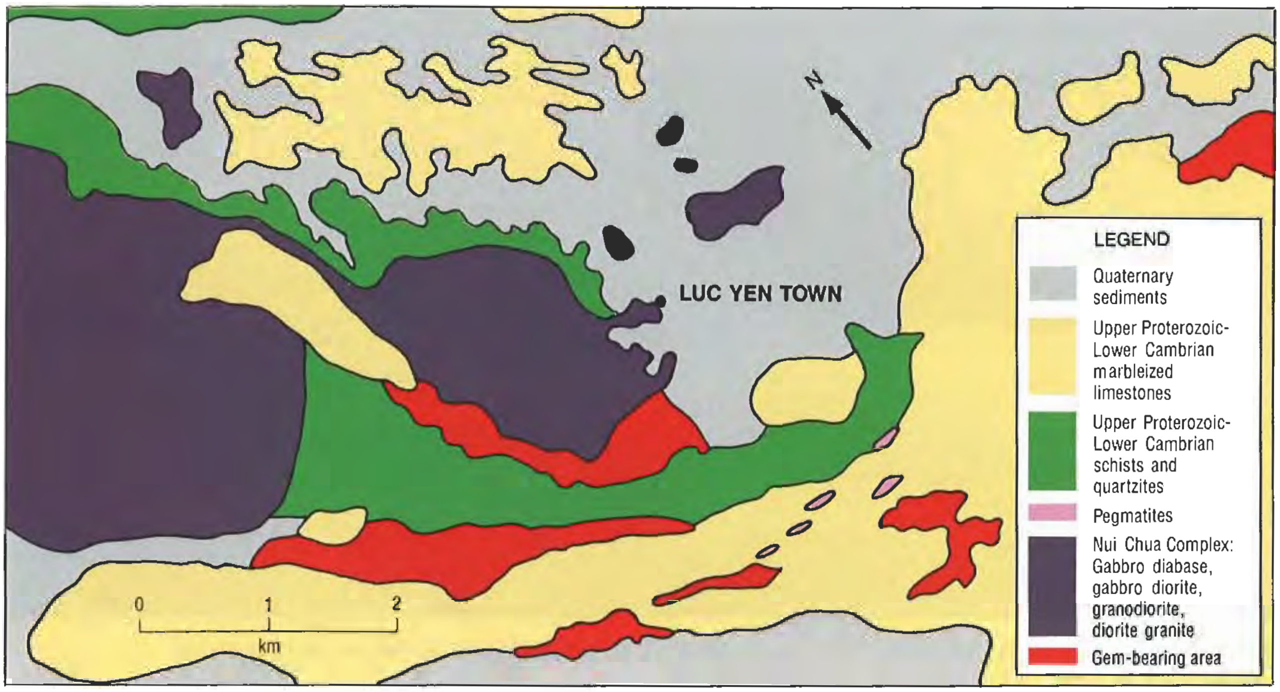


Figure 4. This geologic map of the Luc Yen region shows the areas where gems have been found in Quaternary sediments lying in karst-like depressions in a northeast-southwest trending belt of Upper Proterozoic-Lower Cambrian marbleized limestones, schists, and quartzites. Map prepared by N. D. Khoa; artwork by Carol Silver.

miners would spray the dry pits with water cannons and then pump the resulting mud into an inclined wood channel that leads to a large jig. In this sluice-type arrangement (figure 6), the water softens the earth and removes the dirt, while the largest rocks are removed by hand. At the jig, the corundum is sorted from the gravels by a combination of vibrating action and specific gravity. The

Figure 5. This corundum crystal in syenite matrix was found in the Luc Yen area of Vietnam. Photo by N. D. Khoa.

last step is to separate the corundum from the remaining concentrate by hand. Gem recovery at Khoan Thong has been very high, averaging 19.6 grams per cubic meter.

Distribution of the final gem production is ostensibly controlled by the provincial government; however, local miners and dealers commonly travel to Hanoi and other major cities to sell their rough. To date, it appears that large amounts of this material have not arrived on the world gem markets (Weldon, 1991). An auction widely reported in the trade press has been delayed three times, with no date confirmed to the authors' knowledge as of October 1991 ("Ruby Auction in Vietnam," 1990; Federman, 1991; "Viets Delay Ruby Sales until . . .," 1991; "No Date for Ruby Auction in Vietnam," 1991; "Long-Awaited Auction May Come Off in July," 1991).

QUY CHAU

Location and Access. Late last year, mining was begun in northern Nghe An Province (again, see figure 2), near the village of Quy Chau. The potential ruby-bearing area covers approximately 400 km^2. The Quy Chau mining district is located about 120 km by road northwest of the city of Vinh, the administrative center of Nghe An Province, and 36 km northwest of the district center of Nghia Dan. As many as 10,000 miners have descended on the area during periods of peak mining, from all over Vietnam (figure 7).

The gem-bearing region is a mountainous area that reaches heights of 1,058 m near the villages of Quy Chau and Quy Hop. However, the actual gem deposits are concentrated in narrow valleys and along streams that form upper tributaries of the Hieu River. As at Luc Yen, mining is difficult in this tropical area during the May to November rainy season.

Geology and Occurrence. The Quy Chau deposits lie within the Bu Khang ruby zone of central Vietnam; geologists report that ruby mineralization covers approximately 2,000 km^2 near Bu Khang Mountain, with, as mentioned above, a 400 km^2 zone that appears to have the best ruby-bearing potential. The rubies have been found associated with tin minerals in Quaternary sediments. Detailed geologic study has not yet been conducted on the Quy Chau area.

The deposits near the village of Quy Chau, where the best rubies in the area have been found thus far, appear to be eluvial. Smaller, less transparent gems have been found in alluvial deposits near Quy Hop, south of Quy Chau.

Mining Methods. To date, mining at Quy Chau has been very primitive. Although some stones have

Figure 6. The Khoan Thong mining operation has been the most sophisticated to date in the Luc Yen area. The sluice carries the gem-bearing gravels, mixed with water, to a jig, where they are sorted. Photo by C. Mora.

Figure 7. At the height of activity in 1991, "independent" miners descended on the Quy Chau area from all over Vietnam in search of rubies and other gems. Photo by C. Mora.

Figure 8. In many parts of the Quy Chau ruby-bearing district, the gem-bearing gravels can be reached only by removing layers of clay and kaolin. Here a pile of wet gray kaolin (foreground) that has just been removed lies next to mounds of dry white kaolin. In the back can be seen the clay-like soil that covers the surface of the region. Photo by C. Mora.

Figure 9. At Quy Chau, pits may be dug as deep as 7 m to reach the gem-bearing gravels, and are reinforced with bamboo poles. Photo by C. Mora.

been found literally on the surface of the ground and in streams, the miners usually must first remove layers of kaolin and clay-like soil to reach the corundum-bearing gravels (figure 8). Pits—anywhere from one to several meters round or even square—are dug in the relatively soft overburden approximately 3 to 7 m deep to reach the gem-bearing layer. The pits are reinforced with bamboo canes (figure 9). Flooding is a constant problem, but thus far we have not seen pumps used. The gem-bearing gravel layer has been observed to be anywhere from approximately 1 to 8 m thick.

Once the gravels are removed, they are washed and sorted by hand (figure 10). In addition to ruby, miners have found pink and yellow sapphire, various colors of spinel, and some garnet. As at Luc Yen, spinel is the most common gem material found. Although the provincial government is holding monthly auctions of the material produced in its operations, to date most of the rough has been sold outside of legal government channels: at the mining area, in towns throughout the province, especially the city of Vinh, and in Hanoi and Ho Chi Minh City.

DESCRIPTION OF THE RUBIES AND FANCY SAPPHIRES

Luc Yen. Most of the gem-quality material ranges from 2 to 6 mm long. Although large pieces of rough are rare, they have been known to exceed 20 ct. Crystals from Luc Yen exhibit a regular prismatic shape typical of corundum (figure 11). Most of the rough is moderately worn, but some of the crystals found to date show unusually sharp faces, which suggests that they have not traveled far from their original source. In addition, at least one (inclined axis) twin crystal has been identified (E. Fritsch, pers. comm., 1991). The stones range in color from medium light to medium pink and medium to dark red, purplish red, and pinkish purple.

Quy Chau. Because this deposit is relatively new, little can be generalized about the rubies and fancy sapphires found there. Both extremely worn and relatively well-formed crystals have been seen to date. Our examination of the rough seen thus far indicates that in general these stones appear to be less included and, therefore, more transparent than much of the material from Luc Yen. One of the authors (NDK) has seen pieces of rough as large as 10 ct, and believes that this deposit could yield

Figure 10. For the most part at Quy Chau, the miners wash the gravels by hand using rudimentary "pans" in their search for rubies and other gem materials. Photo by C. Mora.

stones that are larger on average than Luc Yen. The material ranges from near colorless to red; most is pink to a lower saturation of red.

GEMOLOGICAL CHARACTERISTICS OF SOME RUBIES AND PINK TO PURPLE SAPPHIRES FROM VIETNAM

Four of the authors (REK, SFM, RCK, and JIK) examined more than 100 faceted rubies and pink to purple sapphires, ranging in weight from 0.17 to 1.94 ct, that were reported to be from the Luc Yen and Quy Chau mining areas in Vietnam. All of the 124 research stones were obtained by FIMO representatives in Vietnam from government sources, from independent miners in the Luc Yen and Quy Chau areas, and from "dealers" in Hanoi and Ho Chi Minh City. Routine gemological testing established that out of the 124 faceted samples that were provided to these investigators, one was a flame-fusion synthetic ruby, two were purple-red almandite garnets, and nine were natural spinels (ranging in color from pink to orangy red); thus leaving 112 natural rubies and fancy sapphires. This was not the first time the authors had seen flame-fusion synthetic rubies being represented as natural Vietnamese stones and reports in the trade press indicate that this is happening with some frequency (e.g., "Synthetic Found Mixed with Rough Ruby," 1991; Weidinger, 1991).

The remaining test samples, which were confirmed to be natural corundum, exhibited many characteristics that are typical of natural rubies and pink to purple sapphires from various geo-

Figure 11. A number of relatively well formed crystals (here, 4.75 cm long) have been found at Luc Yen. Photo © GIA and Tino Hammid.

TABLE 1. Gemological characteristics of rubies and pink to purple sapphires from the Luc Yen and Quy Chau gem districts of Vietnam.

Property	No. samples	Observations
Color	112	Moderate to highly saturated purplish red to purplish pink through reddish purple to pinkish purple in medium light to dark tones
Clarity	112	Most heavily included; few "eye clean"
Refractive indices	55	Most within the range: e = 1.759–1.762 o = 1.768–1.770
Birefringence	55	0.008–0.009
Optic character	55	Uniaxial negative
Specific gravity	9 cut 3 xls	3.97–4.00 3.99–4.00
Pleochroism	43	Moderate to strong dichroism; usually reddish purple to purplish red parallel to *c*-axis and orangy pink to orange-red perpendicular to *c*; colors vary slightly with body color of stone
U.V. luminescence	112	Strongest reactions in stones of medium to high saturations and medium to dark tones of pink to red; weaker reactions in lighter and/or more purplish stones; weakest reactions in stones with an orange component
Long-wave		Weak to very strong red to orangy red
Short-wave		Similar but weaker
Optical absorption spectrum (nm)	55	468.5 (sharp, narrow) 475 (extremely weak)] doublet 476.5 (sharp, narrow)] 659.2 (faint, narrow) 668 (faint, narrow) 692.8 (distinct, narrow)[a] 694.2 (distinct, narrow)[a]
Internal features	112	Distinct blue color zones, swirled growth features, laminated twinning planes, clouds of minute particles, orange-stained fractures, and solid inclusions of: calcite, apatite, nordstrandite, pyrrhotite, phlogopite, and rutile

[a]*May appear as a single bright (emission) line.*

graphic localities, in addition to some microscopic features that are distinctly different from any that we have observed thus far in natural rubies and fancy sapphires from other sources. Table 1 summarizes the gemological characteristics determined in this study for rubies and pink to purple sapphires from the Quy Chau and Luc Yen areas of Vietnam.

Visual Appearance. The most noticeable feature of many of the stones examined in this study is the similarity in color to rubies and pink sapphires from Mogok, although some of the stones are more purple than what is commonly thought of as "Burmese" color. These colors range from moderate to high saturations of purplish red to purplish pink through reddish purple to pinkish purple in medium light to dark tones (figure 12). A significant number of the sample stones also exhibited eye-visible blue color zones, giving them an uneven color appearance.

The clarity of the stones examined was relatively low. Very few were eye clean and some were so included that they were uniformly translucent. In fact, some stones appeared to be orangy red or orangy pink due to the presence of large orange-stained fractures, which are discussed later in the text. To date, the material examined by Savitech in Ho Chi Minh City has been 64% carving quality, 30% cabochon quality, and 6% faceting quality.

Refractive Indices and Birefringence. We obtained refractive index values with a GEM Duplex II refractometer and a near-monochromatic light source that approximates sodium vapor. The observed refractive index and birefringence values (see table 1) are within the ranges previously reported for rubies and pink to purple sapphires in general (Webster, 1983; Liddicoat, 1989), as well as those reported specifically for Vietnamese material (Bank and Henn, 1990; Henn and Bank, 1990, 1991; Brown and Chill, 1991; Koivula and Kammerling, 1991). One stone had values of 1.764–1.773, outside the normal range. However, this variation has been reported in corundums from other sources (Arem, 1987).

Specific Gravity. The specific gravity values for nine faceted stones (0.71–1.94 ct) and three pieces of transparent to translucent rough (7.10, 8.30, and 14.52 ct) were determined by the hydrostatic weighing method. The observed values agree with those previously reported in the literature for corundums from Vietnam and localities worldwide.

Polariscope Reaction. Surprisingly, it was difficult —and in some cases, impossible—to resolve an

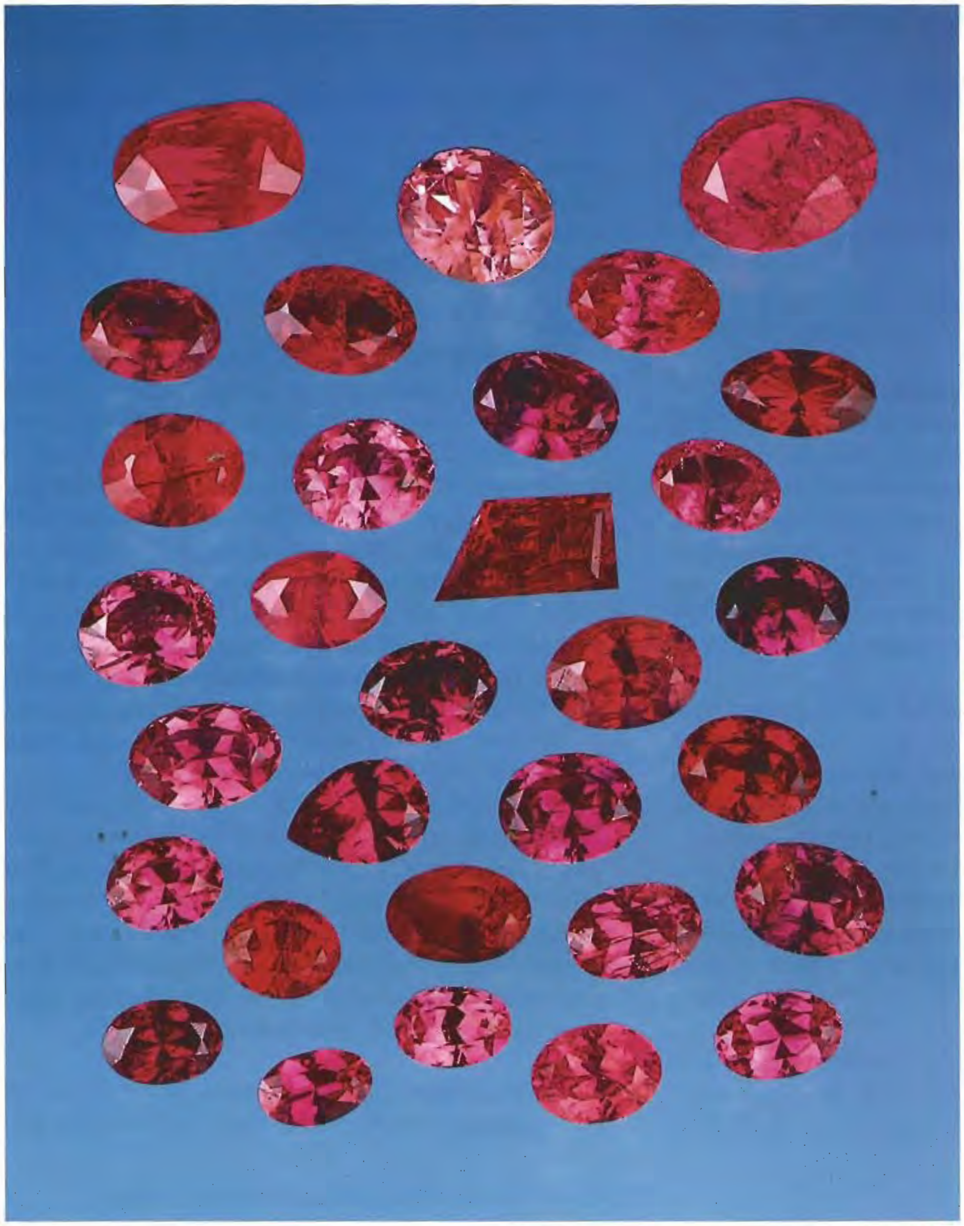


Figure 12. Rubies and fancy sapphires have been found in a broad range of colors and saturations at the Luc Yen and Quy Chau deposits in Vietnam. Note that the stone at the top center appears orangy because of the presence of large orange-stained feathers. These stones range from 0.17 to 1.94 ct. Photo by Shane McClure.

interference optic figure in the polariscope for many of the stones so examined with a standard condensing lens. This is believed to be due to the twinning structures that many of these stones exhibit (see "Growth Features" below).

Pleochroism. Forty-three of the Vietnamese stones were examined using a calcite dichroscope. The reactions observed are typical for rubies and pink to purple sapphires from other localities.

Reaction to Ultraviolet Radiation. All 112 Vietnamese corundums were exposed to long-wave (366 nm) and short-wave (254 nm) ultraviolet radiation. Stones of lower saturations and darker tones tended to be correspondingly weaker in fluorescence, as were stones of predominantly purple hues, possibly due to the presence of nonfluorescing blue zones and/or quenching by iron.

Approximately 40% of the stones exhibited very small to large zones that were completely inert to both wavelengths. These nonfluorescing areas correspond directly to the blue color zones in these stones (as is discussed below and was noted previously in Koivula and Kammerling, 1991).

Absorption Spectra. Visible-light absorption spectra were obtained with a Beck prism spectroscope mounted on a GIA GEM spectroscope base unit. Spectra for the Vietnamese rubies are essentially the same as the diagnostic absorption spectra described by Liddicoat (1989) for natural and synthetic ruby, purple sapphire, and dark "pad-paradscha" sapphire. The distinct lines at 692.8 nm and 694.2 nm often appear as a single bright fluorescent (emission) line, also typical for ruby.

Internal Characteristics. Careful microscopic examination of all 112 samples in this study revealed a wealth of interesting internal features. Some of the most commonly encountered internal features are reminiscent of those found in Burmese rubies, while others are similar to some found in rubies from Thailand. Still others are unlike those we have observed in stones from any other locality and appear at this time to be unique to rubies from Vietnam.

Note that the physical evidence indicates that most of the stones we examined had not been subjected to heat treatment. However, we have received reports that at least some Vietnamese rubies now in the trade have been heat treated (e.g., R. Crowningshield, pers. comm., 1991). It is reasonable to assume that the majority of the material from Vietnam, like ruby from virtually all other localities, will be heat treated at some point before it reaches the jeweler.

Color Zoning. One of the most notable features of these Vietnamese rubies and pink to purple sapphires is the presence of distinct medium-dark to dark blue color zones (figure 13) in most, though not all, of the specimens examined. These zones range in size from large areas to tiny slivers that follow growth planes. All are fairly to extremely well defined with sharp edges and distinct borders. Some consist of uniformly colored areas, whereas others consist of rather distinct, parallel color bands.

The fact that areas of blue zoning were observed in so many of the sample stones implies that such zones are typical of material from Vietnam; their presence has previously been noted in Vietnamese stones examined by other investigators (see, e.g., Brown and Chill, 1991; Hughes and Sersen, 1991; H. Hänni, as quoted in "Vietnam: An Important Potential New Source of Fine Ruby," 1990). They are not unique, however, to Vietnamese stones, having also been observed in some rubies from Jegdalek in Afghanistan (e.g., Bowersox, 1985) and from Nepal (Harding and Scarratt, 1986) as well as, by some of the authors, in pink sapphires from Montana and Sri Lanka.

In addition to the blue zoning, we also observed pink, orangy pink, red, and/or near-colorless zones in many samples (figure 14), as well as yellow zones in a few. In many cases, these color zones are so distinct as to be visible with the unaided eye, although details of the zoning are best seen using magnification in conjunction with immersion in methylene iodide (figure 15).

Growth Features. The stones we examined contain an abundance of irregular, "swirled" growth fea-

Figure 13. Distinct dark blue color zones were a common feature in the Vietnamese corundums examined in this study. Darkfield with shadowing and partially polarized illumination, magnified 35×; photomicrograph by Robert E. Kane.

Figure 14. Color distribution was very inhomogeneous in the stones examined in this study. Distinct red, pink, and near-colorless zones were common in many forms. Darkfield and shadowing, magnified 25×; photomicrograph by Robert E. Kane.

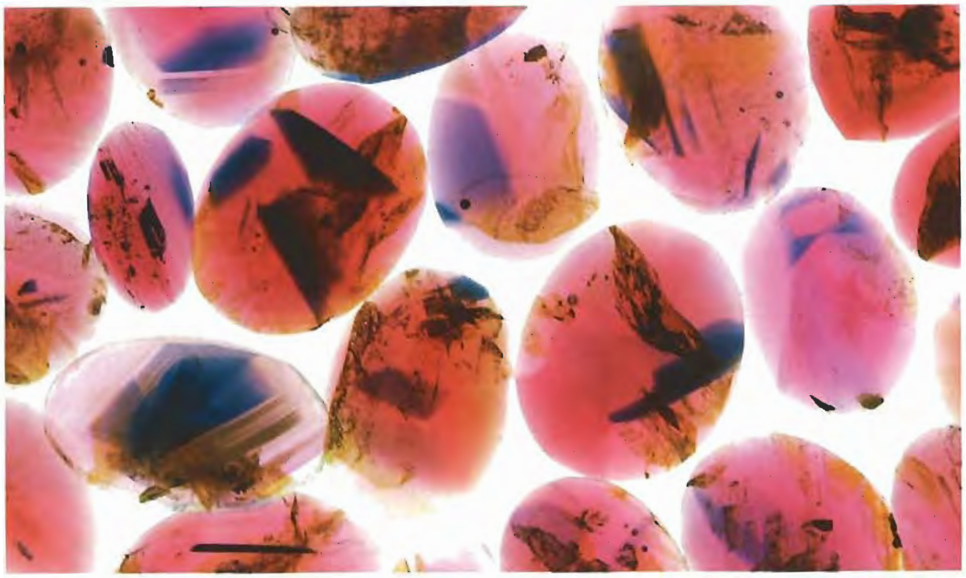


Figure 15. With immersion in methylene iodide, the numerous color zones found in these stones are easily seen. Transmitted light; photo by Shane McClure.

tures (figure 16). These are commonly referred to as a "treacle" or "roiled" effect (Webster, 1983) and were once considered unique to Burmese rubies (Gübelin and Koivula, 1986). In recent years, however, such swirl-like growth features have been observed by the authors (and reported by others) in rubies from several localities other than Myanmar—e.g., India and Tanzania—to which Vietnam should now be added. The pink, orangy pink, red, blue, and colorless zones previously mentioned are frequently related to this feature.

Straight and angular parallel growth features are also quite common and at times exhibit a wedge-shaped pattern. Such growth features have been observed by the authors and reported in the literature in natural rubies from many localities, such as Tanzania (Hänni and Schmetzer, 1991) and Myanmar. Care should be taken not to confuse these with similar-appearing features in flux-grown synthetic rubies (Kane, 1983).

Further research is being done on these growth features, and the results will be presented in a forthcoming article.

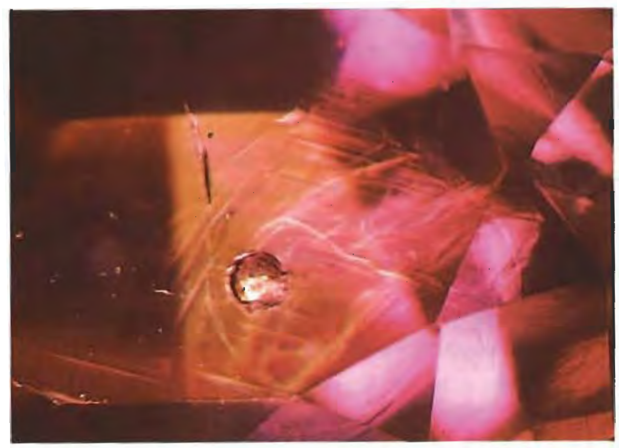


Figure 16. The swirl-like "treacle" or "roiled" effect that is frequently observed in Burmese rubies and fancy sapphires was also quite common in the Vietnamese stones examined. Darkfield, shadowing, and oblique fiber-optic illumination, magnified 30×; photomicrograph by Robert E. Kane.

Twinning. Curiously, a structural feature that is most commonly associated with Thai rubies was also frequently observed: abundant well-developed laminated twinning planes (figure 17). In many of the samples, thin, closely spaced twinning occurs throughout the entire stone. Other stones have more widely spaced, polysynthetic twinning; at some angles of observation, we noted different pleochroic colors from the adjacent, widely spaced twinning planes (figure 18). In most of the stones where this feature is present, the twinning runs in one direction only. In a minority of the stones examined, the twinning planes run in two directions and intersect. Other investigators have also noted this feature in Vietnamese stones (see, e.g., Henn and Bank, 1990; Hughes and Sersen, 1991; Brown and Chill, 1991).

Inclusions. To those who find the study of inclusions interesting, these rubies and fancy sapphires will be desirable for that reason alone. Although

Figure 17. Laminated twinning was observed in many of the Vietnamese corundums. Polarized light, magnified 35×; photomicrograph by Robert E. Kane.

Figure 18. What appears at first glance in this photo to be color zoning is actually the effect of differences in pleochroic colors between adjacent widely spaced (polysynthetic) twinning planes. Diffused transmitted illumination, magnified 25×; photomicrograph by Robert E. Kane.

some of the inclusions and growth features observed in these Vietnamese stones closely resemble those found in corundums from other deposits, there are some that the authors have not encountered before.

The most common such inclusions are two types of "clouds." One type is irregular to angular in outline and is composed of minute whitish particles dispersed fairly evenly throughout the cloud. Typically, the cloud appears to have a bluish cast, perhaps the result of a light-scattering effect. Although this bluish cast may be visible with darkfield illumination, it is extremely prominent when a fiber-optic light source is used. These clouds often correlate directly with the pink, yellow, or near-colorless areas that are usually associated with irregular (swirl-like) growth zones, as seen with diffused transmitted illumination (figure 19).

The second type of cloud, consisting of larger

Figure 19. Left: Distinctly bluish clouds were frequently encountered, although oblique fiber-optic illumination (as here) was usually necessary to see them. Right: These clouds were often observed in conjunction with red, pink, and near-colorless zones, as seen here in diffused transmitted light. Magnified 25×; photomicrographs by Robert E. Kane.

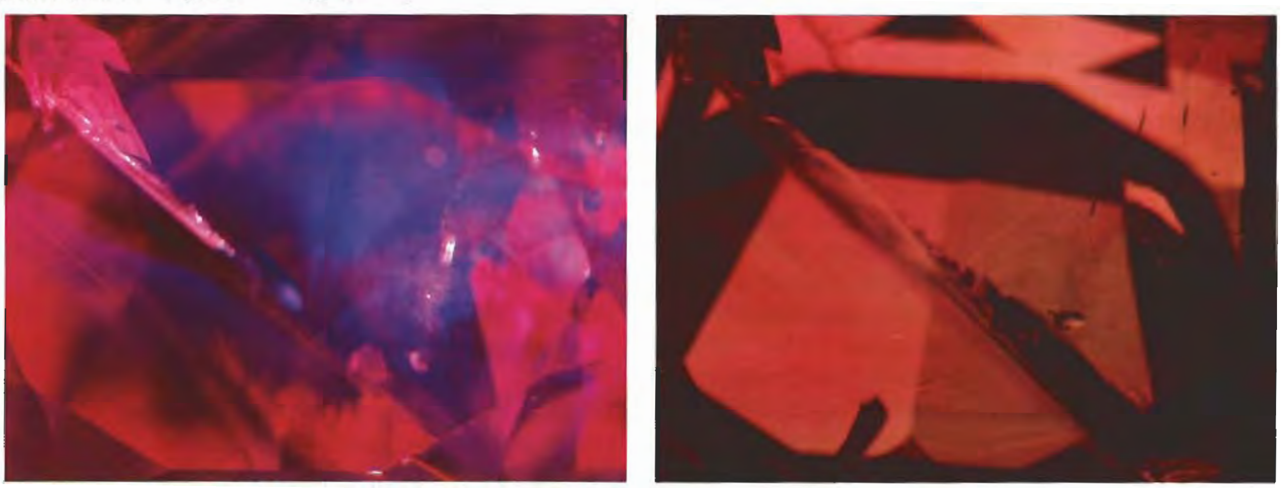


Figure 20. Irregular, whitish clouds that are somewhat wispy in appearance were often observed confined to straight growth planes in the stones in this test sample. Oblique fiber-optic illumination, magnified 20×; photomicrograph by Robert E. Kane.

Figure 21. Needle-like inclusions of what are probably boehmite were observed in some stones along the junctions of laminated twinning planes. Oblique fiber-optic illumination, magnified 30×; photomicrograph by Robert E. Kane.

whitish particles, has a less distinct outline and areas of varying density that give it a wispy appearance (figure 20). This type of cloud, which is typically confined to straight growth planes, may occur in small, often planar clusters or dominating large areas of a stone. When some of these clouds were examined with high magnification (above 50×), it was readily apparent that they are composed of tiny, acicular (needle-like), parallel inclusions of various lengths, probably rutile. Similar "needles" and minute to small particles have previously been identified as rutile in corundum from various localities.

We did not observe, in any of the stones, features that resemble the longer, acicular or shorter, wedge-shaped rutile needles that are most commonly associated with rubies and pink sapphires from Sri Lanka and Myanmar.

We did, however, see another type of acicular inclusion: very long, relatively coarse "needles" along the junctions of laminated twinning planes (figure 21). In both appearance and position relative to the twinning planes, they resembled the boehmite inclusions frequently seen in rubies from Thailand (Gübelin and Koivula, 1986) and many other sources. However, they were observed in relatively few of the Vietnamese stones and were less abundant within an individual stone than is typical of rubies from Thailand. (Note that Hughes and Sersen [1991] also report the presence in Vietnamese rubies of boehmite at crossing twin lamellae, although they do not indicate how they confirmed the identity of the inclusion.)

Partially healed fractures, planes of liquid inclusions, and two-phase inclusions were also commonly seen in this Vietnamese material, as they are in rubies from most localities.

Fractures, in fact, are perhaps the most common feature of the Vietnamese stones examined, and many stones had several of significant size. Interestingly, virtually all of these fractures contained bright yellowish orange to reddish orange staining (figure 22), most likely an iron oxide or

Figure 22. Orange staining was observed in nearly all of the numerous fractures present throughout this sampling of Vietnamese corundums. Darkfield illumination, magnified 25×; photomicrograph by Robert E. Kane.

Figure 23. Transparent irregular crystals of calcite were the most commonly encountered solid inclusion found in these stones. Darkfield and partially polarized illumination, magnified 25×; photomicrograph by Robert E. Kane.

hydroxide. Although such staining has been noted by the authors in corundum from a number of localities, e.g., Thailand and Myanmar, its prevalence in the Vietnamese stones seems unusual.

In addition to the different types of needles described above, we observed various other solid inclusions in these stones. Where inclusions broke the surface of the stone, we were able to identify them conclusively by means of X-ray powder diffraction analysis.

Figure 25. Subhedral transparent crystals of apatite were randomly arranged in a significant number of stones. Darkfield and partially polarized illumination, magnified 30×; photomicrograph by Robert E. Kane.

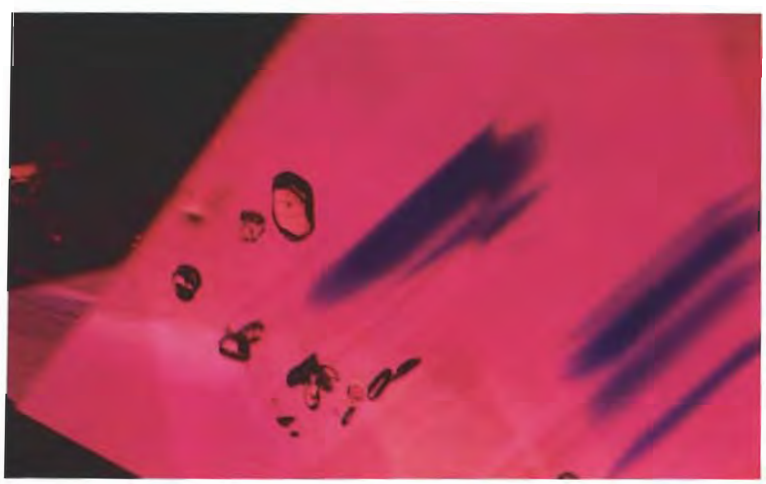


Figure 24. Several stones in this study contained unusual rod-like transparent crystals that proved to be an uncommon form of calcite. Darkfield and oblique fiber-optic illumination, magnified 40×; photomicrograph by Robert E. Kane.

The most common included crystals encountered were transparent, colorless, doubly refractive grains and masses with extremely variable and sometimes complex forms (figure 23). These crystals, which are subhedral to anhedral, proved to be calcite. Many are reminiscent of the calcite crystals encountered in Burmese rubies (Gübelin and Koivula, 1986).

Several stones also exhibited groups of very unusual transparent, elongated rod-like crystals that were curved and bent in some areas (figure 24). These unusual inclusions are visually somewhat similar to the etch pits observed by the authors in a number of gem species, including corundum. Where they reach the surface, however, reflected light readily revealed that they are solid crystals. X-ray diffraction proved these to be calcite as well.

Also seen with some frequency was another type of transparent, colorless, doubly refractive crystal. These are subhedral, range from tabular to short prismatic, and appear to be randomly oriented with respect to the host corundum (figure 25). X-ray diffraction confirmed these crystals to be apatite.

Using darkfield illumination, we observed in several stones what appeared to be black opaque rod-like crystals that also display no readily identifiable outward crystal form (figure 26) and are somewhat similar in shape to the transparent rod-like crystals described above. In fact, these black crystals were frequently associated with thin strings and rods of transparent crystals that are possibly the same material as pictured in figure 24. Fiber-optic illumination gives the crystals a distinct brownish color. Where these opaque crystals reach the surface it can be seen in reflected light

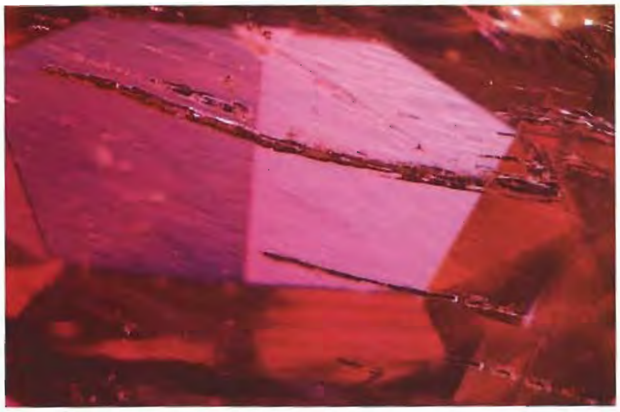


Figure 26. Black-appearing rod-like inclusions were also noted in some stones. These unusual inclusions are pyrrhotite, an iron sulfide. Darkfield illumination, magnified 35×; photomicrograph by Robert E. Kane.

that they are actually brassy yellow with a metallic luster. They were proved to be pyrrhotite.

Several stones had very unusual clusters of bright orange prismatic inclusions (figure 27). These very distinctive crystals were identified as rutile (again by X-ray diffraction). Peretti and Boehm previously identified crystals of rutile in Vietnamese rubies with microprobe analysis (as reported in Weldon, 1991).

At least 10 of the stones in this study contained irregular masses of a translucent yellowish orange material. These masses displayed no recognizable crystal form, were slightly fibrous to granular in appearance, and looked more like a secondary filling material than a primary inclusion (figure 28). X-ray diffraction produced a pattern that matched published values for the rare aluminum hydroxide nordstrandite [$Al(OH)_3$]. Comparison of our relatively weak pattern to a pattern obtained from a known sample of nordstrandite from Quebec, Canada, by Dr. Anthony Kampf of the Los Angeles County Natural History Museum showed an exact match.

Figure 27. Several stones exhibited clusters of bright orange crystals that were proved to be rutile. Oblique fiber-optic illumination, magnified 30×; photomicrograph by Robert E. Kane.

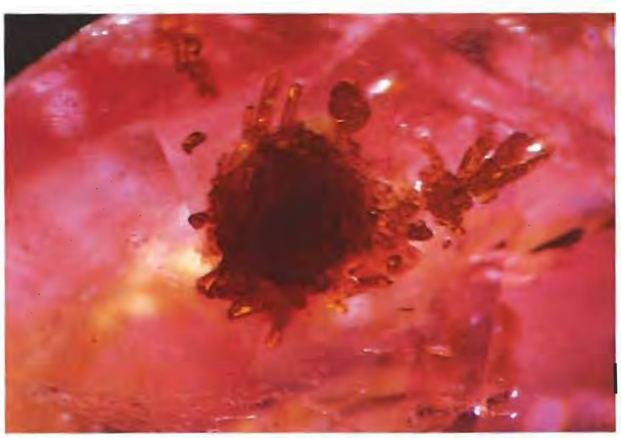


Figure 28. This unusual yellowish orange inclusion, consisting of the rare mineral nordstrandite, may be confused with flux found in Ramaura synthetic rubies. Darkfield and oblique fiber-optic illumination, magnified 30×; photomicrograph by Robert E. Kane.

Nordstrandite is a rarely encountered mineral that is trimorphous with gibbsite and bayerite. It was first described when produced synthetically in 1956 by Robert A. Van Nordstrand of Sinclair Research Laboratories in Illinois (Chao and Baker, 1982). Not until 1962 was it reported to occur naturally in Sarawak, Borneo, and in Guam, in both cases associated with limestone deposits (Wall et al., 1962). Since then it has been reported from other localities around the world, frequently as a secondary solution mineral filling cavities and fissures in limestone. On several occasions, it has been associated with syenite (Chao and Baker, 1982; Petersen et al., 1976). The authors could find no reference to nordstrandite previously being reported as an inclusion in gem corundum.

This inclusion should be of special concern to

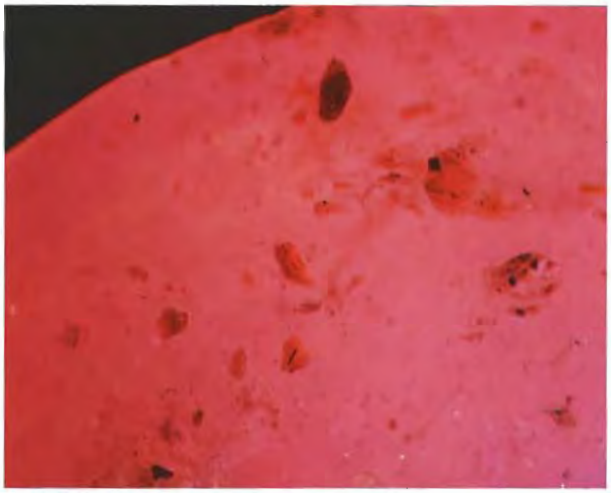
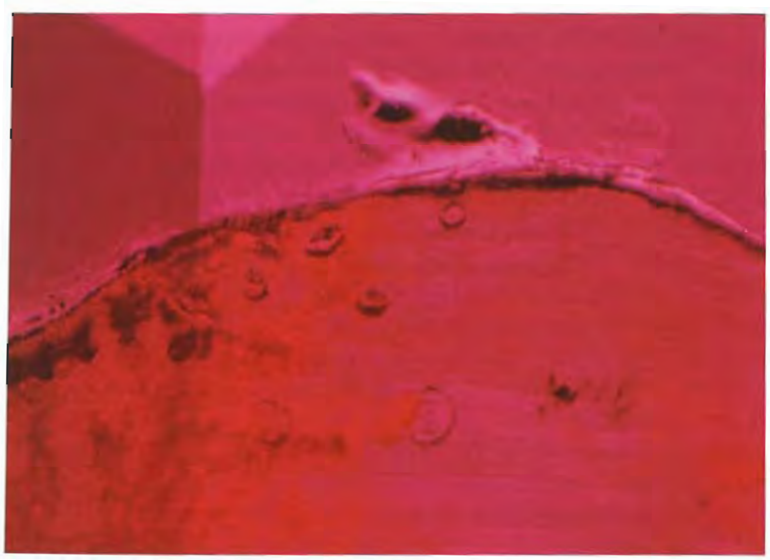


Figure 29. Brownish orange crystals of phlogopite mica were among the many solid inclusions found in these Vietnamese stones. Darkfield and oblique fiber-optic illumination, magnified 35×; photomicrograph by Robert E. Kane.

gemologists because it is very similar in appearance to the orange flux found in Ramaura synthetic rubies (Kane, 1983). However, the fibrous to granular appearance and yellower color of the nordstrandite inclusions should be sufficient to distinguish them from the crackled appearance and more orange color typical of the flux in the Ramaura synthetics.

Figure 30. One sample was found to have been repaired. Note the glue layer and the misalignment of the reattached portion. Magnified 30×; photomicrograph by John I. Koivula.



Also noted were transparent, brownish orange tabular crystals that appear somewhat rounded (figure 29). X-ray diffraction identified these as phlogopite mica. Other solid inclusions were observed in various forms and colors, but most have not yet been conclusively identified. There are some hexagonal platelets that are most likely hematite, but none in the stones we examined reached the surface.

Interestingly, one stone in the sample group was found to have been repaired. The bottom half of the pavilion had apparently separated along a fracture after faceting and was subsequently glued back on. The glue layer was easily seen, and the reattached portion was slightly misaligned (figure 30).

Chemical Analysis. The average chemical compositions of three samples, representative in color of the ruby and pink-purple sapphire from Luc Yen and purchased in Vietnam prior to the discovery of the Quy Chau deposits, were obtained by electron microprobe analysis at the California Institute of Technology (Paul Carpenter, analyst). These samples contain chromium as the most abundant minor element (0.19 to 2.08 wt.% Cr_2O_3), followed by smaller amounts of titanium (0.01 to 0.23 wt.% TiO_2), iron (0.01 to 0.04 wt.% FeO), and vanadium (0 to 0.03 wt.% V_2O_3). Small amounts of Zn and Ga were also found. These minor elements are all found in gem corundums from numerous localities. These results have been generally confirmed by Sam Muhlmeister and Bertrand Devouard during an ongoing study in GIA Research on the quantitative chemical analysis of rubies by energy-dispersive X-ray fluorescence (EDXRF; Muhlmeister and Devouard, in press). Slightly higher Fe content (0.02–0.30 wt.% FeO) has been found by these researchers in some purplish red stones from Vietnam. The Vietnamese rubies we have analyzed by both methods show low Fe contents, similar to those in Burmese material but lower than the Fe contents in rubies from Thailand (Tang et al.,1988).

Cutting. Experiments with a variety of cutting shapes and proportions have been performed at the Savitech cutting laboratory in Ho Chi Minh City. A variety of instruments, including a video camera, are used to study the passage of light as it is

Figure 31. A number of stones have been cut in Vietnam. This Vietnamese ruby, which was cut in Ho Chi Minh City, is set in a necklace designed and manufactured by Gianni Giacoppo.

refracted inside a stone in order to determine all the variables related to shape, color, and transparency.

To date, Savitech has produced thousands of transparent faceted (figure 31) and semi-transparent cabochon-cut stones from Luc Yen and Quy Chau. Most of the stones are small, ranging from 0.5 to 1.1 ct; the largest stone cut so far by the joint venture is approximately 5 ct.

OTHER GEM OCCURRENCES

Occurrences of other gem materials have also been identified in southern and central Vietnam (again, see figure 2). Although none of these is currently being mined commercially, all show promise for the production of economic amounts in the future.

The Sapphire, Ruby, Zircon, and Garnet Gem-Bearing Zones of Southern Vietnam. Blue and green sapphires, minor amounts of ruby, yellow and brown zircons, and pyrope garnets are widespread in alluvial or eluvial deposits on small basalt layers of various areas of southern Vietnam. Specifically, in addition to the deposits of rubies and fancy sapphires noted above, major occurrences of blue (figure 32) and other fancy-color sapphires have been discovered recently in the areas of Di Linh/Binh Dien (Lam Dong Province), Phan Thiet (Thuan Hai Province), and Gia Kiem (Dong Nai Province, at Xa Vo and Tien Co). These deposits, which range from about 1 to 4 km^2, occur in the weathering crust of alkali basalts. Approximately 60% of the sapphires found thus far are green; yellow sapphires are seen only rarely. Rough sapphires as large as 50 ct have been recovered.

Recent exploration also revealed yellow and brown zircons up to 20–25 mm in the Gia Kiem district, specifically at Sau Le and Gia Kiem. And beautiful red pyrope garnets up to 20–30 mm have been found at Bien Ho (Gia Lai-Kon Tum Province).

The Xuan Le Topaz-Beryl Zones of Central Vietnam. Aquamarine and colorless topaz have been found in Quaternary sediments in an area of the Thuong Xuan region (Thanh Hoa Province) that is estimated to be 1,200 km^2. These gem minerals are probably related to pegmatite bodies that intrude acidic volcanic rocks and Triassic sedimentary rocks.

In addition, minor amounts of aquamarine and other beryls, as well as amethyst and smoky quartz, have been found throughout Vietnam.

Figure 32. Vietnam is not only producing commercial amounts of rubies and fancy sapphires, but also has potentially significant deposits of blue sapphire. These stones, all of which were obtained in Vietnam, range from 0.28 to 0.42 ct. Photo © GIA and Tino Hammid.

CONCLUSION

Literally millions of carats of ruby and fancy sapphires have been mined in Vietnam since November of 1989. The first major discovery was at Luc Yen, in Yen Bai Province. In 1990, another major area began production in the vicinity of Quy Chau, in Nghe An Province, with as many as 10,000 "independent" miners working the deposit at one time. Although mining has been sporadic in recent months due to the annual rainy season, there appears to be considerable potential for the production of significant amounts of gem corundum for some years to come.

Much of the Vietnamese material is comparable to Burmese stones. For the most part, the gemological properties of the Vietnamese rubies and pink to purple sapphires are consistent with those of rubies and fancy sapphires from Mogok and other marble-type localities. Notable internal features in the Vietnamese samples examined include distinct blue color zones, a swirled growth ("treacle") effect, wedge-shaped growth features, well-developed laminated twinning planes, "clouds" of minute (rutile?) particles, and orange-stained fractures. A number of solid inclusions have been identified by X-ray diffraction analysis: calcite, apatite, pyrrhotite, phlogopite, and clusters of rutile. Irregular masses of translucent yellowish orange nordstrandite observed in some of the Vietnamese stones could cause the gemologist to confuse this material with some flux-grown synthetic rubies. It should be noted again that we have seen flame-fusion synthetic rubies that were purchased as Vietnamese rubies both in Vietnam and elsewhere.

While it is not unusual to find most of these minerals as inclusions in rubies and pink to purple sapphires, the form in which some of them occur in the stones from Vietnam is unique in the authors' experience: the rod-like habit of the pyrrhotite and some of the calcite inclusions; rutile crystals in the form of large, bright orange prisms; and the slightly bluish clouds of fine particles. We have not seen nordstrandite as an inclusion in rubies from any other locality.

The above is not meant to suggest that these inclusions, taken individually or as a suite of internal features, can be used to designate locality origin of rubies and pink to purple sapphires from Vietnam. In fact, as new sources of gem-quality ruby are discovered, we may learn that these features are not unique to material mined in Vietnam. Significantly, the recently reported deposits in southwestern China are not far from the Vietnamese border, and could conceivably be contiguous with the Vietnamese deposits (see, e.g., "Ruby Discovered in China Is Similar to Vietnamese," 1991). In addition, we have learned that rubies are currently being mined in Laos. It is quite possible, then, that many of the "Vietnamese" rubies now entering the world market are actually from any one of several deposits in Southeast Asia.

It also appears that heat-treated Vietnamese rubies have reached the market. While in-depth studies have not yet been performed on the heat treatment of rubies and sapphires from Vietnam, there is no reason at this time to believe that these stones will react differently from those from other geologically similar localities.

The gems described here are from the first significant gem deposits in Vietnam, and it is anticipated that they will not be the last. Discoveries of corundum and other gem materials in various regions of Vietnam suggest that this country could become a rich source as future exploration reveals additional deposits of economic significance.

REFERENCES

Arem J. (1987) *Color Encyclopedia of Gemstones*, 2nd ed., Van Nostrand Reinhold Co., New York.

Bank H., Henn U. (1990) Borsen Bulletin: Rubies from Vietnam. *Goldschmiede und Uhrmacher Zeitung*, No. 12, December, p. 106.

Bowersox, G.W. (1985) A status report on gemstones from Afghanistan. *Gems & Gemology*, Vol. 21, No. 4, pp. 192–204.

Brown G., Chill B. (1991) Vietnamese ruby. *Wahroongai News*, Vol. 25, No. 2, pp. 3–4.

China's ruby similar to ruby from Myanmar (1991). *Jewellery News Asia*, No. 85, p. 180.

Chao G.Y., Baker J. (1982) Nordstrandite from Mont St-Hilaire, Quebec. *Canadian Mineralogist*, Vol. 20, part 1, pp. 77–85.

Federman D. (1991) Gem profile: Vietnamese ruby. *Modern Jeweler*, Vol. 90, No. 8, pp. 23–24.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones*, ABC Edition, Zurich.

Hänni H.A., Schmetzer K. (1991) New rubies from the Morogoro area, Tanzania. *Gems & Gemology*, Vol. 27, No. 3, pp. 156–167.

Harding R.R., Scarratt K. (1986) A description of ruby from Nepal. *Journal of Gemmology*, Vol. 20, No. 1, pp. 3–10.

Henn U., Bank H. (1990) A gemological examination of ruby from Vietnam. *ICA Gazette*, November, pp. 9–10.

Henn U., Bank H. (1991) Rubine aus Vietnam. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 40, No. 1, pp. 25–28.

Hughes R.W., Sersen W.J. (1991) Bangkok gem market review: Vietnamese ruby. *Gemological Digest*, Vol. 3, No. 2, pp. 68–70.

Kane R.E. (1983) The Ramaura synthetic ruby. *Gems & Gemology*, Vol. 19, No. 3, pp. 130–148.

Koivula J.I., Kammerling R.C. (1990) Gem news: Rubies from Vietnam? *Gems & Gemology*, Vol. 26, No. 2, pp. 163–164.

Koivula J.I., Kammerling R.C. (1991) Gem news: More on Vietnam gem finds. *Gems & Gemology*, Vol. 27, No. 1, pp. 51–52.

Liddicoat R.T. (1989) *Handbook of Gem Identification*, 12th ed., 2nd rev. printing. Gemological Institute of America, Santa Monica, CA.

Long-awaited auction may come off in July (1991). *JewelSiam*, June–July, p. 25.

Muhlmeister S., Devouard B. (in press) Trace element chemistry of natural and synthetic rubies. In A. S. Keller, Ed., *Proceedings of the 1991 International Gemological Symposium*, Gemological Institute of America, Santa Monica, CA.

No date for ruby auction in Vietnam (1991). *Jewellery News Asia*, No. 77, p. 48.

Petersen O.V., Johnsen O., Leonardsen E.S. (1976) Nordstrandite from Narssârssuk, Greenland. *Mineralogical Record*, Vol. 7, No. 2, pp. 78–82.

Ruby discovered in China is similar to Vietnamese (1991). *ICA Gazette*, August, p. 11.

Ruby auction in Vietnam (1990). *Thailand Jewellery Review*, August, p. 34.

Synthetic found mixed with rough ruby (1991). *Jewellery News Asia*, No. 85, p. 172.

Tang S.M., Tang S.H., Tay H.S., Retty A.T. (1988) Analysis of Burmese and Thai rubies by PIXE. *Applied Spectroscopy*, Vol. 42, No. 1, pp. 44–48.

Tien P.C., Ed. (1989) *Geology of Kampuchea, Laos and Vietnam*. Institute for Information and Documentation of Mines and Geology, Hanoi, Vietnam.

Vietnam: An important potential new source of fine ruby (1990). *ICA Gazette*, November, p. 8.

Vietnam claims major ruby find (1990). *Jewelers' Circular-Keystone*, Vol. 161, No. 12, pp. 22, 24.

Viets delay ruby sales until . . . (1991). *Jewelers' Circular-Keystone*, Vol. 162, No. 3, p. 36.

Wall J.R.D., Wolfenden E.B., Beard E.H., Deans T. (1962) Nordstrandite in soil from West Sarawak, Borneo. *Nature*, Vol. 196, No. 4851, pp. 264–265.

Webster R. (1983) *Gems: Their Sources, Descriptions and Identification*, 4th ed., Rev. by B. W. Anderson. Butterworth & Co., London.

Weidinger W.A. (1991) Beware of deception on Vietnamese rubies. *Jewelers' Circular-Keystone*, Vol. 162, No. 7, p. 92.

Weldon R. (1991) Why the Vietnam reds are giving us the blues. *Jewelers' Circular-Keystone*, Vol. 162, No. 5, pp. 46–48.

NEW RUBIES FROM THE MOROGORO AREA, TANZANIA

By H. A. Hänni and K. Schmetzer

The authors present the mineralogical and gemological properties of rubies found recently in the Morogoro area of Tanzania that have many features in common with rubies from Myanmar (Burma) and other comparable marble-type deposits. Specifically, microscopic investigations of these Morogoro stones revealed some internal characteristics that are also seen in Burmese rubies—such as angular growth zoning, curved growth zoning ("swirls"), negative crystals, spinel crystals, rutile needles, and clouds of minute particles in areas defined by both types of growth zones, which may also be related to color zoning. However, the Morogoro material appears to have (1) lower amounts of V and Ga than Burmese rubies, and (2) a characteristic angular growth with r, a, *and* r' *faces. A gemological comparison of the recently produced Morogoro rubies with rubies found earlier in this area shows significant differences.*

ABOUT THE AUTHORS

Dr. Hänni is director of the Swiss Gemological Institute (SSEF), Zurich, and associate professor of gemmology at Basel University. Dr. Schmetzer is a research scientist residing in Petershausen, near Munich, Germany.

Acknowledgments: The authors are grateful to W. Spaltenstein, of Bangkok, Thailand, for providing the Morogoro specimens examined; to R. Guggenheim and M. Düggelin, of Basel University, Switzerland, for peforming the SEM-EDS analyses; and to H.-J. Bernhardt, of Ruhr-Universität Bochum, Germany, and H. Schwander, of Basel University, for the microprobe analyses.

Gems & Gemology, Vol. 27, No. 3, pp. 156–167.

In June 1987, one of the authors first received samples of gem-quality spinels from an apparently new source. The red, orange, reddish purple, purplish blue, and blue spinels reportedly originated from the Morogoro area in Tanzania. Physical, chemical, and spectral characteristics of the spinels were found to be within the range of natural gem spinels from classic localities such as Myanmar (Burma) and Sri Lanka (see, e.g., Schmetzer et al., 1989). Microscopic examination revealed the presence in about 70% of the samples of a characteristic feature that had not previously been noted in spinels: intersecting, doubly refractive, thin lamellae of what was later determined to be högbomite (Schmetzer and Berger, 1990), oriented parallel to the octahedral faces of the host spinel crystals.

Several parcels of rough and faceted stones subsequently examined were found to contain a high percentage of material with these högbomite lamellae, which suggested that the samples originated from a common source. All but one of the independent dealers who showed us these parcels cited the Morogoro area of Tanzania as the origin of the gem spinels (see also, Bank et al., 1989).

In the course of examining parcels of these spinels, the authors identified several samples of ruby; in fact, approximately 10% of the stones in these large "spinel" parcels were determined to be ruby or "light ruby."*

The two superficially similar minerals—rhombohedral ruby crystals and octahedral spinel crystals—were generally identified as two different materials before cutting. However, some dealers did not know that their spinel parcels contained facetable rubies, some of good to excellent quality (figure 1).

In recent months, significant quantities of Morogoro rubies of the type described here have been seen in the trade (E. Fritsch, pers. comm., 1991). According to C. Bridges (pers. comm., 1991), the principal ruby mines within the Morogoro area are the Epanko, Kitonga,

Figure 1. A new find of fine rubies has emerged from the Morogoro area of Tanzania. These cut stones range from 0.51 to 3.31 ct; the rough ranges from 5.65 to 8.55 ct. Photo by Shane F. McClure.

Lukande, Matombo, and Mayote. C. Forge, a French geologist who has visited the region, reports that Matombo is the locality where rubies occur together with spinels (pers. comm., 1991; figure 2).

Initial inspection of the samples using routine gemological methods revealed that they contained some types of inclusions that had long been regarded exclusively as characteristic of Burmese rubies. Because determination of the locality origin of rubies, sapphires, and emeralds is one of the most difficult tasks for gemological laboratories that provide this service, the authors attempted to ascertain definitive criteria that would allow these new Tanzanian rubies to be distinguished from those from Mogok and comparable marble or marble-related deposits.

We also noted that these new Morogoro rubies differ significantly from the largely cabochon-quality rubies that emerged earlier from this same area (Schmetzer, 1986b). Features that distinguish these two types of Tanzanian rubies are also presented in this article.

MATERIALS AND METHODS

More than 60 samples of new material from Morogoro were examined, including approximately 50 rough crystals, 10 faceted stones, and three cabochons. All were taken from the parcels of spinels with distinctive högbomite lamellae that were reported to be from the Morogoro area of Tanzania.

Refractive indices and densities were obtained by standard gemological methods. Seven samples (four rough and three cut), representing the range

* *Editor's note: "Light rubies" (lighter tones and/or lower saturations of red) would be called pink sapphires by the GIA Gem Trade Laboratory, Inc.*

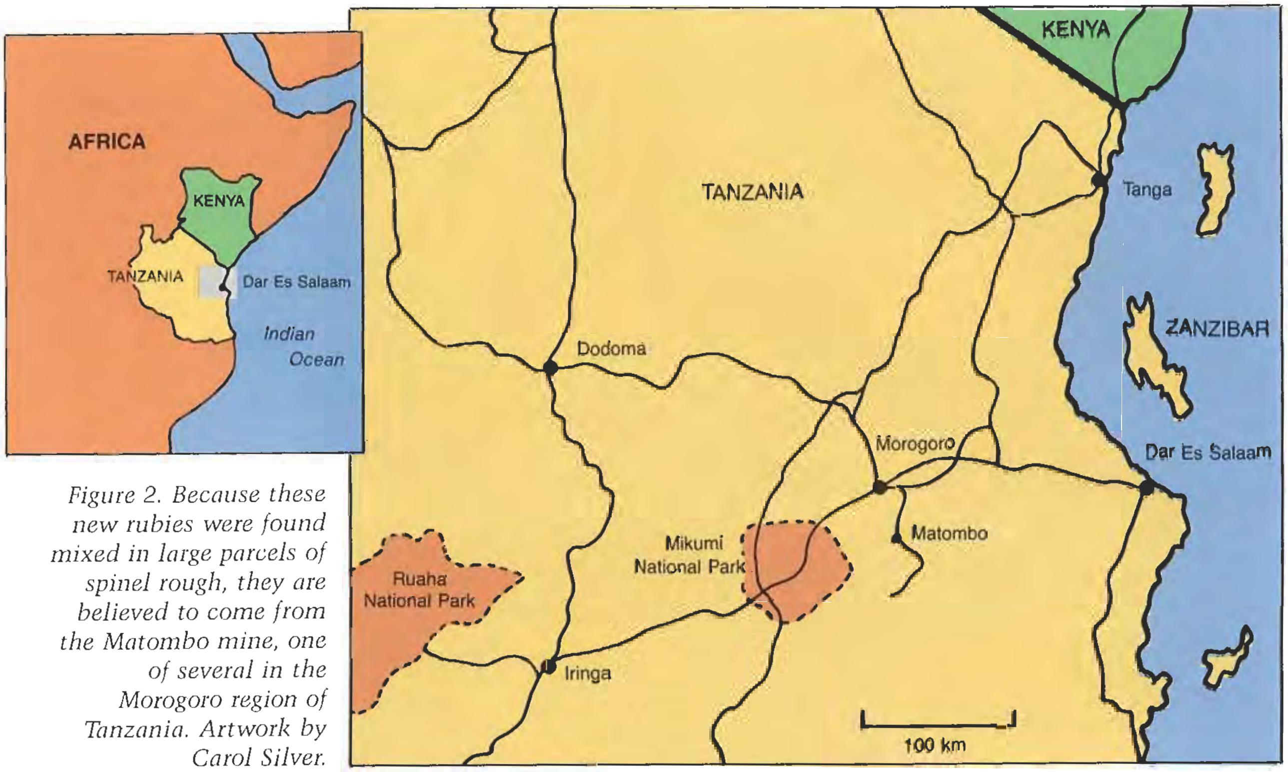


Figure 2. Because these new rubies were found mixed in large parcels of spinel rough, they are believed to come from the Matombo mine, one of several in the Morogoro region of Tanzania. Artwork by Carol Silver.

of typical appearances, were analyzed for trace-element contents by energy-dispersive X-ray fluorescence spectroscopy (Tracor X-ray instrument; operating conditions available on request to the authors). A total of 48 point analyses were performed on three faceted ruby samples with a Cameca Camebax microprobe operating at 15 kV and 15 nA, using wavelength-dispersive spectrometry. Two microprobe analyses of one spinel inclusion were performed with a JEOL JAX-8600 Superprobe with combined energy-dispersive/wavelength-dispersive spectrometry under operating conditions of 15 kV and 15 nA. Zn was not quantified, but it was determined to be present. Zircon, apatite, and garnet inclusions were identified by qualitative analysis on a Philips SEM 515 with Tracor EDS system. Spectral data in the U.V.–visible range were obtained with Leitz-Unicam SP.800 and Pye-Unicam SP8-100 UV-Vis spectrophotometers, on approximately 20 representative samples.

Indexing of internal and external growth planes was performed on selected samples with a horizontal (immersion) microscope by the methods described in Schmetzer (1986a) and Kiefert and Schmetzer (1991). Photomicrographs were obtained with a Schneider immersion microscope with Zeiss optics and with a Wild-Leitz Stereomicroscope M8 with Fotoautomate MP S 55.

RESULTS

Visual Appearance. The rough samples examined varied from small, mostly elongated, flat to isometrically shaped crystals, and included irregularly terminated rough (figures 1 and 3) The largest piece of rough examined was 20 ct. Diaphaneity varied from translucent to transparent, depending on the relative content of inclusions. When rutile is

Figure 3. These ruby crystals were sorted from parcels of rough spinels that were reportedly from the relatively new find at Morogoro. The largest pieces are approximately 20 ct. Photo by H. Hänni.

Figure 4. Some of the Morogoro stones had sufficient rutile throughout to produce asterism when cabochon cut, as was the case with the approximately 4-ct stone in this ring. Photo by Shane F. McClure.

densely distributed throughout a crystal, asteriated stones may be cut (figure 4). The largest cut stone examined was approximately 4 ct.

Our samples varied from a red of medium saturation to a purplish red of medium to weak saturation. These colors compare favorably to those associated with medium-toned and "light" Burmese rubies.

Although we saw few fully transparent rubies, approximately one-fifth of the rough Morogoro stones we examined were sufficiently transparent for faceting. Most of the material was cabochon quality. However, such stones are commonly heat treated to improve clarity by burning off irregularly distributed rutile silk. Fractured rubies also may be subjected to a type of heat treatment—similar or identical to that used to produce glass-filled cavities in corundum—in which a borate melt fills the voids and, after prolonged heating, acts as a flux that causes a certain recrystallization of fracture planes (as described by Hänni, 1986a and b).

Physical and Optical Properties. We obtained refractive indices of n_o = 1.769 to 1.770 and n_e = 1.761 to 1.762, resulting in a birefringence of 0.008. Densities, determined hydrostatically, were found to vary between 3.99 and 4.01 g/cm^3. These values are typical for rubies from all localities. We observed a strong red fluorescence to long-wave ultraviolet radiation (365 nm), and a weaker red to short-wave U.V. (254 nm); these reactions are identical to those of Burmese rubies. Pleochroism of yellowish red parallel to the c-axis and reddish violet perpendicular to *c* was the same as that for rubies from similar marble-type deposits.

Chemical Properties. Energy-dispersive X-ray fluorescence (EDXRF) analyses (Stern and Hänni, 1982) of five samples revealed the presence of chromium and small concentrations of gallium, iron, and titanium. No vanadium was detected.

Three faceted samples were analyzed by electron microprobe to provide quantitative data on major and trace elements. The results are listed in table 1, along with optical data for the samples. Chromium is the only effective color-causing element observed and thus governs and correlates with the intensity (saturation) of red color. Titanium was present above, while iron and vanadium were found at or below, the limit of detection for the microprobe (approximately 0.02 wt.%). Because Fe and V are very low or absent, they provide no superimposed effect on color in this instance. The small variations in optical values and density

TABLE 1. Optical properties and chemical data for three rubies from the new deposit in the Morogoro area, Tanzania.

	Sample 1	Sample 2	Sample 3
Optical properties and color			
Color	Medium strong red	Medium red	Pink
Refractive indices			
n_o	1.770	1.770	1.769
n_e	1.762	1.762	1.761
Δn	0.008	0.008	0.008
Electron microprobe analyses[a]			
No. of analyses	14	16	18
Al_2O_3	99.04 – 99.58	99.40 – 99.80	99.46 – 99.79
TiO_2	0.02 – 0.05	0.02 – 0.03	0.02 – 0.04
V_2O_3	$\leq$ 0.02	$\leq$ 0.02	$\leq$ 0.02
Cr_2O_3	0.29 – 0.49	0.21 – 0.37	0.10 – 0.22
Fe_2O_3	$\leq$ 0.02	$\leq$ 0.02	$\leq$ 0.02

[a]*Ranges in wt.%. See text for details of analysis.*

noted above occur because of the minor substitution of aluminum by other elements, especially chromium.

For comparison with the chemistry of rubies from other localities, see Kuhlmann (1983), Schmetzer (1986b), Tang et al. (1988, 1989), and Muhlmeister and Devouard (1991).

Optical Spectroscopy. In the hand spectroscope, Morogoro rubies reveal the typical ruby spectrum without characteristic iron bands. The absorption spectrum as recorded by spectrophotometer (figure 5) is also without any peculiarities. Again, there are no signs of iron in either the visible or the ultraviolet range. The curve in the ultraviolet to blue portion of the spectrum exhibits broad absorption minima at 365 and 480 nm for the *o* vibration and at 350 and 484 nm for the *e* vibration. These spectra are nearly identical to those reported for most Burmese rubies (Bosshart, 1982; Schmetzer, 1985, 1986b). A shoulder near the absorption edge at 315 nm is not always as prominent in the spectra of Morogoro rubies as is shown in figure 5, and may actually be absent.

Microscopic Characteristics. *Growth Features.* Two types of growth zoning were observed in rubies from Morogoro: curved (swirl-like) and

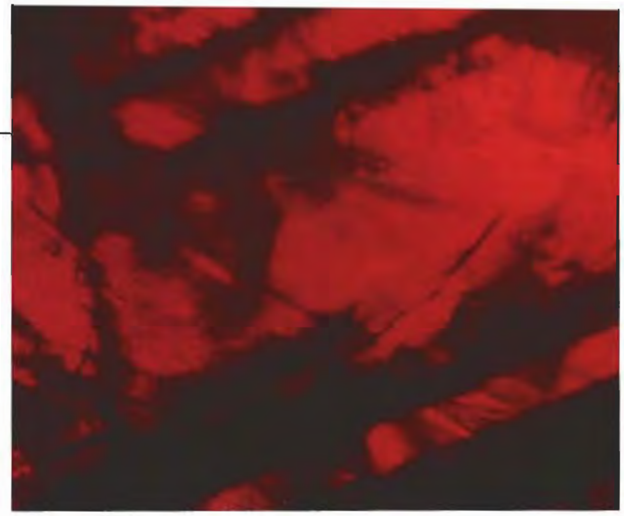
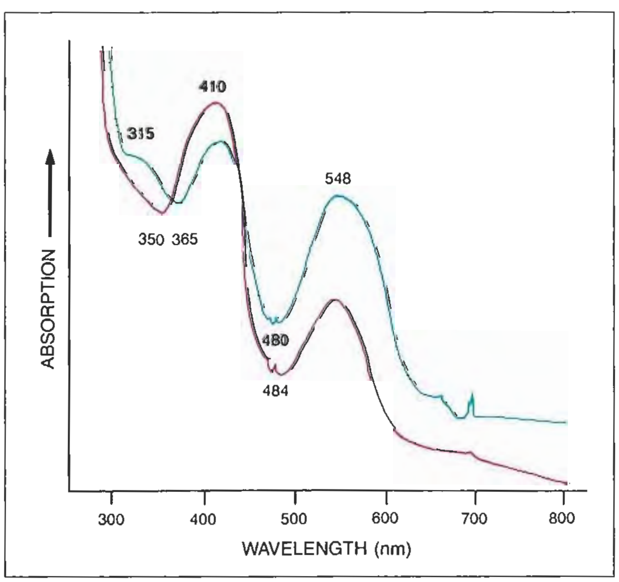


Figure 6. Some of the Morogoro stones revealed swirl-like growth features. Immersion, magnified 50×; photomicrograph by K. Schmetzer.

straight or angular. Irregular "swirls" that are quite similar to those long associated with Burmese rubies occasionally occur in the Morogoro material (figure 6) and, as discussed elsewhere in this issue (Kane et al., 1991), have recently been observed in Vietnamese rubies as well. These curved growth features, which commonly occur as swirled color zoning, too, are due to complex surfaces (e.g., stepped surface growth or etched, dissolved surfaces) that were subsequently overgrown during crystal formation by layers of corundum of different chemical composition (especially chromium) and/or inclusion content. Such optical inhomogeneities are well known in, and have been considered a typical feature of, Burmese rubies (e.g., Gübelin and Koivula, 1986; Schmetzer, 1986b). Although present in some of the Tanzanian stones, such swirled growth zoning was not observed in the majority of samples examined.

Figure 5. The absorption spectrum of a Morogoro ruby is typical of that commonly observed in rubies from different localities, especially Mogok or other marble-type deposits.



Most of the Morogoro rubies exhibited combinations of straight growth planes that were observed to lie parallel to the three major morphologic faces *c*, *r*, and *a* (figure 7). These straight or angular layers may differ from one another in chemical composition—and thus, for example, in transparency or color. In these rubies from Tanzania, inclusions are usually concentrated in specific zones defined by these straight or angular growth planes. In addition, most color zoning is related to these same growth features. In fact, we found that angular color zoning parallel to faces *r*, *a*, and *r'* (two rhombohedral and one prism) is characteristic of these Morogoro rubies (again, see figure 7). Less frequently, we observed color zoning parallel to a combination of the two rhombohedral faces *r* and *r'*.

The angle between the faces *r* and *a* equals 137.0° (see Box A, figure A-2, and figure 7), and the

BOX A: CRYSTAL MORPHOLOGY

We distinguished three predominant shapes of rough: (1) flattened to tabular pseudo-cubes (referred to here as "pseudo-squares"); (2) pseudo-cubes; and (3) corroded, irregularly terminated samples. In all samples examined, the basal plane *c* (0001) and the positive rhombohedron *r* (10$\bar{1}$1) were observed to be dominant faces (figure A-1a). In some of the samples, six additional subordinate prism faces *a* (11$\bar{2}$0) were found (figure A-1b); these were sometimes similar or equal in size to the positive rhombohedron *r* and the basal plane *c* (figure A-1c). The angles between rhombohedral faces *r* and *r'* of corundum are 86° and 94°, respectively – very close to a right angle. Rubies with dominant rhombohedral faces, therefore, form cube- to square-like shapes, according to the relative size of the six rhombohedral faces. On one crystal, a small hexagonal dipyramid *n* (22$\bar{4}$3) was also observed.

In all of the crystals we examined, two of the eight corners of each "cube" are cut off by triangular faces (figure A-1a), the crystallographic basal planes *c*. If parts of the edges of the pseudo-cubes or pseudo-squares are also cut off, the faces of the hexagonal prism *a* are formed. These prism faces form right angles with the basal planes *c* and exhibit lath-like forms (figures A-1b,c).

When two of the eight corners of a pseudo-square or a pseudo-cube are replaced by triangular faces, habits that superficially resemble spinel octahedra are formed (figure A-1a). In other words, the six quadrilateral faces *r* of a corundum crystal without basal faces *c* are altered to pentagonal faces by the addition of two basal pinacoids *c*.

If the crystal faces are of a certain size, fine parallel striations can be seen with the unaided eye or a 10× loupe. These lines represent the traces of narrow twin lamellae of corundum that cut the crystal faces *c*, *r*, and *a*.

Normally, ruby and spinel are easily distinguished with a spectroscope or dichroscope, but this is not always possible. For example, in heavily twinned crystals, which have three sets of lamellae, the dichroic colors of the main crystal may be hidden by the many narrow twin lamellae, which are present in different orientations. Therefore, observation of the traces of protruding twin lamellae (which show up as sets of parallel lines on the crystal faces) or closer examination of the crystal morphology may be helpful in some situations to indicate that a crystal is corundum with rhombohedral habit rather than spinel. Note that the octahedral angle of spinel, at 109.5°, is distinctly different from the rhombohedral angle of corundum, which is 93.9° (figure A-2).

The morphologic characteristics observed in our Morogoro ruby samples have also been described for some Burmese rubies (Bauer, 1896; Melczer, 1902). Tanzanian crystals with rounded shapes and outlines that have a smooth but corroded surface also strongly resemble ruby crystals from Mogok. The only differences that can be cited at present are that the hexagonal dipyramid *n* seems to be more common and/or somewhat larger in Burmese rubies than in those from Morogoro, and that the prism faces *a* may be more dominant or larger in Burmese rubies.

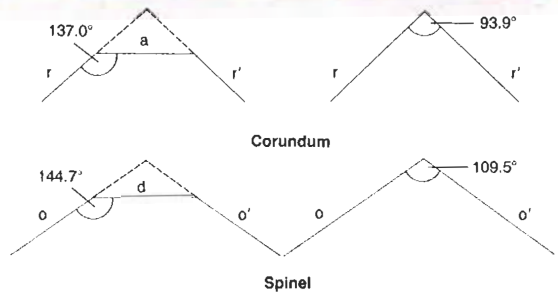
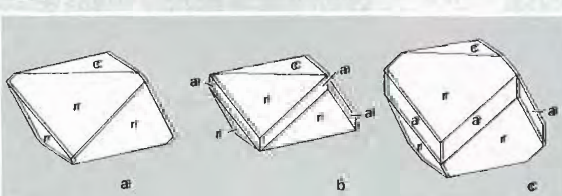


Figure A-2. The characteristic angles of corundum (left in photo), formed by rhombohedral and prism faces, are distinctly different from the characteristic angles of spinel (right in photo), formed by octahedral and dodecahedral faces. Photo by Shane F. McClure.

Figure A-1. The ruby crystals from Morogoro show the basal plane c (0001), the positive rhombohedron r (10$\bar{1}$1, and the prism a (11$\bar{2}$0) as dominant crystal faces.



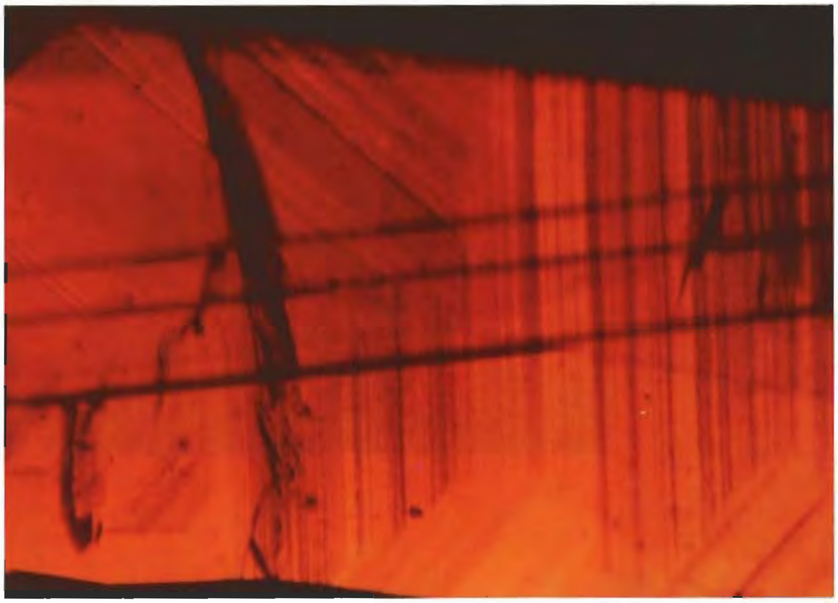


Figure 7. Growth planes parallel to two rhombohedral and one prism face, evident here as straight and angular layers of color, are characteristic of the Morogoro rubies examined. Note also the irregular distribution of what appears to be rutile dust in the growth zones. This growth structure is easily seen in faceted samples as well. Immersion, magnified 40×; photomicrograph by K. Schmetzer.

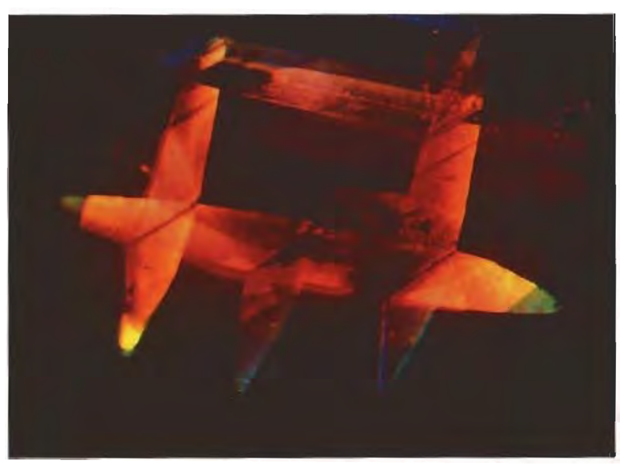
angle between faces *r* and *r'* is 93.9°. In one cut stone, growth structures parallel to *n*, *r*, and *n'*—i.e., with two angles of 154.0°—were observed. Growth planes parallel to two rhombohedral faces and one prism face that form two angles of 137.0° have been, until now, observed only rarely in rubies from other localities, including those from Mogok. Consequently, since this structural feature is encountered very frequently in the type of Tanzanian ruby described here, it can be regarded as characteristic of this locality. It is useful for purposes of identification as well, since it has never been observed in synthetic rubies. These structural differences are useful for distinguishing rough, faceted, or even cabochon-cut samples (Schmetzer, 1986a).

The Morogoro rubies also frequently exhibit narrow twin lamellae oriented parallel to one or, commonly, two or three rhombohedral faces. When these sets of thin lamellae occur parallel to only one rhombohedral face, the interference figure of the ruby commonly looks somewhat distorted, but it is still visible. When there are two intersecting systems of lamellae, the intersection forms a set of relatively coarse, parallel straight lines that can easily be seen with a microscope (figure 8). With twin lamellae present parallel to three rhombohedral faces, there will be three sets of these straight lines intersecting one another at angles of 94° and forming a nearly rectangular, three-dimensional framework.

Since the twin lamellae possess a certain thickness, the portions of corundum that lie in straight lines within the intersections (figure 9) appear as rods with square or rectangular cross-sections. Eppler (1974) referred to these as "inclusions of corundum needles." Schmetzer (1986b) noted that the side walls of these rods are often covered with polycrystalline boehmite (again, see figure 9). Such features are common in rubies and sapphires from several localities that show repeated twinning parallel to more than one rhombohedral face (Hänni, 1987), and provide a quick, conclusive method of separating natural from synthetic stones.

Occasionally, small fissures are confined to

Figure 8. The Morogoro rubies frequently exhibited narrow twin lamellae oriented parallel to one or more rhombohedral faces. Here, two systems of lamellae intersect. Immersion, crossed polarizers, magnified 25×; photomicrograph by K. Schmetzer.



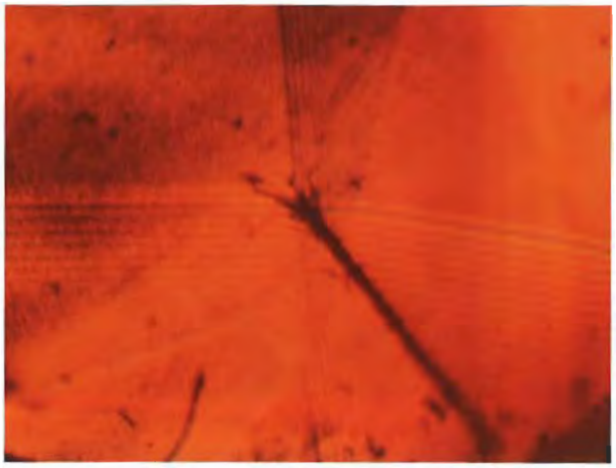


Figure 9. When the stones are viewed with immersion at high magnification (80×), the intersecting lamellae are apparent as coarse, parallel straight lines. In this stone, small boehmite particles can be seen confined to the intersection line of the lamellae. Photomicrograph by K. Schmetzer.

these intersection lines from which they hang like flags on a rope (figure 10). While it is not currently known what causes these fissures, they may arise from stress and strain due to deformation forces applied to the parent rock.

Negative Crystals. Also well known in Burmese rubies is the presence of negative crystals that repeat, in the case of our Tanzanian rubies (figure 11), the externally dominant faces *c*, *r*, and *a*, and thus resemble small octahedral crystals. These inclusions were recognized in Burmese rubies by Eppler (1976) as negative crystals, although they had frequently been mentioned earlier as spinels (e.g., Eppler, 1974).

When examined with the microscope, these inclusions showed a very strong Becke line and, where they were exposed at the surface, were determined to be cavities.

Figure 10. Small fissures were occasionally seen confined to the intersection lines of the twin lamellae, hanging from them like flags. Magnified 20×; photomicrograph by H. Hänni.

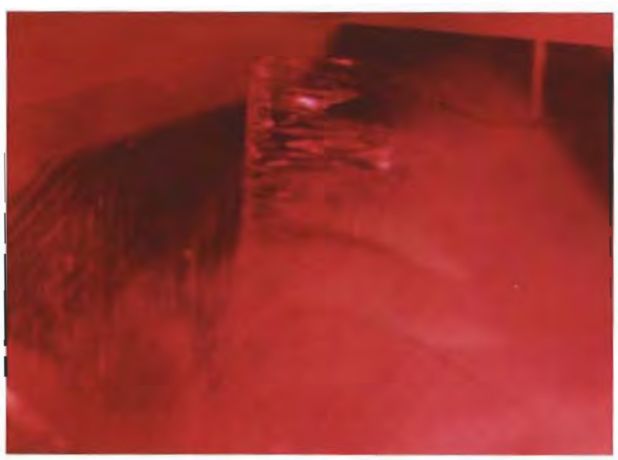


Figure 11. Negative crystals with a rhombohedral habit were observed in many of the Morogoro rubies. Immersion, magnified 80×; photomicrograph by K. Schmetzer.

Rutile. Rutile occurs in various forms in rubies from the Morogoro area. The rutile precipitations appeared near-colorless, probably due to the absence of iron. Typically, fine needles and lancet-like rutile twins were observed (figure 12) and may cause asterism in cabochon-cut stones (figure 13).

In addition, dusty to flaky disseminations, often referred to as clouds, of very fine particles caused turbidity in many of the stones; these may consist of rutile as well (figure 14). These fine inclusions of rutile and/or other particles were concentrated in varying densities and were often seen in growth zones bound by planes parallel to *c*, *r*, or *a* (figures 7, 14). They also occurred in irregularly defined areas, apparently related to a process of alternating growth and dissolution.

Other Mineral Inclusions. Four additional mineral species have, to date, been recognized in the subject gem-quality rubies from the Morogoro area.

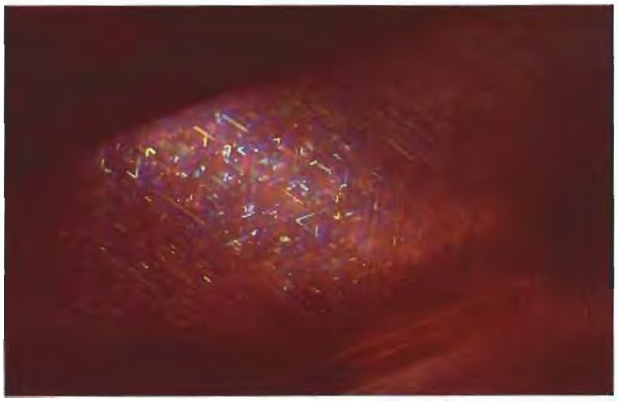


Figure 12. Rutile was commonly present as needles and lancet-like twins in the Morogoro rubies examined. Magnified 20×; photomicrograph by H. Hänni.

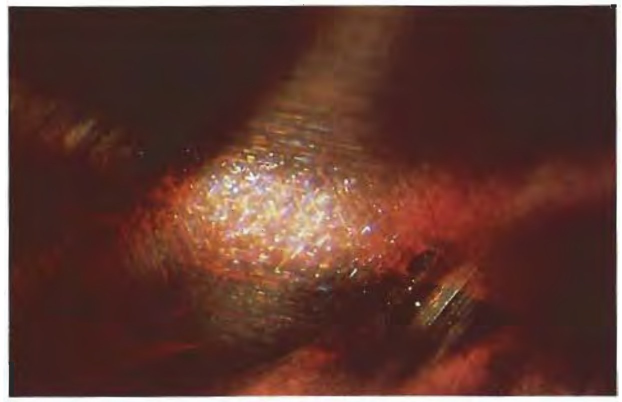


Figure 13. Dense concentrations of rutile inclusions produced asterism in some of the Morogoro stones. Magnified 10×; photomicrograph by H. Hänni.

Spinel crystals were seen that are similar to negative crystals both in octahedral habit and in lack of birefringence. Thus, these small octahedra cannot always be differentiated from negative crystals with a microscope. One of these spinel inclusions was exposed at the surface of a faceted sample and so was examined by electron microprobe (see table 2). Analysis revealed small amounts of Ti, Cr, V, and Fe, in addition to the major elements Mg and Al.

Small prismatic to rounded crystals with tension cracks (figure 15) were identified as zircon by SEM-EDS on the basis of Zr and Si present as the major elements.

Apatite was observed as small prismatic crystals (figure 16) and was identified by the presence of Ca and P as determined by SEM-EDS.

Pyrope inclusions were also identified by SEM-EDS, which detected major components of Si, Al,

Figure 14. Extremely fine inclusions of rutile and/or other particles were concentrated in varying densities and were often, as here, confined to growth zones in the ruby. Immersion, magnified 65×; photomicrograph by K. Schmetzer.

TABLE 2. Electron microprobe analyses of one spinel inclusion in a ruby from the new deposit in the Morogoro area, Tanzania.[a]

Oxide (wt.%)	Analysis 1	Analysis 2	Cations (calculated to O = 4)	Analysis 1	Analysis 2
Al_2O_3	70.46	69.90	Al	2.002	2.000
V_2O_3	0.02	0.02	V	0.000	0.000
Cr_2O_3	0.47	0.36	Cr	0.009	0.007
FeO	0.47	0.54	Fe	0.009	0.011
MgO	27.09	27.00	Mg	0.973	0.977
Total	98.51	97.82		2.993	2.995

[a]*See text for details of analysis. Note that Zn was identified as present and estimated in the range of 1–5 wt.% ZnO.*

and Mg. In the Morogoro stones examined, pyrope appeared as irregularly shaped to rounded pink grains.

Fluid inclusions were seen in the microscope as primary voids and pseudo-secondary healing feathers. The voids predominantly contain a monophase filling, but two-phase (liquid/gas) fillings, although rare, were also observed.

Unhealed open fissures, usually filled with secondary FeOOH phases that had stained the fissures brownish red, were occasionally observed during microscopic examination.

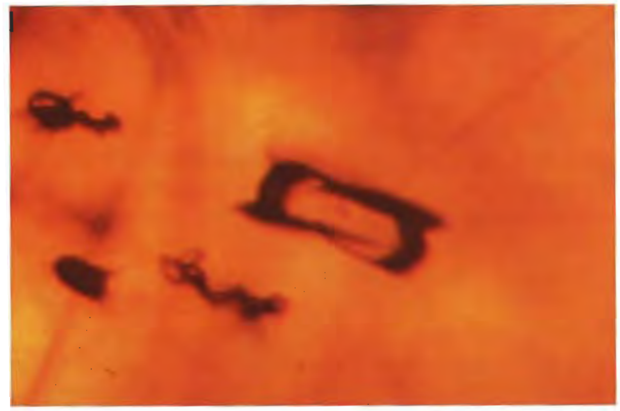


Figure 15. Small prismatic crystals such as this, with tension cracks, were identified as zircon. Immersion, magnified 100×; photomicrograph by K. Schmetzer.

COMPARISON WITH BURMESE RUBY

The rubies from the new deposit at Morogoro are significantly different from the rubies that were found earlier in this general area (Box B). However, a number of key features are common to rubies from Mogok and this new deposit at Morogoro. These include:

- A characteristic color.
- Inhomogeneities in growth zoning parallel to distinct faces, as well as irregular "swirls," both often observed in conjunction with irregular color distribution.
- Sets of thin twin lamellae parallel to one, two, or three rhombohedral faces.
- "Clouds" of rutile needles and/or other disseminated particles.
- Coarse rutile.
- Octahedral inclusions of slightly rounded solid material (spinel) or similar-appearing negative crystals.

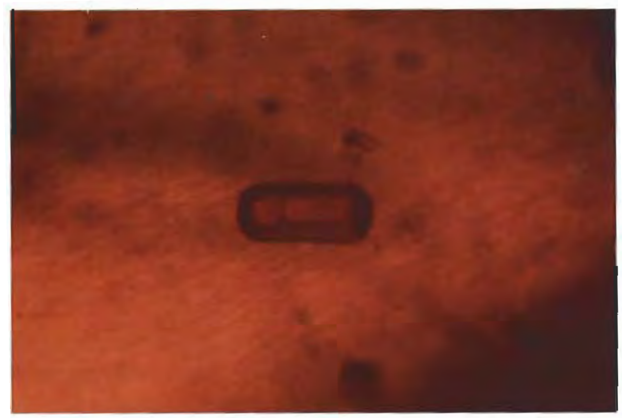


Figure 16. A second type of small prismatic crystal observed in the Morogoro rubies was determined to be apatite. Magnified 50×; photomicrograph by H. Hänni.

These similarities between the rubies from Morogoro and those from the Mogok district are probably due to a similarity in the geologic settings of the two occurrences. The Mogok rubies derive from a dolomitic marble in which red spinels are even more abundant than ruby (Keller, 1983). Tanzanian rubies from the new source in the Morogoro area are also found with an abundance of red and purple spinels. Therefore, it may be conjectured that these Tanzanian rubies also originate from a marble or marble-related parent rock. Other comparable occurrences of rubies and spinels situated in marble include Hunza, Pakistan (Bank and Okrusch, 1976; Gübelin, 1982); and Luc Yen, Vietnam (Weldon, 1991; Kane et al., 1991); gem-quality ruby with similar properties is also known from Nepal (Harding and Scarratt, 1986; Bank et al., 1988).

Characteristics that, to a certain extent, may be used to distinguish the new Morogoro rubies from those of Mogok are summarized as follows:

- Swirl-like growth structures are more frequently observed and more pronounced in Burmese rubies.
- Straight or angular color zoning may be more distinct in Burmese rubies.
- Angular color zoning parallel to the *r*, *a*, and *r'* faces has thus far been seen only in these rubies from Morogoro.

BOX B: COMPARISON OF NEW AND OLDER TYPES OF RUBIES FROM THE MOROGORO AREA

Rubies and pink sapphires from the Morogoro area of Tanzania have been known in the gem trade since the mid-1980s, or even earlier, as reported to us by a number of dealers (Schmetzer, 1986b). The first gemological description of material from this area involved stones that are somewhat different from those described in the present article; descriptions were provided by Schmetzer (1986b), with additional information in papers by Barot (1989) and Bank and Henn (1989). The "earlier" rubies from the Morogoro area are generally of cabochon quality, and most are translucent at best; only a very small percentage are facet grade. The following summary of diagnostic features of this earlier material from Morogoro may be useful:

- The color is usually medium to light red to "pink" with brownish tints.
- The material reveals high iron contents, as evidenced by the iron-related absorption bands at 450, 388, and 376 nm in the visible spectrum.
- Rutile inclusions are absent, although stones in one parcel examined revealed transparent colorless needles, which microprobe analysis proved to be sillimanite or kyanite.
- Neither color zoning parallel to growth planes nor irregular color distribution ("swirls") has been observed.
- Narrow twin lamellae are frequently found, mostly in three directions; these form dense, three-dimensional frameworks of intersecting straight lines.
- Intersecting lamellar straight lines are often confined to boehmite particles, so that the intersecting lines have a lath-like framework.
- Twin lamellae are frequently confined to parallel planes of polycrystalline boehmite.

Consequently, no difficulties arise in distinguishing samples of the older material from those stones discovered more recently at the Morogoro area. Nor does material from the earlier mining operations share any distinctive characteristics with Burma-type stones.

- Growth planes parallel to two rhombohedral faces and one prism face that form two angles of 137.0° are common in Morogoro rubies and rare in those from other localities, including Mogok.
- The presence of two or three systems of twin lamellae is less common in Burmese rubies, which usually have only one such system, as are intersecting straight, parallel lines, or even a three-dimensional framework of lines, which are related to the twin lamellae.
- Vanadium and gallium contents are generally higher in Burmese rubies, as measured by EDXRF (Stern and Hänni, 1982; Hänni and Stern, 1982).

Consequently, it seems evident that an unequivocal determination of origin of rubies from marble deposits can be ascertained only under favorable conditions and may be possible only for certain stones, even by the best-equipped gemological laboratory. Thus, the distinction between Burmese and Tanzanian marble-related rubies will be very difficult for the practicing gemologist.

CONCLUSION

Appreciable amounts of good-color, translucent to transparent rubies have recently emerged from the Morogoro area of Tanzania, possibly the Matombo mine. These rubies share many distinctive features with rubies from the historic locality at Mogok, in Myanmar (Burma). This is an important consideration to certain segments of the trade for whom origin is of critical concern. However, our examination of several Morogoro rubies and innumerable Burmese stones suggests that swirl-like growth features are more frequent, and straight or angular color zoning more prominent, in Burmese stones, while the presence of two or three systems of twin lamellae is more common in the Morogoro material. However, only the Morogoro rubies very frequently show growth features and color zoning parallel to the *r*, *a*, and *r'* faces, forming two angles of 137°. EDXRF analyses of seven samples of the Morogoro material indicate that there are lower amounts of the trace elements vanadium and gallium in the Morogoro stones than in their Burmese counterparts.

The examination of Morogoro rubies reinforces the observation that deposits of quite similar geologic conditions (in this case, marble or marble-related deposits) may be encountered in a variety of localities. The products of such deposits may also be quite similar, as appears to be the case for ruby from Myanmar, Pakistan, Vietnam, Nepal, and Tanzania.

REFERENCES

Bank H., Gübelin E., Harding R.R., Henn U., Scarratt K., Schmetzer K. (1988) An unusual ruby from Nepal. *Journal of Gemmology,* Vol. 21, No. 4, pp. 222–226.

Bank H., Henn U. (1989) Schleifwürdige Korunde von Ngoronghoro, Tansania. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 38, No. 1, pp. 44–46.

Bank H., Henn U., Petsch E. (1989) Spinelle aus dem Umba-Tal, Tansania. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 38, No. 4, pp. 166–168.

Bank H., Okrusch M. (1976) Über Rubin-Vorkommen in Marmoren von Hunza (Pakistan). *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 25, No. 2, pp. 67–85.

Barot N.R. (1989) Outlook for world gem production is good. *ICA Gazette,* September, pp. 7–10.

Bauer M. (1896) Ueber das Vorkommen der Rubine in Birma. *Neues Jahrbuch für Mineralogie Vol. 1896, Band II,* pp. 197–238.

Bosshart G. (1982) Distinction of natural and synthetic rubies by ultraviolet spectrophotometry. *Journal of Gemmology,* Vol. 18, No. 2, pp. 145–160.

Eppler W.F. (1974) Über einige Einschlüsse in Birma-Rubin. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 23, No. 2, pp. 102–108.

Eppler W.F. (1976) Negative crystals in ruby from Burma. *Journal of Gemmology,* Vol. 15, No. 1, pp. 1–5.

Gübelin E.J. (1982) Gemstones of Pakistan: Emerald, ruby, and spinel. *Gems & Gemology,* Vol. 18, No. 3, pp. 123–139.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones.* ABC Edition, Zurich.

Hänni H.A., Stern W.B. (1982) Über die Bedeutung des Gallium-Nachweises in Korunden. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 31, No. 4, pp. 255–260.

Hänni H.A. (1986a) Behandelte Korunde mit glasartigen Füllungen. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 35, No. 3/4, pp. 87–96.

Hänni H.A. (1986b) Glass-like fillings in rubies and sapphires. *Swiss Watch and Jewelry Journal,* No. 9, p. 779.

Hänni H.A. (1987) On corundums from Umba Valley, Tanzania. *Journal of Gemmology,* Vol. 20, No. 5, pp. 278–284.

Harding R.R., Scarratt K. (1986) A description of ruby from Nepal. *Journal of Gemmology,* Vol. 20, No. 1, pp. 3–10.

Kane R.E., McClure S.F., Kammerling R.C., Khoa N.D., Mora C., Repetto S., Khai N.D., Koivula J.I. (1991) Rubies and sapphires from Vietnam. *Gems & Gemology,* Vol. 27, No. 3, pp. 136–155.

Keller P.C. (1983) The rubies of Burma: A review of the Mogok stone tract. *Gems & Gemology,* Vol. 19, No. 4, pp. 209–219.

Kiefert L., Schmetzer K. (1991) The microscopic determination of structural properties for the characterization of optical uniaxial natural and synthetic gemstones. Part 1: General considerations and description of the method. *Journal of Gemmology,* Vol. 22, No. 6, pp. 344–354.

Kuhlmann H. (1983) Emmissionsspektralanalyse von natürlichen und synthetischen Rubinen, Sapphiren, Smaragden und Alexandriten. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 32, No. 4, pp. 179–195.

Melczer G. (1902) Ueber einige krystallographische Constanten des Korund. *Zeitschrift für Krystallographie und Mineralogie,* Vol. 35, pp. 561–581.

Muhlmeister S., Devouard B. (in press) Trace element chemistry of natural and synthetic rubies. In A. S. Keller, Ed., *Proceedings of the 1991 International Gemological Symposium,* Gemological Institute of America, Santa Monica, CA.

Schmetzer K. (1985) Distinction of natural and synthetic rubies by ultraviolet absorption spectroscopy—Possibilities and limitations of the method. *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 34, No. 3/4, pp. 101–129.

Schmetzer K. (1986a) An improved sample holder and its use in the distinction of natural and synthetic ruby as well as natural and synthetic amethyst. *Journal of Gemmology,* Vol. 20, No. 1, pp. 20–33.

Schmetzer K. (1986b) *Natürliche und synthetische Rubine—Eigenschaften und Bestimmung.* Schweizerbart, Stuttgart, Germany.

Schmetzer K., Berger A. (1990) Lamellar iron-free högbomite-24R from Tanzania. *Neues Jahrbuch für Mineralogie Monatshefte,* No. 9, pp. 401–412.

Schmetzer K., Haxel C., Amthauer G. (1989) Colour of natural spinels, gahnospinels and gahnites. *Neues Jahrbuch für Mineralogie Abhandlungen,* Vol. 160, No. 2, pp. 159–180.

Stern W.B., Hänni H.A. (1982) Energy dispersive X-ray spectrometry: A non-destructive tool in gemmology. *Journal of Gemmology,* Vol. 18, No. 4, pp. 285–296.

Tang S.M., Tang S.H., Tay T.S., Retty A.T. (1988) Analysis of Burmese and Thai rubies by PIXE. *Applied Spectroscopy,* Vol. 42, No. 1, pp. 44–48.

Tang S.M., Tang S.H., Mok K.F., Retty A.T., Tay T.S. (1989) A study of natural and synthetic rubies by PIXE. *Applied Spectroscopy,* Vol. 43, No. 2, pp. 219–223.

Weldon R. (1991) Why the Vietnam reds are giving us the blues. *Jewelers' Circular-Keystone,* Vol. 162, No. 5, pp. 46–48.

BOHEMIAN GARNET—TODAY

By Jochen Schlüter and Wolfgang Weitschat

Red garnets have been mined in the Bohemian Hills of Czechoslovakia since the 16th century. These pyrope garnets reached their height of popularity in jewelry of the Victorian era. Although the deposits had been generally regarded as depleted, today a small mining operation is working on garnetiferous gravels near the village of Podsedice, northwest of Prague.

The pyropes of Czechoslovakia have been known since the Middle Ages, but they were first commercially exploited and cut locally in the 16th century. Although in recent years it was commonly assumed that the deposits had been exhausted, production does continue in a small mining operation in the Bohemian Hills, approximately 50 km northwest of Prague. The rough is sold to the Granát cooperative in the city of Turnov, where it is faceted and then set into a wide variety of jewelry pieces (figure 1).

In the world of antique jewelry, the name *pyrope garnet* immediately recalls the elaborate, glittering pieces manufactured in Bohemia (once a kingdom, now a province of Czechoslovakia) by local craftsmen and studded with small locally mined faceted pyropes. Today, only one garnet deposit is being mined, near the village of Podsedice in the Bohemian Hills, but it is producing commercial quantities of these attractive stones. The following discussion examines the history of the garnet industry in this area, the geology and current mining operation, the manufacturing of the gem-quality stones, and the properties of the Bohemian pyropes.

ABOUT THE AUTHORS

Dr. Schlüter is curator of the Mineralogical Museum, and Dr. Weitschat is curator of the Geological Museum, University of Hamburg, Germany.

Acknowledgments: The authors would like to thank the organizations Artia, in Prague, and Granát, in Turnov, Czechoslovakia, and the German firm Herrling-Schmuck, in Bramsche, for providing information and enabling visits to mines and other facilities.

Gems & Gemology, *Vol. 27, No. 3, pp. 168–173.*

HISTORY

The collecting of garnets in the area now known as Bohemia dates back at least to the Middle Ages. Then, stones were simply gathered from the surface after heavy rainfalls or, in some places, small pits were dug and the loose ground sifted and washed.

Traditionally, the stones were cut by local farmers as an occupation during the long winter. About 400 years ago, cutting centers were established in the towns of Turnov and Prague. Foreign lapidary specialists were attracted to the region by the growing industry, and in 1780 the Venetian gold- and silversmith Callegari moved to Turnov, which encouraged other craftsmen to follow. In the Turnov museum known as "Czech Paradise," examples of Callegari's art can still be seen today.

According to O'Day (1974, p. 62), Bohemian garnets appeared abundantly in Victorian jewelry

Figure 1. Today, fine jewelry continues to be made in the city of Turnov, Czechoslovakia, from pyrope garnets mined in the Bohemian Hills. Courtesy of Herrling-Schmuck, Bramsche, Germany.

of the 1880s, "when clusters of small brilliant or rose-cut stones were pavé-set in almost invisible silver settings." Bauer (1896, pp. 405–409), provided an unsurpassed (for its time) description of the pyropes, their geologic setting, mining, cutting, and distribution. His book, written when pyrope-set jewelry was near the height of fashion, gives some insight into the extent of mining and trade activity. He notes that the garnet-cutting works of Bohemia are "very old-established" and that "at the present time [ca 1896] in Bohemia there are 3,000 men engaged in garnet-cutting, some hundreds of garnet-drillers, about 500 goldsmiths and silversmiths, and some 3,500 working jewellers. The collecting of garnets employs some 350 or 400 persons, so that, including the many persons whose work is indirectly connected with the industry, there must be between 9,000 and 10,000 persons gaining their livelihood by labour connected with the working of this precious stone."

Production began to slow down after the turn of the century, as changing fashions led to a decline in the popularity of garnet jewelry and an economic depression in the 1920s affected the jewelry market as a whole (Rouse, 1986). After World War II, the new political environment in Eastern Europe led to a shift in economic interests, notably away from luxury items. Although small-scale mining continued in the years that followed, it is only with the opening of Czechoslovakia's borders to western Europe and the rest of the world that interest has been renewed in exploiting these deposits (K. Hurwit, pers. comm., 1991).

LOCATION AND ACCESS

Currently, the only locality being worked is approximately 10 km southwest of the town of Lovosice just outside the small village of Podsedice (figure 2), which is less than 50 km from the border of Czechoslovakia with Germany. The area is readily accessible by car from Prague. At the present time, a small open-pit mining operation is being conducted by the Rudné Doly cooperative. The site is located in the Bohemian Hills, south of the towns of Bilina, Teplice, and Ústí, where in years past many sites were exploited for alluvial garnets by means of trenches and pits.

GEOLOGIC SETTING

Sediments in the basins along the southern slope of the Bohemian Hills contain garnetiferous gravels up to 6 m thick that are covered by overburdens of no more than 6 m. The gravels consist of angular

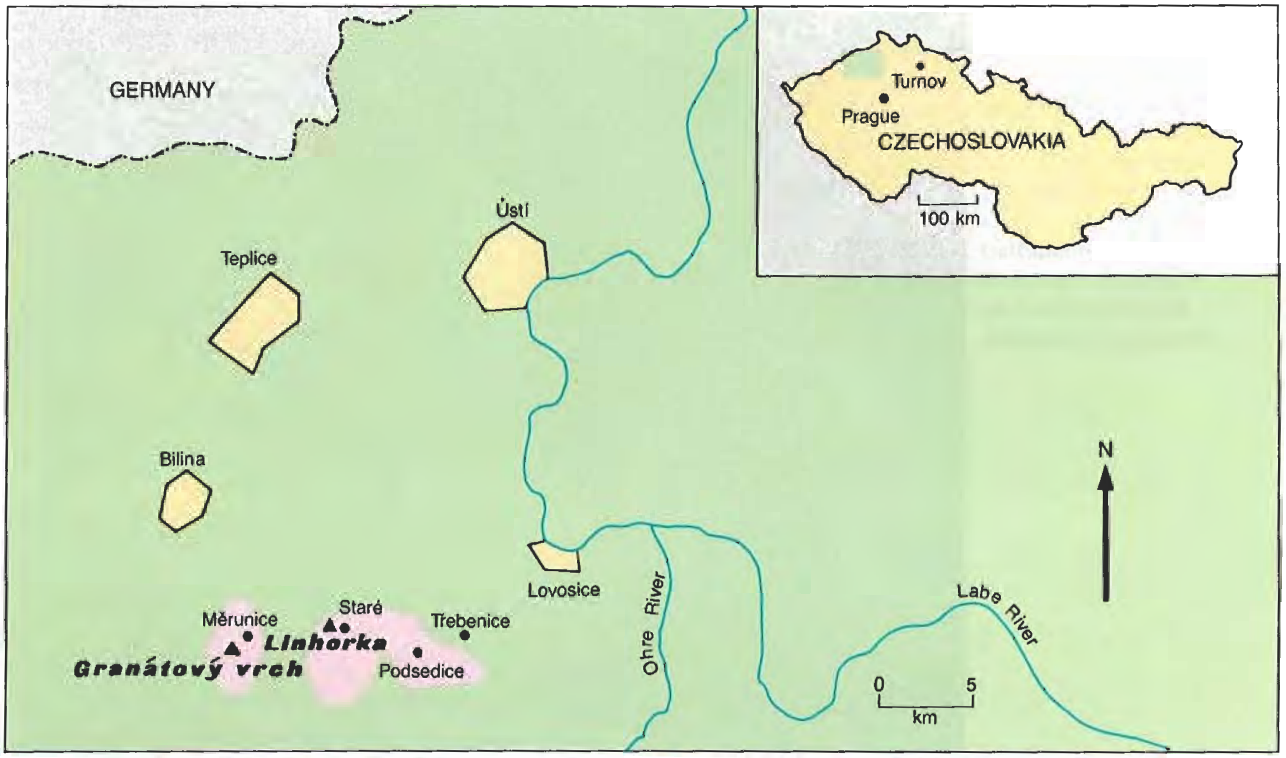


Figure 2. This map shows the main occurrences of garnetiferous gravels in the Bohemian Hills of Czechoslovakia, around the villages of Měrunice, Staré, Trebenice, and Podsedice. The peridotites in which the garnets formed, which originated in the earth's mantle, were brought to the surface by pipes such as the Linhorka and the Granátový vrch.

rock fragments of various sizes embedded in a fine clayey to sandy matrix. At Podsedice, approximately 2.5 acres of gravels are worked by open-pit mining each year. Once the gravels have been worked out, the ground is carefully restored to a state suitable for agriculture.

The sequence of events responsible for the deposition of pyrope in these young sediments is as follows. The original pyrope host rock is a serpentinized garnet peridotite (dunite/lherzolite; Fiala and Paděra, 1977) that is believed to have formed initially at a depth of at least 60 km in the earth's mantle. South of Teplice, such rocks have been emplaced in the upper crust by tectonic processes. A drill hole near Staré, for example, reached garnetiferous peridotites at depths between 209 and 436 m (Rost and Griegel, 1969). In this area, the Precambrian basement consists mainly of granulites, gneisses, and migmatites, with intercalations of such peridotitic rocks, and is covered by a 160-m-thick stratum of Cretaceous sandstones, marls, and limestones. Locally, additional sediments consist of Oligocene sands and clay, in some places covered by basaltic flows (Stutzer and Eppler, 1934).

Following Alpine orogeny during the Tertiary period, crustal stretching in the Bohemian Hills region triggered alkalic volcanism (feldspathoid and feldspathoid olivine basalts). In the Miocene (25 million years ago), molten rocks from the upper mantle erupted to the surface through fissures and cracks. In some areas, these volatile-rich melts built up high pressures before they blasted free their vents. These violent eruptions brought abundant fragments of crustal rocks to the surface. Some of these explosion pipes protrude today as volcanic necks above the surrounding Cretaceous country rocks (figure 3). The pipes at Staré and Měrunice transported fragments of peridotites, gneisses, granulites, and Cretaceous sediments upward and incorporated them into their volcanic breccias and tuffs. At the Staré pipe, called Linhorka, fragments of serpentinized garnetiferous peridotites can be found (figure 4) which are rich in gem-quality pyrope.

Since the Miocene epoch, about 400 m of rock have been eroded. Consequently, most of the volcanic rocks have been decomposed and their resistant components transported to the present alluvial gravels. The garnets occur therein as

Figure 3. A power shovel is used to remove the overburden and garnetiferous gravels at Podsedice. In the background can be seen remnant pipes of Tertiary volcanism in the Bohemian Hills. Photo by J. Schlüter.

individual grains. Around Podsedice, there is an area of approximately 70 km² (again, see figure 2; Oehmichen, 1900) that is underlain by garnetiferous gravels of varying thickness, which, as mentioned above, are covered by recent sediments.

MINING AND RECOVERY

In the open-pit operation near Podsedice, 320 tons of gravel are mined each day with conventional power shovels (again, see figure 3) and trucked to a washing plant. The pyropes, which average 16–18 grams per ton, are separated out by a sieving process using a 1-cm mesh. Because of their high specific gravity, the garnets are then easily recovered by density separation (figure 5). Some 45 kg of pyrope concentrates (figure 6) are produced daily, from which about 5 kg of cutting-grade pyrope in sizes over 3 mm are picked out by hand by female workers (figure 7). This selected material is sold to the cooperative society called Granát, in the town of Turnov, where the stones are faceted.

Figure 4. This serpentinized garnet peridotite from the Linhorka pipe near Staré contains several small gem-quality pyropes. Photo by U. Mahn.

Cutting losses amount to about 10% by volume, with the result that 4.5 kg of faceted stones are made available to the numerous Granát jewelers each day. The stones are still set using traditional techniques, with the aim of producing mountings studded by numerous closely set faceted gems which emphasize the beauty of the pyropes and relegate the metal of the setting to a minor role (again, see figure 1). Over time, jewelry makers in Turnov have developed about 20,000 different models of garnet jewelry that can be manufactured on demand.

This jewelry is exported through the Czech foreign trade company known as Artia, which is headquartered in Prague, or through Herrling-Schmuck, which is located in Bramsche, Germany. If mining continues at its present pace, it is estimated by leaders of the Rudné Doly cooperative that the Podsedice deposits have sufficient reserves to continue for more than 15 years (J. Hlavsa, pers. comm., 1989). Other garnet-bearing

Figure 5. Density separation is used to concentrate the pyropes in this jig at Podsedice. Photo by J. Schlüter.

alluvials elsewhere in the Bohemian Hills are currently being explored.

DESCRIPTION OF THE GARNETS

The classic Bohemian garnet is the Mg-Al-rich member of the garnet group known as pyrope, in which minor substitutions of iron and especially chromium are responsible for the characteristic "fire-red" hue. Specimens of the finest color contain between 1.5 and 2.5 wt.% chromium as Cr_2O_3. In general, the crystals occur as rounded grains (figure 8) up to 5 mm in diameter, with larger sizes being very rare. Most of the cut stones are very small, around 0.10 ct.

Six representative samples were selected for study. Refractive indices, as obtained with a refractometer and sodium light source, ranged from 1.748 to 1.750. Three of the six samples displayed anomalous birefringence when immersed in methylene iodide and viewed between crossed polarizing filters. All appeared red when viewed through a Chelsea filter and were inert to both long- and short-wave ultraviolet radiation. Density determinations were considered unreliable due to the small size of the stones. The optical spectra, as seen with a prism hand spectroscope, were typical for chrome-bearing pyrope, with chromium lines in the red and a broad region of absorption in the yellow.

Figure 6. In this garnet concentrate from the Podsedice deposit, red pyropes (up to 5 mm) are easily seen among the other mafic minerals and rock fragments. Photo by J. Schlüter.

M. Bauer (1896) stated that "the Bohemian garnet is generally without exception of ideal purity; it is the only gemstone deposit where all stones are equally free of inclusions and impurities." Nevertheless, J. Bauer (1966) has described three morphologic types of zircon inclusions (up to 0.57 mm) as well as chrome-diopside inclusions. The changes in volume that zircons undergo due to metamictization cause internal stress which results in both anomalous birefringence and distinct cracks around the inclusions. In accord with J. Bauer's observations, our six study samples contained small colorless inclusions (probably zircon), as well as larger ones surrounded by stress cracks. These inclusions are reminiscent of the zircon inclusions typically found in Sri Lanka rubies. Generally, however, Bohemian garnets are rela-

Figure 7. At Podsedice, a worker in the Rudné Doly cooperative carefully selects gem-quality stones from the pyrope concentrate. When the mine is in operation, approximately 5 kg of cutting-grade pyrope are produced daily. Photo by J. Schlüter.

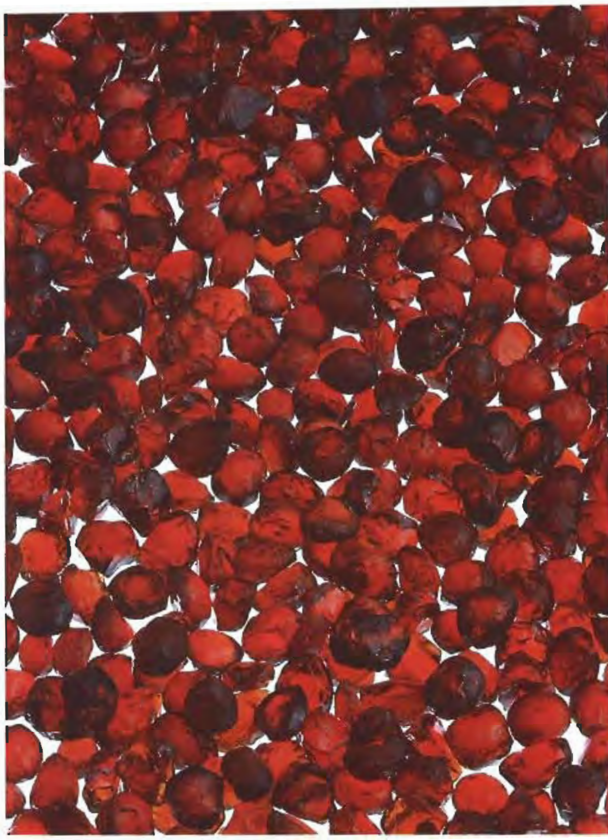


Figure 8. These rounded garnet crystals, which average approximately 0.25 ct (2.5 mm in diameter), are typical of the pyropes currently being mined in Bohemia. Photo by Shane F. McClure.

tively free of microscopic features, including growth zoning and healing planes (feathers).

Chemical data were obtained for the same six stones by electron microprobe analysis. The results revealed a limited range of compositional variability. Data for two representative samples are provided in table 1; the chemical compositions of the Bohemian garnets appear to be comparable to those of chrome-bearing pyropes from other localities.

CONCLUSION

Pyrope garnets are still being mined from the historic Bohemian Hills region, now part of Czechoslovakia, although currently from a single alluvial deposit. Nevertheless, production is sufficient to support a local cutting and jewelry-manufacturing operation that exports finished pieces worldwide. If production continues at its present pace, the Podsedice deposit should be able to provide garnets for more than 15 years.

Other localities are currently being explored in the Bohemian Hills. With the opening of trade barriers throughout Europe, increased demand for all types of jewelry may anticipate the discovery—or rediscovery—of other commercially viable deposits of this historically renowned gemstone.

TABLE 1. Representative microprobe[a] chemical analyses for two samples of pyrope garnet recently mined in the Bohemian region of Czechoslovakia.

Oxide (wt%)	Sample 1		Sample 2	
	Core	Rim	Core	Rim
SiO_2	41.46	41.02	41.06	41.13
Al_2O_3	21.51	21.47	21.39	21.53
FeO[b]	9.17	9.20	9.10	9.21
MgO	21.29	21.28	20.82	20.93
MnO	0.32	0.31	0.31	0.34
CaO	4.45	4.46	4.48	4.45
TiO_2	0.70	0.67	0.55	0.56
Cr_2O_3	1.66	1.62	1.76	1.75
V_2O_3	0.09	0.03	0.05	0.08
Total	100.65	100.06	99.52	99.98

[a]*Operating conditions and details of analyses available on request to the authors.*
[b]*Total iron as FeO.*

REFERENCES

Bauer J. (1966) Inclusions in garnets of ultrabasic and granulitic rocks in the northern tract of the Bohemian Massif. *Krystalinikum*, Vol. 4, pp. 11–18.

Bauer M. (1896) *Edelsteinkunde*. Chr. H. Tauchnitz, Leipzig.

Fiala J., Paděra K. (1977) The chemistry of the minerals of the pyrope dunite from borehole T-7 near Staré (Bohemia). *Tschermaks Mineralogische und Petrographische Mitteilungen*, Vol. 24, pp. 205–219.

O'Day D. (1974) *Victorian Jewellery*. Charles Letts and Co., London.

Oehmichen H. (1900) Die böhmischen Granatlagerstätten und die Edelsteinseife des Seufzergründels bei Hinterhermsdorf in Sachsen. *Zeitschrift für Praktische Geologie*, January, pp. 1–17.

Rost F., Griegel W. (1969) Zur Geochemie und Genese granatführender Ultramafitite des mitteleuropäischen Grundgebirges. *Chemie der Erde*, Vol. 28, pp. 91–177.

Rouse J.D. (1986) *Garnet*. Butterworths, London, pp. 46–47.

Stutzer O., Eppler W.F. (1934) *Die Lagerstätten der Edelsteine*. Gebrüder Bornträger, pp. 399–404.

GEM TRADE LAB NOTES

EDITOR
C.W. Fryer
Gem Trade Laboratory, West Coast

CONTRIBUTING EDITORS
Robert Crowningshield • David Hargett • Thomas Moses
Gem Trade Laboratory, East Coast

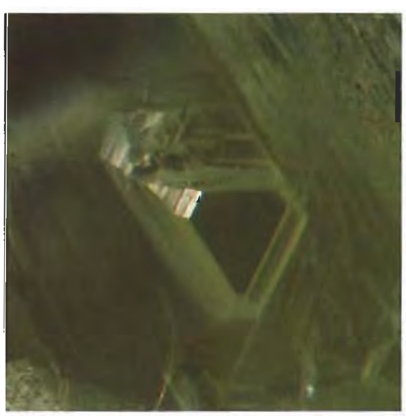
Karin Hurwit • Robert E. Kane
Gem Trade Laboratory, West Coast

DIAMOND

With Hexagonal Indented Natural

Triangular depressions (usually referred to as trigons) that are sometimes present on the octahedral faces of diamond crystals can occur in two orientations: They are referred to as "positive" when they point in the same direction as the crystal face and "negative" when they point opposite the crystal face. Numerous studies and observations have proved that both types of trigons can result from either the growth process or from chemical etching (see, e.g., "Etch Pits on Diamond Surfaces," by A. R. Patel and S. Ramanathan, *Philosophical Magazine*, Vol. 7, No. 80, 1962, pp. 1305–1314). If the temperature and/or composition of the surrounding solution varies during formation of the trigons, a reversal in orientation is possible. Thus, both positive and negative depressions can occur in separate areas of the same octahedral plane, or they may be superimposed in such a way that features with a distinctly hexagonal outline develop. In the latter case, either the positive or the negative form will usually dominate, creating mostly cut-cornered triangle shapes (figure 1). However, if the reversal is equal in extent, a perfectly symmetrical hexagon can occur.

Figure 1. This 1.35-ct light greenish yellow diamond crystal shows a predominantly positive trigon that has been modified by a negative trigon, thus creating a cut-cornered triangular indented natural on the octahedral face. Magnified 35×.



A striking example of this was recently seen in the West Coast laboratory: Examination of a 1.55-ct fancy gray-yellow pear-shaped diamond with magnification revealed an indented natural that displayed a hexagonal outline where it reached the surface of a bezel facet on the tip of the stone. What was so extraordinary was the combination of symmetry and depth that resulted in a hollow hexagonal column extending deep within the stone (figure 2). Shallow geometric features are common on the surfaces of rough crystals and sometimes appear as naturals on cut stones, but an example as dramatic as this is rarely seen in a faceted stone.

Christopher P. Smith

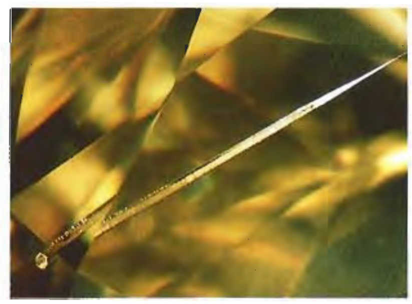


Figure 2. The hexagonal outline of a columnar indented natural is readily visible in the bezel facet of this diamond. The striations seen across the width of the inclusion, running down the entire length of the column, are parallel to the octahedral faces and indicate the orientation of the faceted stone to the original crystal. Magnified 20×.

Type IIb with Natural Irradiation Stains

In the laboratory, we often observe natural irradiation stains on rough and sometimes even polished diamonds. They are thought to be caused by the proximity of the diamond crystal to a natural source of radiation. Although such stains may be green, they are usually brown because of exposure to heat either in the earth or during fashioning.

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

Gems & Gemology, Vol. 27, No. 3.

Figure 3. Irradiation stains can be seen on the girdle of this type IIb fancy blue diamond. Magnified 60×.

These stains have been seen on some type Ia and IIa diamonds and, rarely, on type Ib diamonds (for a brief discussion of diamond types, see *Gems & Gemology,* Winter 1986, Vol. 22, No. 4, p. 197). Recently, the East Coast laboratory observed brown irradiation stains on a type IIb fancy blue diamond. Figure 3 shows several small stains on the girdle of this 0.40-ct old European-cut brilliant. To our knowledge, this is the first time irradiation stains have been reported on a type IIb diamond. *DH*

PEARLS

Cultured Pearl, Accidentally Tissue-Nucleated

To the best of our knowledge, there is no commercial operation to tissue nucleate saltwater mollusks for the production of cultured pearls. Therefore, when we identify such a tissue-nucleated pearl, we assume that it is the result of bead-nucleus rejection or some other mishap in the nucleation process.

The East Coast lab recently examined what may be the largest such "accidental" saltwater tissue-nucleated cultured pearl we have yet encountered: At 12 mm × 10.50 mm, this baroque cultured pearl weighed 15.17 ct. The X-radiograph (figure 4) clearly shows a void that is typical of tissue nucleation. *GRC*

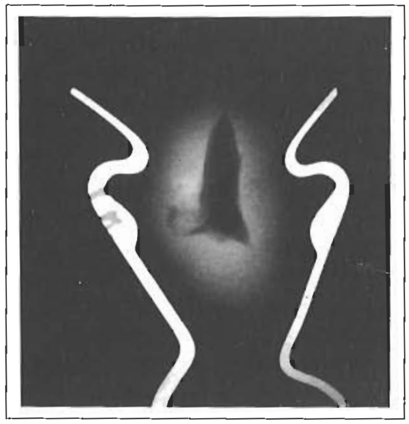


Figure 4. This X-radiograph clearly shows the void typical of tissue nucleation in this unusually large (15.17 ct) "accidental" saltwater tissue-nucleated cultured pearl.

Green-Dyed Natural Pearls

Most jewelers and gemologists are familiar with the wide range of colors seen in dyed freshwater cultured pearls, most commonly green, yellow, purple, and blue. Dyed saltwater natural pearls, however, are typically gray to black and "bronzy"; other strong colors are virtually unknown.

Figure 5. All of the 111 natural pearls in this necklace—ranging from 3.40 to 7.05 mm in diameter—had been dyed green.

We at the East Coast laboratory were, therefore, somewhat surprised to identify as natural a long necklace of graduated saltwater pearls with a decidedly unnatural green to gray-green appearance (figure 5). Magnification revealed green dye concentrated around the drill holes and distributed just below the surface in conjunction with iridescent rings. *GRC*

Natural- and Treated-Color Black Cultured Pearls in the Same Necklace

The East Coast laboratory examined a fine necklace of what appeared to be 39 black pearls graduated from 9.75 to 13.25 mm. X-radiography not only proved that all of the pearls were cultured, but it also indicated that, because two of the pearls showed lower contrast on the film between the shell bead and the nacre, they were probably treated. While the necklace was being prepared for X-radiography, the same two pearls had appeared browner in the immersion fluid (figure 6), thus providing another useful clue to their true nature.

Figure 6. Immersed in film cleaner in preparation for X-radiography, the two dyed cultured pearls appear brown when compared to the others in this necklace.

Natural-color black pearls appear a faint brownish red when exposed to long-wave ultraviolet radiation, while dyed pearls appear chalky green. As expected, these two pearls turned chalky green when exposed to long-wave U.V.

This particular necklace emphasizes the importance of careful examination and testing because, be-

Figure 7. It is impossible to detect a difference in color between the two dyed cultured pearls (arrows) and their natural-color counterparts.

fore testing these two treated-color cultured pearls looked just like their natural counterparts (figure 7).

Nicholas DelRe

Remarkable Cultured Pearl

The East Coast laboratory received a very unusual pearl for identification. The hollow, partly worked, gray bullet-shaped cultured pearl shown in figure 8 proved to be of natural color and is probably from the Tahiti area. Looking through the base of the pearl (figure 9), however, we saw a black round cultured pearl nearly filling the hollow space. The X-radiograph (figure 10) shows that the nacre of the round pearl is unusually thin for natural-color cultured pearls from this area.

It is intriguing to speculate how this specimen grew. Probably, the round pearl started growth normally in a pearl sac. If it was somehow ejected from the pearl sac and became lodged on the shell, then the resulting bullet-shaped pearl would be considered a blister. However, how such a blister would have the round pearl at the apex of the dome rather than at the base is puzzling. One possible explanation is that the blister pearl formed on the upper shell of the mollusk, and gravity caused the round pearl to somehow fall free of the shell and thus become part of the inside of the rounded part of the blister.

GRC

Figure 8. This "hollow" bullet-shaped natural-color cultured pearl measures approximately 11.6 to 12 × 11.3 mm and weighs 9.62 ct. Note the opening in the base.

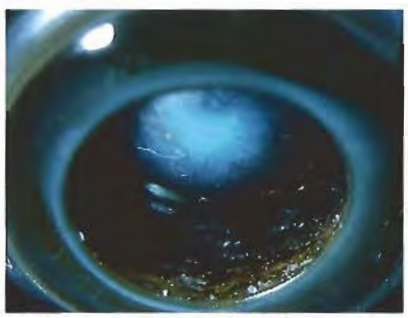


Figure 9. The "hollow" cultured pearl in figure 8 was found to contain a mysterious round black cultured pearl, seen here toward the apex of the dome. Magnified 10 ×.

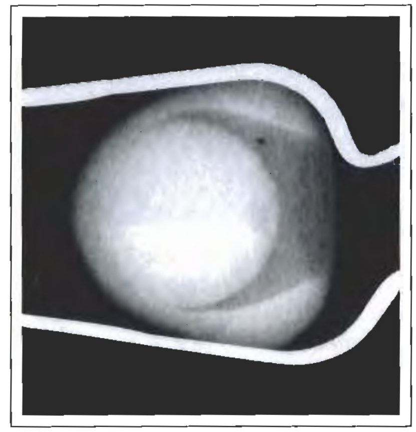


Figure 10. The X-radiograph of the cultured pearl in figure 8 shows the very thin nacre on the round pearl inside.

A "Teething" Problem

Informal testing methods may lead to inaccurate conclusions if not backed up with more rigorous tests. A good gemologist usually relies on several tests to arrive at an accurate identification.

The East Coast laboratory received for identification the beautiful pendant earclip shown in figure

Figure 11. The 17.65-mm cultured pearl in this earclip was first thought to be an imitation because it felt smooth when rubbed carefully along the edge of a tooth.

11. It was set with what appeared to be a half-drilled pearl measuring approximately 17.65 mm in diameter. A cursory examination of the color and luster with the unaided eye and a "tooth test" initially led us to believe that this was an imitation pearl. The tooth test indicated that the surface was smooth, a characteristic of imitation pearls. A natural or cultured pearl will almost always feel gritty when carefully rubbed along the edge of a tooth.

An X-radiograph followed by closer examination with magnification revealed that this was a cultured pearl with a worked surface. Polishing lines could be seen running across the nacre. Undoubtedly, the worked surface caused the smooth "tooth test reaction," falsely indicating that the pearl was imitation.

Nicholas DelRe

"Treated" Mabe Pearls

At the February 1991 Tucson show, several staff members noticed an abundance of quite attractive, but relatively inexpensive, white mabe assembled blister pearls. The majority measured between 15 and 20 mm in diameter, displayed a very high luster, and showed very strong pink overtones. However, some of them showed a slightly spotty, uneven color distribution that raised suspicion that they had undergone some kind of enhancement.

Figure 12. When one of these two 15.5-mm mabe pearls was sawed in half, the mother-of-pearl base, plastic dome, and very thin nacre layer were evident (left). Note also the coating on the plastic dome (right).

Subsequently, the West Coast laboratory received a few samples from a gem merchant who wanted to share his observations regarding this type of mabe pearl. Out of curiosity he had cut one mabe pearl in half to expose the interior. Figure 12 shows the two halves together with another "whole" mabe pearl. The three layers that make up this mabe assemblage—mother-of-pearl base, plastic dome, and outer layer of nacre—are clearly visible in the half on the left.

It was interesting to note that the nacre layer was extremely transparent and ultrathin (measured to be approximately 0.25 to 0.30 mm). In spite of the layer being so thin, our client succeeded in separating it from the plastic dome. We could now see that a very fine, highly reflective coating had been applied to the plastic dome (the sample on the right in figure 12). The texture of this layer reminded us of the "pearl essence" commonly used for imitation pearls. The GIA Research Department obtained an infrared spectrum on this layer and determined that it was just a lacquer, rather than the true, organic "pearl essence." It was obvious, though, that the lacquer improved luster and overtone on these mabe pearls. *KH*

Two Different Mabe Pearls

The East Coast laboratory received a pair of loose mabe assembled blister pearls, with the request that we "determine if they are natural." Both were of very similar outward appearance and weight. Although a mabe pearl by definition is never "natural," the X-radiograph (figure 13) did reveal that the two samples were constructed quite differently. It shows that one is a typical mabe with thin nacre and a shell hemisphere insert, while the other mabe lacks a shell bead insert, but seems to be filled with a substance that is relatively transparent to X-rays and approximates the specific gravity of shell, since the two mabes weigh approximately the same. A layer that is opaque to X-rays appears to line the inside of the nacre in both mabe pearls. *GRC*

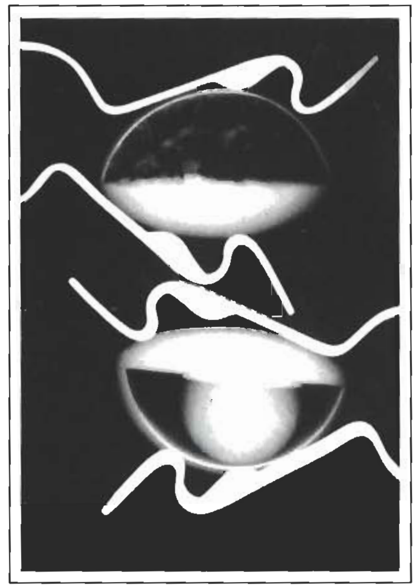


Figure 13. Although these two mabe pearls are similar in outward appearance, X-rays reveal that one has a shell bead insert and the other does not.

Early SYNTHETIC RUBIES

Staff members in the East Coast laboratory were particularly excited to examine the ruby and diamond pendant shown in figure 14. Only eight of the 94 calibre-cut red stones (each approximately 3–4 mm long) are natural rubies; the balance are synthetics, possibly of the early type known as "Geneva rubies." Judging from the cut of the diamonds and the design and workmanship of the pendant, the piece could well have been manufactured before the turn of the century.

This was a very trying time for the jewelry industry, as it was being faced with two of the most difficult identification problems in its history. The introduction in 1895 of the solid cultured blister pearls grown by Mikimoto and sold as "Japanese" pearls presented a new challenge in identification. At about this same time, "Geneva rubies" began to appear in the gem industry. These were pro-

Figure 14. This pendant was determined to contain diamonds and eight natural rubies together with 86 synthetic rubies that appear to be of early manufacture.

duced as small, "shoe button"–shaped boules from approximately 1884 until 1904, when Verneuil's larger, more practical product became available. "Geneva rubies" were characterized by very tightly curved striae, prominent gas bubbles, strain cracks, and colorless areas, as well as by areas of black-appearing foreign material. These features must really have confused a jeweler a hundred years ago. One could almost say that modern gemology started then, with these products of "modern" technology.

The "Geneva rubies" had been identified as "artificial" as early as 1886, and the French Syndicate of Diamonds and Precious Stones ruled that they must be sold as man-made. It is likely, though, that their availability in small sizes may have influenced their use in items such as the pendant shown in figure 14 more than their cost.

Figure 15 (taken through the pavilions of the stones) shows a natural ruby on the left and a synthetic on the right. The natural ruby has a low-relief, subhedral crystal and prominent color zoning. The synthetic also has color zoning, including colorless areas, as well as large, irregular gas bubbles – an appearance very similar to that of the natural stone. However, the synthetic rubies had a characteristically stronger fluorescence to short-wave U.V. radiation. Most of the other synthetics also had color zoning, as well as gas bubbles; magnification revealed a black foreign material in some of the synthetic rubies (figure 16). Such black material is occasionally seen in modern Verneuil synthetics; a Swiss manufacturer reports that this is actually unmelted alumina. We did not observe curved striae in any of the stones, but microscopic examination was restricted due to the settings.

GRC

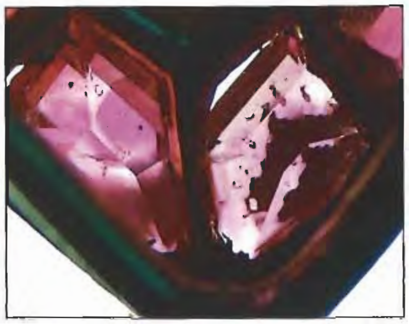
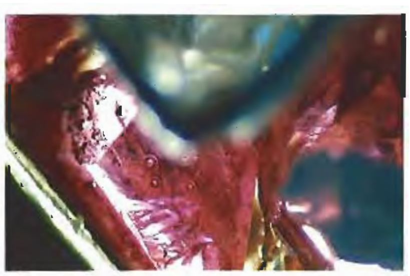


Figure 15. The apparent internal similarities between the natural ruby on the left and the synthetic ruby on the right, both from the pendant shown in figure 14, illustrate the difficulty jewelers must have had identifying these synthetics when they first appeared. Magnified 30×.

Figure 16. Spherical gas bubbles and a black material are clearly seen in the synthetic ruby on the left. (The smudge on the stone on the right was used to indicate for the client that it is natural.) Magnified 45×.



Diffusion-Treated SAPPHIRES in Fine Jewelry

Around 1979, diffusion-treated sapphires were encountered frequently in the trade and a number were submitted to the GIA Gem Trade Laboratory for identification. The first Lab Note regarding diffusion-treated sapphires appeared in the Fall 1979 issue of *Gems & Gemology* (p. 195). Although the first one we saw in the East Coast laboratory was red-orange, practically all of the diffusion-treated sapphires we subsequently examined were blue. That initial influx of diffusion-treated blue sapphires was short-lived, and in time we saw fewer and fewer of them in the trade.

It is important to remember that some treatments appear to be cyclical. At one point they are widespread, and then they seem to all but disappear, only to reappear at a later date. Diffusion-treated blue sapphires seemed to reemerge in the trade at the 1990 Tucson Gem Show; an in-depth article on this treatment process and recent developments was published by R. Kane et al. in the Summer 1990 issue of *Gems & Gemology.*

Over the last year, the laboratories on both coasts have seen a strong comeback for diffusion-treated sapphires and some dramatic examples of how they are being used. The East Coast laboratory recently saw an important gold and diamond necklace that was set with five rather large (4–5 ct) diffusion-treated sapphires, as well as a matching ring set with an even larger diffusion-treated stone. Within the same time frame, the West Coast laboratory received matching sapphire earrings (each 5–6 ct) and a ring (approximately 10 ct) set in gold with diamonds. Again, the large stones were found to be diffusion treated.

This jewelry could be a glimpse of what is to come. Care must be taken by the jeweler when examining all sapphires, since any natural inclusions that might be seen with the microscope will not distinguish a stone that has simply been heat treated from one that has been diffusion treated. Immersion, as described in the above-mentioned article, is still the best method to identify diffusion treatment whether the stone is mounted or unmounted. *DH*

FIGURE CREDITS
Figure 1 was taken by Robert Kane. Shane McClure is responsible for figure 2. Dave Hargett took figure 3. The pictures in figures 5-9, 11, and 14-16 were supplied by Nicholas DelRe. Robert Crowningshield produced the X-radiographs in figures 4, 10, and 13. William Videto furnished figure 12. Tino Hammid took the photo used in the Historical Note section.

A HISTORICAL NOTE

Highlights from the Gem Trade Lab 25, 15 and five years ago

FALL 1966

The New York lab discussed various types of synthetic growth processes, from hydrothermal overgrowth on Lechleitner stones to flux-grown synthetic ruby. Several photos illustrated the difference in transparency to short-wave ultraviolet radiation that is still a valid test to separate natural (more opaque) and synthetic (more transparent) stones. A diamond that had been presented as the finest natural-color green diamond next to the Dresden Green revealed an umbrella-like color zoning around the culet that proved that it had been cyclotron treated.

With the technology provided by laser sawing, fanciful cuts such as this 12-mm sailboat and tennis racket can be obtained from otherwise difficult-to-cut pieces of rough.

FALL 1976

The Santa Monica lab had the opportunity to examine a snuff bottle reportedly carved from rare hornbill ivory. Our examination revealed that the bottle had been assembled from different parts of hornbill, rather than carved from a single piece. This lab also noted unusual devitrification around a spherical gas bubble in glass.

The New York lab illustrated various materials used to simulate emerald, as well as selectively dyed, fine-grained calcite used to imitate jadeite jade. Even today, we still encounter such material, which has been dyed to represent multicolored jadeite – green and white, purple and white, or even all three colors in the same piece.

FALL 1986

Diamonds laser cut in the unusual shapes of a sailboat and a tennis racket were illustrated. A rather complete discussion of light green diamonds and what might be the reason for the color was given. We recommend that the reader review this item in particular (p. 171), as it is still important today. The 10- to 12-mm gray cultured pearls in an attractive brooch and earring set were of interest because their centers were determined to be filled with a white material resembling French pearl cement. There was no bead nucleus.

GEM NEWS

JOHN I. KOIVULA AND ROBERT C. KAMMERLING, EDITORS

DIAMONDS

Argyle set to expand with mining at home . . . To handle increased production from the AK1 pipe in Western Australia, CRA Ltd. plans to expand ore processing from 6 million to 8 million tons per year over the next two to three years. Their goal is to maintain diamond production for the AK1 pipe and nearby alluvial deposits at 33 to 35 million carats annually during the 20-year life of the pipe, as they reach progressively less-productive depths, with lower-yield ore. (*Diamond Intelligence Briefs*, July 23, 1991)

. . . and cutting in China. Argyle has opened a diamond-cutting and polishing factory in China, approximately 30 km from Beijing, that it will manage as well as co-finance. The factory, which will also provide training, was set up as a joint venture between the governments of Australia and China. The Chinese government hopes to develop diamond processing as a major new industry for the country. (*Mining Journal*, September 6, 1991)

Operations re-established at Elizabeth Bay . . . Namibia's diamond deposit at Elizabeth Bay, discovered in the early 1900s but inactive since the mid-1940s, has been officially re-opened. Operated as an open-cast mine by Consolidated Diamond Mines, the mine is expected to produce about 2.5 million carats of predominantly gem-quality diamonds from 38 million tons of ore over its 10-year life. (*Mining Journal*, August 9, 1991)

. . . amid warnings of large-scale theft. As part of his comments at the opening of the Elizabeth Bay mine, Julian Ogilvie Thompson stated that organized crime syndicates are stealing large values of diamonds each year from Namibia's mines. The theft of diamonds rose sharply in the months preceding Namibia's independence. It is believed that the value of diamonds stolen from the Oranjemund mine may be as high as three times that of the entire production from the new Elizabeth Bay mine. (*Diamond Intelligence Briefs*, August 30, 1991)

New Soviet diamond source. According to recent reports on Radio Moscow, a major new diamond field has been discovered in Buryatskaya, close to the border with Mongolia, in the eastern Sayany Mountains. Geologists have reportedly identified more than 10 diamond-bearing sites in the region. This discovery, which is scheduled to be exploited commercially, follows 50 years of small-scale prospecting in the area, during which only minor quantities of diamonds were recovered. (*Mining Journal*, August 23, 1991).

Additional diamonds recovered at Fort a la Corne, Saskatchewan, Canada. Additional diamonds were recovered from drill samples taken at the Fort a la Corne property, 80 km east of Prince Albert, according to Uranerz Exploration and Mining, operator of a 50/50 joint venture with Cameco Corp.

Diamonds recovered in 1991 range up to 0.6 ct (5.5 mm in diameter); the larger stones (over 0.5 mm in diameter) appear to be of gem quality. A total of 160 macrodiamonds have been recovered to date from 15 separate kimberlite pipes. The average weight per stone is 0.04 ct, with a maximum projected grade of approximately 10 ct per 100 metric tons in one drillhole. Preliminary cost estimates indicate that a minable deposit would require a much higher grade. Sample recovery is expensive due to the 100-m-thick blanket of overburden that covers the kimberlite pipes.

The exploration results to date are insufficient to determine the economic significance of the Fort a la Corne property. Further exploration and evaluation is warranted since many target areas remain to be tested by drilling. No additional field work is planned for 1991.

Conference on synthetic diamond and diamond-like coatings. In September 1991, Dr. Emmanuel Fritsch of GIA Research attended the Second European Conference on Diamond, Diamond-like and Related Coatings in Nice, France. Titled "Diamond Film 1991," this annual event focuses on the low-pressure synthesis of diamond and related materials. It was well attended this year, with about 350 participants from 28 countries.

One important aspect of the gathering was the large number of presentations on diamond-like carbon (DLC), an amorphous form of carbon noted for its high hardness and great potential for various industrial applications.

For example, DLC–coated sunglasses are currently being marketed in the United States by the firm Diamonex. Soviet scientists exhibited sheets of various plastics – including flexible ones – covered with hard DLC.

The Norton firm reported that it had succeeded in producing thick (approximately 0.3 mm), polycrystalline, optical-quality synthetic diamond films of large dimensions (at least 4 in. – 10 cm – square) using plasma jet technology. These films are grayish brown and transparent, unlike previously produced films of this type, which have been black, opaque, and of rather poor quality. This opens the way for the development of fairly inexpensive optical-quality synthetic diamond films.

There were also some definitive findings relating to the origin of the brownish color in DLC produced by chemical vapor deposition techniques. This coloration appears to be intrinsic to the hard variety of this material, the type with potential gemological applications. Therefore, the color of DLC films cannot be improved. However, the brown of CVD–produced polycrystalline synthetic diamond films is due to the concentration of various forms of graphitic carbon between the crystals that form the film. With this knowledge, it may now be possible to control (perhaps eliminate) the brownish coloration of this particular type of film.

Figure 1. Visually these "Dream cuts" (0.50 – 0.54 ct) appear larger than their actual weights. Photo © GIA and Tino Hammid.

New diamond cuts. New York–based Maico Diamond recently unveiled their new trademarked "Dream" cuts (figure 1). These new cuts represent modifications of the standard fancy-shape brilliant cuts – the oval, marquise, and pear – to take advantage of relatively flat rough. Note that the standard octagonal table outline has been "squared off" to make the table area appear larger. The Dream marquise also has two elongated star facets toward the points that add to the impression of an enlarged table area. The facet arrangements on the pavilion sides received slight modifications as well. The majority of the pavilion facets that traditionally meet at the keel-line have been shortened and opened up at the girdle, thus giving the impression of a finer subdivision of the pavilion area. The bow-tie effect appears to have been slightly diminished and moved away from the table area into the crown facets. The advantage of all these modifications would appear to be greater weight retention from the rough. Visually, the diamonds appear larger than their actual weight.

Historical diamond photographs. Many gemologists frequent local-area gem and mineral shows, swap meets, and even "yard sales," looking for interesting gems and old pieces of jewelry. Recently, GIA instructor Yianni Melas made an unexpected find of another sort while looking through some old twin-image photographs used in the once-popular stereoscopic viewers. Among the images were photos relating to early diamond mining in South Africa, including ones of Groot Schuur, the country home of Cecil Rhodes at Cape Town; the workers' compound at Kimberley; and a mining scene at Kimberley (figure 2). According to a librarian at the University of California in Riverside, the facility that has archived all the images of the now-defunct Keystone View Company, the photographs from South Africa were taken in approximately 1899–1900.

COLORED STONES

Colombia reports record emerald exports. Colombia's Mineralco announced that emerald exports had reached their highest level ever in February 1991, with sales totaling $16.7 million for the one-month period. Total reported emerald sales for 1990 came to $116.7 million, with Japan accounting for $91.6 million and the U.S., $16 million. (*Mining Magazine*, July 1991)

Large South Sea pearl. William A. Weidinger, a goldsmith and jewelry designer from Columbus, Ohio, reports having seen an unusual South Sea pearl on a trip to Thailand this past May. The gray pearl, seen at Naga Noi Island off the coast from Phuket, Thailand, was egg shaped, approximately 42 mm long, and had a high luster. Of particular interest, the pearl appeared to be an "enhydro," that is, to contain a liquid, probably water, in a pocket of air. The liquid was readily apparent when the pearl was shaken.

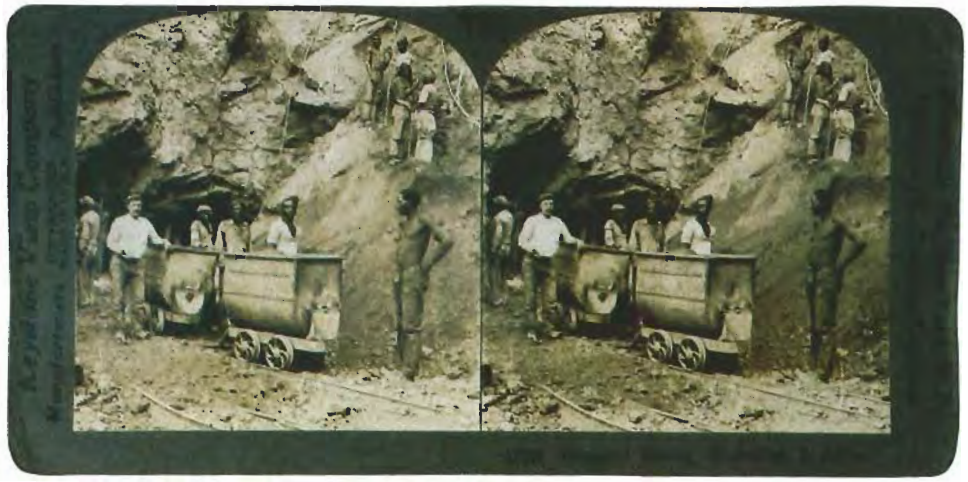


Figure 2. This twin-image "slide" for a stereoscopic viewer illustrates a turn-of-the-century mining scene at Kimberley, South Africa.

Myanmar to authorize Thai buyers. The Myanmar (formerly Burma) goverment has agreed to allow AGD Gem Dealer Co. of Thailand to open an office in Yangon (Rangoon). AGD, a buying company established by 72 members of the Thai Gem and Jewelry Traders Association, will purchase rough and fashioned gems from private mining companies in Myanmar as well as from stocks held by the state's Myanma Gems Enterprise. (*Jewellery News Asia*, July 1991)

Postage stamp commemorates large Burmese ruby. Earlier this year the government of Myanmar issued a special commemorative postage stamp (figure 3), both in honor of the 1991 Gems, Jade, and Pearl Emporium and to celebrate an exceptionally large ruby crystal mined in the historic Mogok region.

According to a report that appeared in the August 21, 1990, issue of *The Working Peoples' Daily*, an English-language journal published in Yangon (Rangoon), the crystal weighs 496.5 ct, measures 43 × 37 × 44 mm, and has a "crimson rose" color. As a special Emporium guest of the government's gem exploration, recovery, and marketing division—Myanma Gems Enterprise (MGE)—the GIA Gem Trade Laboratory's Robert Kane was allowed to examine this exceptional crystal. He reports that it was typical of the fine color for which Burmese rubies are renowned. It was reportedly recovered in the Mogok region in 1990, and was part of the 30,728 carats of illegally mined rubies confiscated by members of the government's Defence Services Intelligence Office on August 18 of that year; this particular stone was confiscated "from abroad." Originally dubbed the "Nawata ruby," the crystal was subsequently renamed the "SLORC ruby," after the acronym for State Law and Order Restoration Council, the ruling government body.

Figure 3. This postage stamp from Myanmar (Burma) features an exceptionally large ruby crystal mined recently in the Mogok region.

Small-scale sapphire mining continues in Thailand. Although much attention has been paid to the large, mechanized mining operations developing around Bo Phloi in western Thailand, much mining activity in this country is still carried out by traditional hand methods. On his trip to Southeast Asia in early 1991, GIA-GTL's Robert Kane also had the opportunity to visit some of these traditional sapphire mines. One typical small-scale operation, approximately 6 km (10 mi.) outside Chanthaburi, consisted of a single round, vertical shaft 1

Figure 4. A "handful" of sapphire rough is recovered in a good week of working this small mine near Chanthaburi, Thailand. Photo by Robert E. Kane.

m in diameter and 4 m deep (figure 4). In place of a ladder, the miner simply dug footholes into the walls of the shaft. He then tunneled laterally when he encountered the sapphire-bearing gravels. The buckets of soil brought to the surface were washed in artificial pools and hand sorted in rattan baskets. The miner indicated that in a good week he could recover a "handful" of green, blue, and dark brown sapphire rough.

Tanzanian spinel. In the Spring 1990 Gem News section, we mentioned spinels from the Umba Valley of Tanzania and showed three representative pieces of rough. This year at the February Tucson Show, a number of dealers were selling faceted stones from this locality. Some of the more attractive spinels ranged from a medium pink reminiscent of pink sapphire to a light purplish pink that strongly resembled fine kunzite. In general, these Tanzanian stones display more saturated colors in lighter tones than what we are accustomed to seeing in Sri Lankan spinels.

In some of these stones, we noted a soft, "velvety" look and reduced transparency similar to that for which sapphires from Kashmir are famous (figure 5). We believe this effect is due to the presence of submicroscopic mineral inclusions. Other gemological properties are consistent with those reported in the literature for spinels of similar color from other localities.

Update from Tanzania. Dr. Allen M. Bassett, currently working as chief geologist and gemologist for the Swiss company Tofco in northern Tanzania, has provided the editors with an update on activity at the Longido ruby deposit. The mine, which had been abandoned at the time it was nationalized in 1971, is now being worked by Tofco in a joint venture with Tanzania Gemstone Industries, a government parastatal.

When the mine was closed some 20 years ago, it had reached what is described as the "4th level." Since operations were renewed, miners have reached down to the 7th level, 270 ft. (approximately 83 m) below the surface. Plans call for the mine eventually to extend to the 10th level. At different levels, different types of rock

Figure 5. This 4.28-ct spinel from Tanzania has a pleasing "velvety" look that is probably caused by minute inclusions. Photo by Maha Smith.

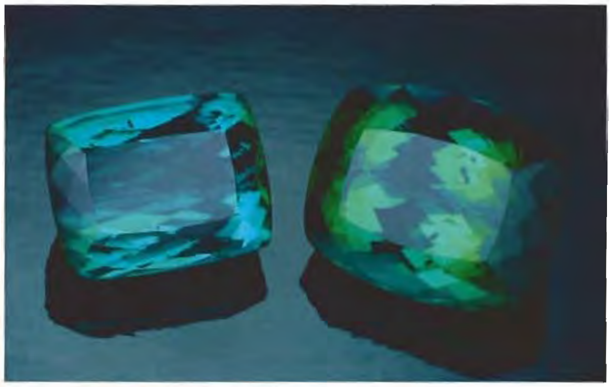


Figure 6. These 21.78-ct (left) and 33.13-ct (right) tourmalines are reportedly from Paraíba, Brazil; they are unusually large for this locality. Photo by Robert Weldon.

have been encountered. In addition to the chrome zoisite and ruby for which the deposit is well known—tons of cabochon-grade material but only a few carats of facetable material are being recovered—other potential gem materials include feldspar, apatite, and actinolite.

Tanzania invites tenders for mineral rights. The Tanzanian Ministry for Water, Energy and Minerals has invited urgent tenders for companies to apply for mineral rights to the Merelani area of Arusha, where tanzanite is mined. To be considered, a company must have experience in the mining, processing, and marketing of gem materials and indicate the prospecting methods, equipment, and drilling techniques to be used. Applicants must also provide a detailed work program and indicate their proposed minimum financial commitment to exploration and development as well as their security arrangements for the protection of the mine. Successful applicants will be awarded mineral rights for 200 m × 300 m blocks, nine of which are available, and will be required to post a bond. (*Mining Journal,* September 6, 1991)

Large Paraíba tourmalines. The majority of the distinctively colored tourmalines from Paraíba we have observed have been relatively small. Recently, however, we had the opportunity to examine two exceptionally large stones that are reportedly from this source: a 33.13-ct green and a 21.78-ct bluish green, both rectangular cushion cuts (figure 6).

EDXRF analysis by GIA Research revealed the presence of copper in both stones. This supports their purported origin as Paraíba, which to date is the only locality known to produce tourmalines colored by copper (see the Fall 1989 *Gems & Gemology,* p. 204).

Tourmaline with unusual "color change." Gem dealer Don Clary loaned GIA Research an interesting matched pair of "golden" yellow tourmalines from East Africa (Tanzania or Kenya). These two "opposed bar" cut stones, 2.48 and 2.56 ct, exhibit a most unusual color phenomenon: When examined under either incandescent *or* fluorescent lighting, they appear slightly brownish yellow (figure 7, left). However, when viewed under a combination of incandescent *and* fluorescent lighting, the stones become distinctly more greenish yellow (figure 7, right). To our knowledge, this type of color behavior has not been reported previously in the literature.

Microprobe analysis identified the stones as dravite tourmalines with approximately 9.9 wt.% MgO. Titanium is the major impurity, with minor amounts of vanadium and iron, and traces of manganese and chromium. The optical absorption spectrum shows a broad absorption feature centered at about 450 nm and a much less intense broad band at about 630 nm. This type of spectrum is typical of dravite and is attributed to $Fe^{2+} \rightarrow Ti^{4+}$ charge transfer and V^{3+}, respectively.

The luminescence of the stones was found to be

Figure 7. These two dravite tourmalines appear slightly brownish yellow when seen under incandescent (or *fluorescent) lighting (left), but they become distinctly greenish yellow when illuminated simultaneously with incandescent* and *fluorescent lighting (right). Courtesy of Don Clary; photos by Robert Weldon.*

somewhat unusual in that they were inert to long-wave ultraviolet radiation but fluoresced a moderate chalky yellow to short-wave U.V.

Tourmaline/andalusite: A pleochroism caveat. Gemologists learn to take full advantage of their most sensitive gemological equipment, their eyes. Visual observation – noting features with the unaided eye – thus becomes a first critical test. This includes such characteristics as transparency, color, color distribution, dispersion, brilliance, surface condition, and eye-visible inclusions.

Another important feature to note with colored stones is any eye-visible pleochroism. This can be very useful in identifying a number of gems such as tanzanite and iolite. It can also help separate tourmaline and andalusite, two stones with overlapping R.I.'s. Students are taught that, in general, the two pleochroic colors seen in tourmaline are different tones of the basic body color, and stones are usually cut to show the more desirable color through the table. Andalusite, as normally oriented in cutting, displays two distinct pleochroic colors through the table (figure 8, right).

Figure 8. Note the similarity in pleochroism between the oval 1.13-ct dravite tourmaline on the left and the round 1.48-ct andalusite on the right. Photo by Robert Weldon.

Becoming overly reliant on such gemological generalities can cause problems, as we were reminded recently when examining some dravite tourmalines from Sri Lanka. The pleochroic colors of these stones typically are significantly different in hue, and both can be seen through the table of a faceted stone (figure 8, left) – in a manner similar to the pleochroism in andalusite.

Purple and "chrome" green vesuvianites from Quebec. Vesuvianite, also known by gemologists as idocrase, is most often seen as a massive ornamental stone resembling jade. Less commonly, transparent single-crystal material is seen. Reports (see, e.g., *Mineralogical Record*, September/October 1991, p. 386) indicate that significant quantities of purple and green vesuvianite crystals have been recovered recently from the Jeffrey mine, in the province of Quebec, Canada, although most of the material is not gem quality.

Recently, GIA's Dr. Emmanuel Fritsch had a chance to study some faceted vesuvianites of these unusual colors, which were loaned by Guy Langelier of Montreal. The stones had been recovered from the Jeffrey mine between 1988 and mid-1990. The lot consisted of three purple, two saturated green, and two bicolored (light green and light pink) stones (see figure 9 for representative samples).

Figure 9. These unusual-colored vesuvianites, ranging from 0.48 to 2.79 ct, were recovered recently from the Jeffrey mine, Quebec, Canada. Courtesy of Guy Langelier; photo by Maha Smith.

EDXRF and U.V.–visible absorption spectroscopy were used to determine the cause of color in the green and purple stones. The purple stones were found to be colored by Mn^{3+}, apparently in a distorted octahedral site, which would account for their fairly pronounced pleochroism. The vivid green stones were determined to be colored by Cr^{3+}, also presumably in an octahedral site. Small amounts of nickel were also discovered in both the green and bicolored stones, but the data were insufficient to determine whether Ni^{2+} contributes to the coloration of these gems.

Unusual red zoisite. Dr. Allen Bassett has provided us with a brief note on an unusual zoisite, a 38.8-gram piece of dark-toned material that was brought to the Tanswit laboratory in Arusha, Tanzania. The specimen had one crystal face measuring approximately 4 × 2.5 × 2.5 cm, and was nearly clean, exhibiting some unidentified black specks and shallow surface-reaching fractures. The stone appeared to be too dark to facet into a gem. The owner, however, disagreed and proceeded to grind and polish its surfaces, which only served to destroy the specimen value of the piece.

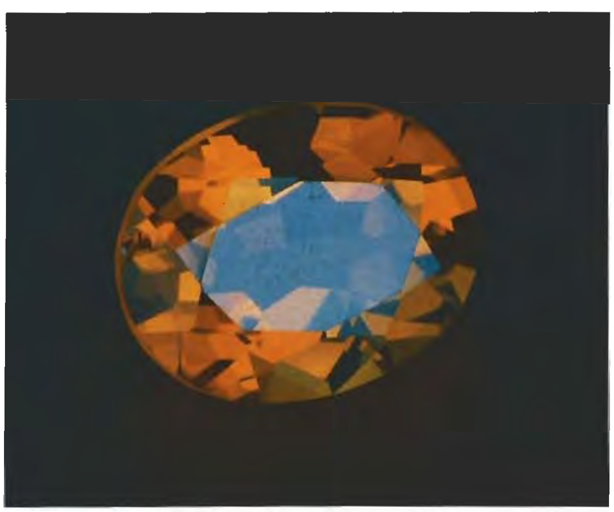
With strong fiber-optic illumination, the optic axis direction of the stone transmitted pure red, showing no hint of either orange or purple secondary hues; under ordinary incident light, the stone appeared black when viewed in this direction. One of the two other axial directions appeared medium greenish blue under intense illumination and almost black in weaker incident light, while the third, perpendicular direction transmitted a deep, pure purple with red flashes from the dichroic ends of the piece. Thin edges in the blue direction appeared to be almost pure yellow tinged with green. Dr. Bassett volunteered that, had the stone been lighter in tone, it would have been a unique gem.

When examined through a dichroscope, the red direction was seen to be composed of pure red and yellow-orange components; in the blue direction, the pleochroic colors were greenish blue and yellow-orange; and in the purple direction, they were red and greenish blue.

ENHANCEMENTS

Faceted gems coated with diamond-like carbon. A number of reports have appeared in the trade press relating to gemstones supposedly coated with synthetic diamond. To our knowledge, however, the only documented faceted gemstones so treated to date are the three diamonds that were experimentally coated with blue type IIb synthetic diamond, as reported in the Summer 1991 Gem News section. All other reports refer instead to coating with diamond-like carbon (DLC). The two materials are quite different. Specifically, DLC is amorphous and brownish in color, has a refractive index around 2.00, a hardness between that of diamond and corundum, and often contains hydrogen as a major constituent. The thin films described in the Summer 1991 issue are truly synthetic diamond: They are monocrystalline, bluish gray in color, have an R.I. of 2.4, and a hardness of 10. These particular synthetic diamond thin films do not contain hydrogen.

Figure 10. Note the unusually high luster of this 2.32-ct citrine, which has been coated with a thin film of diamond-like carbon. Courtesy of J.-L. Mansot and Pierre Fumey; photo by Robert Weldon.



At the International Gemological Symposium held in Los Angeles this past June, Dr. Fritsch reported on the experimental coating of faceted gemstones with diamond-like carbon (DLC). The treatment was carried out so that both the identifying characteristics of the coating as well as its impact on various durability aspects of the stones could be determined.

The deposition of DLC films on faceted stones was performed at the University of Nantes, France, by Prof. Yves Catherine, Prof. Jean-Louis Mansot, and Mr. Pierre Fumey. They covered the top portions of faceted beryls (aquamarine and emerald), amethyst, citrine, tourmaline, garnet, and strontium titanate with a thin film of diamond-like carbon approximately 0.08 micron thick, using a specially designed plasma reactor.

All DLC films did adhere to their gem substrates and could not be scratched with a corundum (Mohs 9) hardness point. When placed in a gem tumbler along with uncoated gems of the same species and varieties, the DLC–coated gemstones showed greater resistance to wear than their uncoated counterparts. Detection of the presence of the coatings is straightforward. Because of its high refractive index, the coating imparts an adamantine luster to the treated stones. This is particularly evident on stones of lower refractive index, such as citrine (figure 10). On lighter-toned stones, the brownish color of the film is evident. In addition, as the adherence is less than ideal, the film tends to wear at facet junctions, a feature that can be easily seen with magnification and surface-reflected light.

Montana sapphire heat treatment. For the past few years, Marc Bielenberg of Hamilton, Montana, has been mining the Dry Cottonwood Creek sapphire deposit in that state. The sapphire-bearing zone, at the valley bottom, is approximately 3,000 ft. (900+ m) long. Exploration has shown that the area contains deposits of gold as well as sapphires. Mr. Bielenberg reports that the recovery of sapphires seems to be good, particularly in sizes over one carat, although many of the crystals recovered to date are very pale.

To enhance the color of these pale crystals, Mr. Bielenberg has been working with Dale E. Siegford of Missoula, Montana, a specialist in the heat treatment of Montana sapphires. To date, the results have been excellent, as illustrated by the pale blue and yellow rough Dry Cottonwood Creek sapphires shown before heat treatment in figure 11 top and after heat treatment in figure 11 bottom. The blue crystals show the greatest improvement.

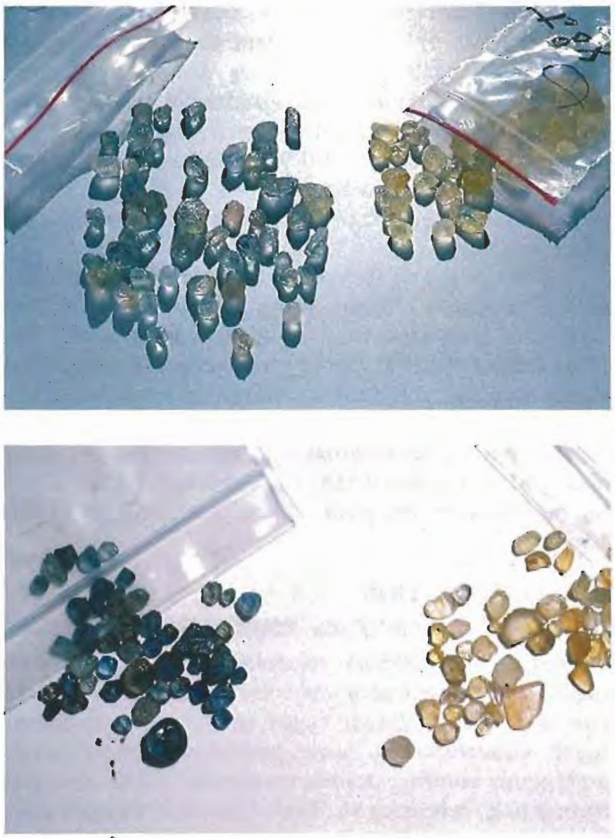


Figure 11. The improvement in color brought about by heat treating sapphires from Dry Cottonwood Creek, Montana, is readily apparent in these photographs showing typical material before (top) and after (bottom) enhancement. Photos by Maha Smith.

More experimentation with blue diffusion-treated sapphires . . . The Summer 1990 issue of *Gems & Gemology* carried a comprehensive article on diffusion-treated sapphires. Among the materials examined were stones marketed by the firm Gem Source of Las Vegas, Nevada, and Bangkok, Thailand. At that time, Jeffery Bergman of Gem Source stated that he used Sri Lankan sapphires as starting material.

Recently, Mr. Bergman shared information relating to experimental diffusion treatment of sapphires from another locality: Montana. He also donated eight of these stones, ranging from 0.53 to 1.18 ct, to GIA for study. According to Mr. Bergman, approximately 50% of the Montana sapphires they have diffusion treated to produce a blue color have also developed unwanted yellowish orange zones.

Examination of the eight sample stones with magnification readily revealed the yellowish orange zones described by Mr. Bergman; also noted in some of the stones were disk-like areas of dark blue surrounding dark crystalline inclusions (figure 12). We believe that the yellowish orange areas are related to zoned growth and reflect a higher iron impurity content, while the disk-like dark blue areas are caused by internal diffusion, a cannibalization of both iron and titanium from possibly iron-rich rutile and/or ilmenite inclusions. Both of these unanticipated color areas no doubt result from the high temperatures used in the diffusion-treatment process.

. . . and red stones too. The Spring 1991 Gem News column mentioned research being conducted by Gem Source to produce red diffusion-treated stones. That entry pointed out one problem being encountered: the simultaneous development of a blue color component, believed to be due to the presence of the appropriate chromophores in the starting gem material.

More recent communication with Mr. Bergman has shed additional light on the issue. He states that the development of the unwanted blue component might also be due to contaminants in the treatment oven, as the same ovens used to carry out this experimentation are used in the commercial production of the blue diffusion-treated stones. Mr. Bergman also indicated that adequate penetration of the desired red-producing chromophore has not been achieved to date, possibly due to insufficiently high temperatures. Repolishing has resulted in the removal of over 90% of the diffused color layer.

Mr. Bergman loaned us two of these experimental treated stones for examination, oval mixed cuts weighing 1.37 and 1.49 ct. The smaller stone had a predominantly violet face-up appearance with some areas that were more red-purple. Face-up, the larger stone seemed to be heavily color zoned, with two quadrants appearing a patchy medium red-purple and the other two appearing a dark purple, approaching black.

Figure 12. It is likely that both the large yellowish orange color zone and the smaller disk-like blue zones in this blue diffusion-treated sapphire from Montana resulted from the high temperatures used in the diffusion-treatment process. Photo by John I. Koivula.

Figure 13. Diffused transmitted illumination reveals that what little diffusion-produced color remained after repolishing this experimentally treated sapphire was concentrated along facet junctions. Photo by John I. Koivula.

Magnification revealed that the dark areas of the larger stone corresponded to areas of the pavilion that were dark red-purple and badly sintered; apparently they had not been repolished after treatment. Diffused transmitted light revealed that the repolished facets on both stones had little remaining surface-diffused color, most of which was found along facet junctions (figure 13).

Interestingly, the surface-diffused color of both stones had less of a blue component than their face-up color. Magnification, however, revealed blue color bands within the stones that no doubt were responsible for the stronger blue component of the face-up appearance. These blue bands were most likely caused by internal color diffusion around stringers of iron-titanium inclusions. The fact that the externally diffused color was red-purple rather than a purer red also gives some credence to the theory of surface contamination from the oven.

SYNTHETICS AND SIMULANTS

Porous Gilson synthetic opal. Hydrophane is a porous natural opal that reveals its play-of-color after it absorbs water or another liquid. Recently, the editors had the opportunity to examine a porous synthetic opal that also improved in appearance after being placed in water. The material, described as Gilson white porous synthetic opal, was provided to GIA by Louis Lo of Sunning Gems Co., Hong Kong. This material currently is not marketed commercially.

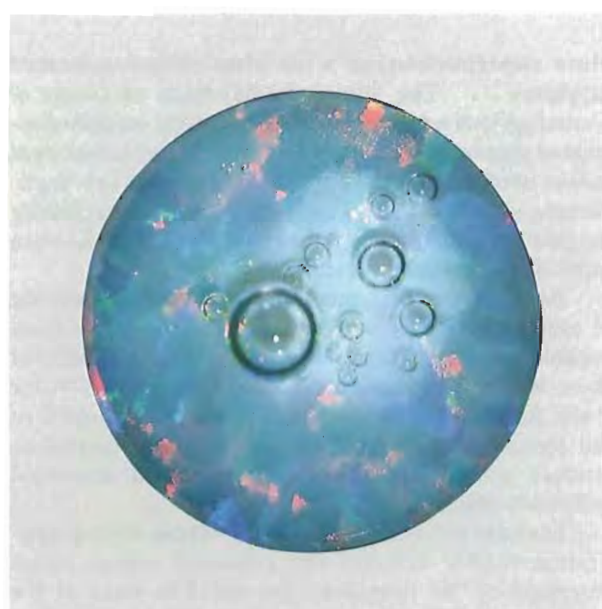
The 6-mm round cabochon had a white translucent body color and a moderate, predominantly orange play-of-color in small, angular patches. The play-of-color was weaker than what is typical of Gilson synthetic opal. The appearance began to change immediately when the cabochon was immersed in water, increasing in transparency first from the periphery and then proceeding inward (figure 14). The complete transformation, observed with magnification using direct transmitted light, took approximately 35 minutes. We also observed bubbles rising from the surface, probably air driven out of the voids between the silica as these were filled with water. As the water was absorbed, the distinctive "chicken wire" structure of the synthetic opal also became more apparent.

When removed from the water, the hydrated cabochon appeared slightly more transparent and less "white" in body color than before it was immersed. The play-of-color was also more pronounced. We dehydrated the stone in the well of a binocular microscope, using the heat of the incandescent bulb. This returned the synthetic opal to its original appearance. As one final observation, we noted that the cabochon sticks to the tongue, as does the porous, smoke-treated opal from Mexico.

INSTRUMENTATION AND NEW TECHNIQUES

Distinguishing diffusion treatment from surface coating. Diffusion treatment and colored surface coating are two distinctly different types of gemstone enhancement. Unfortunately, some confusion exists because ambiguous wording is sometimes used to describe the former (e.g., reference to "heat diffused coating of blue

Figure 14. The peripheral areas of this 6-mm porous Gilson synthetic opal have absorbed water while the lighter central area has not. Note also the air bubbles escaping from the surface. Photo by William Videto.



sapphire" in ICA Early Warning Laboratory Alert No. 45). Such confusion may be compounded by the fact that there can be superficial similarities between the two treatments, such as uneven facet-to-facet coloration and a dark color outlining some facet junctions.

In diffusion treatment, high temperatures are used to literally "cook" chromophores into the gem's crystal lattice. The mechanism that produces the blue color in, for example, blue diffusion-treated sapphires, is the same as that which produces blue in natural untreated (as well as heat-treated and synthetic) blue sapphires. Because it is the same mechanism, the pleochroism of blue diffusion-treated sapphires is essentially the same as that of natural or synthetic blue sapphires of comparable hue and depth of color.

Colored surface coatings, on the other hand, are just that: substances that are applied over the surface of the gem rather than incorporated into its structure. Those colored surface coatings we have examined to date—including Aqua Aura treated quartz and topaz (see the Fall 1990 Gem News section)—are isotropic substances, which have no effect on the stone's pleochroism.

In our experience, the presence or absence of pleochroism is a useful test to separate diffusion treatment from surface coating in anisotropic materials.

New setting method challenges diamond testers. Gemologists are well aware of the limitations that mountings can impose in gem identification. For example, specific gravity cannot be determined on mounted stones, prongs and other metalwork may obscure diagnostic inclusions, and modified lighting techniques may be required when attempting examination with a spectroscope.

Recently, Robert Crowningshield, of the GIA Gem Trade Laboratory, brought to our attention a problem with using thermal conductivity meters ("diamond testers") on very small diamonds set by an ingenious new method. The setting method, introduced by Claar Brothers, of New York, holds full-cut diamonds of about 0.01 ct by embedding them up to approximately one-half the crown area in a transparent, colorless, carbon-based polymer (figure 15). The setting method has been dubbed Carbolokd, with the set pieces called Carbolokd Diamond Jewelry.

Because the setting style has such a novel appearance, it would not be unexpected for some jewelers to suspect the identity of the set stones. And the first line of defense for most would probably be a diamond tester. Unfortunately, all such instruments have a lower size limitation on the stones they can effectively test; with many instruments, this lower limit is around 0.02 ct.

Some instruments, such as those produced by Presidium Diamond, include a small metal block with wells for testing small, loose stones down to 0.02 ct.; diamonds even this small generally read accurately as "diamond" when so tested unmounted or when they are set in traditional metal settings. Recent examination of such small diamonds set in Carbolokd Jewelry, however, shows that they give readings short of the "diamond" indication (although considerably higher than the readings characteristically given by CZ).

It is important that gemologists keep this in mind when attempting to use diamond testers on stones set with this new style, and they should depend more on examination with magnification to help correctly identify the stones. Two important features are characteristic inclusions and the precision of cutting on even very small diamonds (virtually impossible with simulants this size). In addition, since the Carbolokd Diamond Jewelry employs many stones in each piece, a certain percentage of them will undoubtedly fluoresce blue to long-wave U.V. radiation, the most typical reaction of diamond; CZ, the most common simulant these days, tends to fluoresce a uniform orange. Another method that can be used, albeit not available to most jewelers, is X-ray transparency. The X-radiograph of the pendant in the inset in figure 15 clearly shows the diamonds' distinctively high degree of X-ray transparency.

Figure 15. The diamonds in this pendant are mounted in a transparent colorless carbon-based polymer. The X-radiograph clearly shows the distinctive X-ray transparency of the diamonds. Pendant courtesy of Claar Brothers; photo by Nick DelRe. X-radiograph by Robert Crowningshield.

Jewelry imaging/teleconferencing system introduced. A high-resolution color imaging and teleconferencing sys-

Figure 16. This computer-generated image of a gem-set watch was produced on an imaging system developed by Card 'N' Tag Systems.

tem that allows jewelers to store and transmit photographic images of gemstones and jewelry pieces (figure 16) has been developed by Card 'N' Tag Systems of Benicia, California.

The company reports that their system, designed for use in promotions, special orders, electronic catalogs, inventories, customer profiles, repairs and appraisals, uses image compression to solve the problem of color graphic file storage and transmission. Normal color graphics files require more than one megabyte of computer memory, impractical for teleconferencing or most other personal computer applications. The imaging system compresses images by more than 95%, allowing the transmission of full-screen jewelry images in under one minute. The software may be combined with other programs, and images may be combined with text for a point-of-purchase display.

Tweezer improvement. After reading the *Gems & Gemology* article on diamond grit–impregnated tweezers (Summer 1990), Standwood S. Schmidt, a physician from Eureka, California, sent the Gem News editors a sample of 3M Microfoam Surgical Tape to examine. Dr. Schmidt uses this soft tape to "coat" the working surfaces of ordinary tweezers, thereby improving their gripping capacity while eliminating any danger of damaging even very small stones. The tape, which has one adhesive side (the other is soft and pliable), is easy to apply to the tweezers. The excess is simply trimmed away with a pair of scissors or a sharp knife blade.

ANNOUNCEMENTS

The Tucson Gem and Mineral Show will be held February 12–16, 1992, at the Tucson Convention Center. The featured mineral for the show is pyromorphite. For more information, contact the Tucson Gem and Mineral Society, P.O. Box 42543, Tucson, AZ 85733. Note that this year in Tucson a PGA Golf Tournament will be held February 10–16. Early room reservations are encouraged.

The American Gem Trade Association Gem Fair will be held in Tucson February 8–13 at the Convention Center. AGTA will announce the winners of the Spectrum Awards (a jewelry contest aimed at the effective use of colored stones) at that time. For information, contact AGTA at the World Trade Center #181, P.O. Box 581043, Dallas, TX 75258; (214) 742-4367.

The Gemological Institute of America will present various lectures and seminars in Tucson, February 8–13 at the Convention Center. For information, call (800) 421-7250 or (310) 829-2991, ext. 227, or write the GIA Registrar, P.O. Box 2110, Santa Monica, CA 90407.

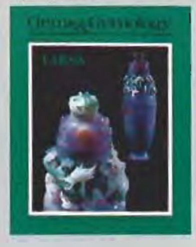
American Craft Association joins fight against design knock-offs. The newly formed American Craft Association has joined The Design Coalition in its fight to pass legislation to discourage copying of original and distinctive U.S. designs. The proposed bill, H.R. 1790, would give copyright-like protection to original, distinctive, and discretionary designs of useful articles. Its goals are to help preserve the creative integrity of original work of designers and help protect their livelihood.

The American Craft Association is a Washington, D.C.–based trade association representing the American Craft Council's 26,000 members. The Design Coalition is composed of more than 40 manufacturers, trade associations, labor unions, and designers working to strengthen U.S. design protection.

Spring 1985

Summer 1985

Spring 1986



Summer 1986

Fall 1986

Winter 1986

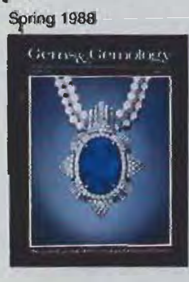
Spring 1987

Summer 1987

Fall 1987

Winter 1987

Spring 1988



Summer 1988

Fall 1988

Winter 1988

Spring 1989

Summer 1989

ORDER NOW!

Complete your back issues of Gems & Gemology NOW!

Single Issues:*	**$ 8.00** ea. U.S. **$ 11.50** ea. Elsewhere
Complete Volumes:* 1986, 1987, 1988, 1989, 1990	**$ 28.50** ea. vol. U.S. **$ 38.50** ea. vol. Elsewhere
Three-year set	**$ 75.00** U.S. **$100.00** Elsewhere
Five-year set	**$120.00** U.S. **$165.00** Elsewhere

*10% discount for GIA Alumni Association members

Back Issues of Gems&Gemology

Limited quantities of these issues are still available.

Spring 1986
A Survey of the Gemstone Resources of China
The Changma Diamond District, China
Gemstone Carving in China: Winds of Change
A Gemological Study of Turquoise in China
The Gemological Characteristics of Chinese Peridot
The Sapphires of Mingxi, Fujian Province, China

Summer 1986
The Coscuez Mine: A Major Source of Emeralds
The Elahera Gem Field in Central Sri Lanka
Some Unusual Sillimanite Cat's-Eyes
An Examination of Four Important Gems
Green Glass Made of Mount Saint Helens Ash?

Fall 1986
A Simple Procedure to Separate Natural from Synthetic Amethyst on the Basis of Twinning
Pink Topaz from Pakistan
Carbon Dioxide Fluid Inclusions as Proof of Natural-Colored Corundum
Specific Gravity—Origins and Development of the Hydrostatic Method
Colombage-Ara Scheelite

Winter 1986
The Gemological Properties of the Sumitomo Gem-Quality Synthetic Yellow Diamonds
Art Nouveau: Jewels and Jewelers
Contemporary Intarsia: The Medvedev Approach

Spring 1987
"Modern" Jewelry: Retro to Abstract
Infrared Spectroscopy in Gem Identification
A Study of the General Electric Synthetic Jadeite
A New Gem Material from Greenland: Iridescent Orthoamphibole

Summer 1987
Gemstone Durability: Design to Display
Wessels Mine Sugilite
Three Notable Fancy-Color Diamonds: Purplish Red, Purple-Pink, and Reddish Purple
The Separation of Natural from Synthetic Emeralds by Infrared Spectroscopy
The Rutilated Topaz Misnomer

Fall 1987
An Update on Color in Gems. Part I
The Lennix Synthetic Emerald
An Investigation of the Products of Kyocera Corp. that Show Play-of-Color
Man-Made Jewelry Malachite
Inamori Synthetic Cat's-Eye Alexandrite

Winter 1987
The De Beers Gem-Quality Synthetic Diamonds
The History and Gemology of Queen Conch "Pearls"
The Seven Types of Yellow Sapphire and Their Stability to Light

Spring 1988
An Update on Color in Gems. Part 2
Chrysoberyl and Alexandrite from the Pegmatite Districts of Minas Gerais, Brazil
Faceting Large Gemstones
The Distinction of Natural from Synthetic Alexandrite by Infrared Spectroscopy

Summer 1988
The Diamond Deposits of Kalimantan, Borneo
An Update on Color in Gems. Part 3
Pastel Pyropes
Examination of Three-Phase Inclusions in Colorless, Yellow, and Blue Sapphires from Sri Lanka

Fall 1988
An Economic Review of the Past Decade in Diamonds
The Sapphires of Penglai, Hainan Island, China
Iridescent Orthoamphibole from Wyoming
Detection of Treatment in Two Green Diamonds

Winter 1988
Gemstone Irradiation and Radioactivity
Amethyst from Brazil
Opal from Opal Butte, Oregon
A Gemological Look at Kyocera's Synthetic Star Ruby

Spring 1989
The Sinkankas Library
The Gujar Killi Emerald Deposit
Beryl Gem Nodules from the Bananal Mine
"Opalite:" Plastic Imitation Opal

Summer 1989
Filled Diamonds
Synthetic Diamond Thin Films
Grading the Hope Diamond
Diamonds with Color-Zoned Pavilions

Fall 1989
Polynesian Black Pearls
The Capoeirana Emerald Deposit
Brazil-Twinned Synthetic Quartz and the Potential for Synthetic Amethyst Twinned on the Brazil Law
Thermal Alteration of Inclusions in Rutilated Topaz
Chicken-Blood Stone from China

Winter 1989
Emerald and Gold Treasures of the *Atocha*
Zircon from the Harts Range, Australia
Blue Pectolite
Reflectance Infrared Spectroscopy in Gemology
Mildly Radioactive Rhinestones and Synthetic Spinel-and-Glass Triplets

Spring 1990
Gem Localities of the 1980s
Gemstone Enhancement and Its Detection
Synthetic Gem Materials
New Technologies: Their Impact in Gemology
Jewelry of the 1980s

Summer 1990
Blue Diffusion-Treated Sapphires
Jadeite of Guatemala
Tsavorite Gem Crystals from Tanzania
Diamond Grit–Impregnated Tweezers

Fall 1990
Majorica Imitation Pearls
Tourmalines from Paraíba, Brazil
Hydrothermally Grown Synthetic Aquamarines from the USSR
Diamonds in Trinity County, California

Winter 1990
The Dresden Green Diamond
Identification of Kashmir Sapphires
A Suite of Black Diamond Jewelry
Emeraldolite

Spring 1991
Age, Origin, and Emplacement of Diamonds
Emeralds of Panjshir Valley, Afghanistan

Some issues from the 1983, 1984, and 1985 volume years are also available. Please call the Subscriptions Office at the number given below for specific details.

TO ORDER: Call: toll free **(800) 421-7250, ext. 201**
OR WRITE: GIA, 1660 Stewart Street, Santa Monica, CA 90404, Attn: G&G Subscriptions

"PERFECT" Challengers

Hundreds of readers participated in the fifth annual *Gems & Gemology* Challenge (see the Spring 1991 issue). As part of the GIA Continuing Education program, the Challenge was created to strengthen the professional jeweler-gemologist's scholarship in this ever-changing field. Those with a score of 75% or better received a GIA Continuing Education Certificate. We are especially proud to list below those respondents who received a perfect score (100%). Congratulations!

Virginia Lee Adams, Pinellas Park, FL; Sue M. Angevine, DeLand, FL; T. J. Arendsen, Lansing, MI; Linda Anne Bateley, Kent, England; Howard W. Beardsley, Naples, FL; Rebecca Ann Bell, Joshua Tree, CA; Christine Blankenship, N. Royalton, OH; Rudi M. Boskovic, Armidale, N.S.W., Australia; Carol Grobe Buck, Indianapolis, IN; Lisa Burbach, Manitowoc, WI; Almir Rodrigues Cardoso, Kaohsiung, Taiwan; Kim Ching Huo Chang, Taipei, Taiwan; Veronica Clark-Hudson, Santa Monica, CA; Margaret T. Clerkin, La Jolla, CA; Ann Coderko, Muscatine, IA; Bruno Cupillaro, Beroucan, France; Roger Davidson, Cooperstown, NY; Robin M. Dinnes, Franklin, NC; Christophe DuBois, Cannes, France; Jean-Davis Duroc-Danner, Geneva, Switzerland; Richard W. Edwards, Kettering, OH; Edward J. Feldman, Jacksonville, FL; Beth I. Fleitman, Milton, MA; Shirley A. Forster, Gresham, OR; Betty Lu Frost, Lonngmont, CO; John Fuhrbach, Amarillo, TX; Amaya Garin, Madrid, Spain; Wayne M. Gilcrease, Santa Monica, CA; Kim Donna Gilling, Harare, Zimbabwe; Robert Gingras, Bristol, CT; Louis J. Ginsberg, Damascus, MD; Sheila Goetz, Tucson, AZ; Cynthia L. Goodwin, Manchester, NH; Anthony De Goutiére, Victoria, B.C., Canada; Manoj B. Gupta, Bombay, India; Sinikka Hagberg, Cairns, Australia; J. L. Harding, London, England; April D. Hartner, Gresham, OR; Donna Hawrelko, W. Vancouver, B.C., Canada; Hayo W. Heckman, The Hague, Netherlands; Franklin Herman, Des Moines, IA; Mary Hicks, Humble, TX; Jacqueline C. Hines, Raleigh, NC; Robert P. Hord, Laguna Park, TX; Myron A. Huebler, Rio Rancho, NM; Michael F. Huegi , Berne, Switzerland; William Iwan, Jacksonville, FL; Toni Lisa Johnson, Fort Worth, TX; Theresa A. Jones, Centerville, OH; Chow Ka-Keung, Kowloon, Hong Kong; Mark Kaufman, San Diego, CA; David A. Keith, Armidale, N.S.W., Australia; Jeff Ketay, Peoria, IL; Carroll J. Kiefer, Jr., Tomball, TX; Dennis G. King, Savannah, GA; Goran Kniewald, Zagreb, Yugoslavia; Mark S. Kochevar, Klamath Falls, OR; Wiraman Kurniawan, Medan, Indonesia; David M. Larcher, Sutton Coldfield, England; Thomas Larsson, Jarfalla, Sweden; Bert J. Last, Sydney, N.S.W., Australia; William A. Lavender, Pelham, AL; Karen Levian, Timonium, MD; David R. Lindsay, Bobcaygeon, Ont., Canada; Anthony Lore, Whitestone, NY; Linda Luz, San Francisco, CA; Michael C. McCoy, Reno, NV; Sandra MacKenzie-Graham, Burlingame, CA; Arby G. Magill II, Santa Monica, CA; Ronald A. Maher, Armidale, N.S.W., Australia; James S. Markides, Sumter, SC; Leona Claire Marsh, Harare, Zimbabwe; Lesley Faye Marsh, Harare, Zimbabwe; D. Elizabeth Martin, Johnson City, TN; Warner J. May, Ozark, AL; Grenville Millington, Birmingham, England; Yehya Sabet Morsy, Alexandria, Egypt; Francisco Muller Bastos, Belo Horizonte, Brazil; Daniel Octeau, Montreal, Que., Canada; Barbara A. Odell, Brentwood, TN; J. Andrew Ontko, Jr., Oklahoma City, OK; Fabrizio Paccara, Terni, Italy; Linda Partney, Marathon, FL; Roberta Peach, Calgary, Al., Canada; Mateo Perez-Garcia, Malaga, Spain; Vincent Peters, Namur, Belgium; Jon C. Phillips, Vancouver, B.C., Canada; Patrick W. Planas, San Antonio, TX; Ron Plessis, Aldergrove, B.C., Canada; Sylvia Ramsey, Chicago, IL; Ronald Redding, Pelham, AL; Carmen Rivet, St. Lambert, Que., Canada; Suzanne Rizzo, Cocoa Beach, FL; Deanna Lynn Rogers, Dayton, OH; Donald G. Rosenstiel, Mobile, AL; A. Samsavar, Seattle, WA; Jack Schatzley, Toledo, OH; Carole Devor Scott, Herndon, VA; Glenn Shaffer, Julian, CA; Alan R. Sheidler, Toledo, OH; Carolyn Sherman, Dallas, TX; Darlene Louise Simpson, Margate, FL; Ben H. Smith, Jr., Wilmington, NC; Peter R. Stadelmeier, Levittown, PA; Diana L. Stanley, Grand Island, NE; Judith Steinberg, Santa Monica, CA; John Stennett, Temple, TX; Cyrille Sureau, Montreal, Que., Canada; Michael A. Tessiero, Fort Johnson, NY; Donald . Tomace, Union, NJ; Alex Tourubaroff, Westminster, CA; Blair P. Tredwell, Advance, NC; Petri Tuovinen, Kouvola, Finland; Belinda Turner, Tyler, TX; E. Th. van Velzen, Rotterdam, Netherlands; Sue Vastalo, Bolingbrook, IL; Gal Vered, Okinawa, Japan; Bruce S. Vick, Belleville, IL; Donald E. Watson, Wailuku, HI; Nean Wilson, East Luthian, Scotland; Kelly Wiseman, Laramie, WY; Amy Wolfe-VanCleave, Wall, TX; Robert C. Wyatt, Sr., Mesa, AZ; Shelley Zamborelli, Laguna, CA; Monique Zander, Sao Paulo, Brazil; Urs Zwyssig, Bangkok, Thailand

Answers (see pp. 59 and 60 of the Spring 1991 issue for the questions): (1) A, (2) C, (3) B, (4) C, (5) C, (6) B or C, (7) D, (8) C, (9) B, (10) A, (11) C, (12) D, (13) A, (14) B, (15) C, (16) D, (17) C, (18) A, (19) D, (20) D, (21) A, (22) B, (23) D, (24) B, (25) B.

BOOK Reviews

ELISE B. MISIORWSKI AND LORETTA LOEB, EDITORS

GEMOLOGY 2nd Edition

*By Cornelius S. Hurlbut and Robert C. Kammerling, 337 pp., illus., publ. by John Wiley & Sons, New York, 1991. US$58.00**

It has been 12 years since the first edition of this well-known book (then with George S. Switzer as second author) appeared. In the interim, there have been many major advances and developments in gemology. This second edition (co-authored by GIA's Robert C. Kammerling) has successfully met the challenge of being a detailed and up-to-date gemological text.

Those familiar with the first edition will find few changes in the second with respect to the fundamentals of crystallography, crystal chemistry, and optical properties, except for improvements in presentation (e.g., an illustration to assist in understanding the spot method). Likewise, the section devoted to "descriptive gemology" (approximately one-third of the book) is very similar to what was present in the first edition. It has been updated where individual gemstones are discussed in alphabetical order, however, to include new gem materials such as sugilite.

The chapters on new advances and developments in the fields of enhancements and their detection, synthetics, and simulants, which dominated gemology in the 1980s, have received the greatest attention in this revision. Most of these chapters have been greatly expanded, and some have been completely rewritten. It is notable that "Gemstone Enhancements" has been given chapter status in this new edition in recognition of its importance. The color plate section (16 pages with a total of 147 photographs) has been completely reworked, and is a collection of excellent photographs that illustrate a wide variety of characteristics (inclusions, phenomena, etc.) for both natural and synthetic gem materials. Regrettably, many of the black-and-white illustrations that accompany the text have been reproduced poorly and are a blemish on an otherwise fine production.

Overall, this second edition of *Gemology* is a welcome addition to the gemological literature. Its approximately 100-page expansion over the first edition is almost entirely in areas considered gemological (e.g., enhancements, synthetics), compared to the mineralogic fundamentals and descriptive gemology. The book deservedly will continue to enjoy its reputation as one of the premier texts in gemology.

ALFRED A. LEVINSON
University of Calgary
Calgary, Alberta, Canada

GEMSTONES OF PAKISTAN – GEOLOGY AND GEMMOLOGY

*By Ali H. Kazmi and Michael O'Donoghue, 146 pp., illus., publ. by Gemstone Corporation of Pakistan, Karachi, Pakistan, 1990. US$24.95**

A long-awaited description of gem materials and gem deposits of Pakistan, *Gemstones of Pakistan* not only examines the interrelationship between geologic environment and gem type, but it also describes the characteristics of each gem material in detail and serves as the single definitive source of information on all known Pakistani gems.

This is concisely and expertly achieved in 146 pages, which include 72 color photographs of gemstones, gem deposits, and beautiful high-mountain scenery; 24 line drawings, including 13 maps and nine cross-sections; and 19 tables that summarize various gemstone characteristics. The remarkable list of Pakistani gem materials includes emerald, vesuvianite, rodingite, ruby, spinel, pargasite, epidote, actinolite, aquamarine, tourmaline, garnet, topaz, moonstone, quartz, zircon, rutile, azurite, agate, hessonite garnet, turquoise, and tsavolite (tsavorite).

The reader is first prepared for the discussion of Pakistani deposits by a description of the important characteristics of minerals, including crystal classes, color, chemistry as it affects color, hardness, specific gravity, fluorescence, and the ways to evaluate these characteristics for gemstone identification. Additional background on Pakistani gem deposits is provided by a chapter on the geology of Pakistan. Using a geologic framework, the authors subdivide the gem deposits of Pakistan into five groups: Indus suture associated, Karakoram suture associated, pegmatite associated, gemstones in hydrothermal veins, and a miscellaneous group for the less easily classified deposits. The origin of most Pakistani gems can be clearly traced

**This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404. Telephone: (800) 421-7250, ext. 282.*

to geologic processes that relate to plate tectonics, and the awe-inspiring Himalaya Mountains are a virtual geologic showcase that displays the effects of these processes as well as the beautiful gemstones themselves. The last two sections of the book are devoted to mineral specimens and marketing, and are very useful.

The book was printed by Elite Publishers in Karachi for the Gemstone Corporation of Pakistan (GEMCP); printing is of good quality and color reproduction is excellent. The price is indeed a bargain for a hard-cover book printed in color.

I am pleased to see another book of this type added to the world literature on gem deposits. As more is learned about the geologic control of gemstones, this knowledge adds to the beauty and enchantment of these exquisite minerals. The readers of *Gems & Gemology* are well served by this nice addition to the literature.

LAWRENCE W. SNEE
U.S. Geological Survey
Denver, CO

GEMS, GRANITES, AND GRAVELS, Knowing and Using Rocks and Minerals

*By Richard V. Dietrich and Brian J. Skinner, 173 pp., illus., publ. by Cambridge University Press, New York, NY, 1990. US$24.95**

Gems, Granites, and Gravels was written by two prominent geologists to introduce the public to minerals and mineralogy and to their impact on the lives of the average citizen. The rationale for writing such a book makes good sense in that, as the authors point out, the average person uses 10 metric tons of minerals each year directly or indirectly.

The content of *Gems, Granites, and Gravels* is not forbidding in any sense, but it is designed to point out the manifold contacts that we have in our daily lives with various minerals and rocks. There is an overview on the mineral world and chapters on crystals, mineral chemistry, and rocks, plus such unglamorous materials as soils, dusts, and muds. Economically important subjects such as ores, ore minerals and building materials are also explored, as are some of the other effects that rocks and minerals have on our well-being. Gems are mentioned, but only briefly, which was somewhat surprising given their prominence in the title.

The authors use a lighthearted approach to their subject matter, perhaps best illustrated in the section under the heading "The Naming of Minerals." A number of illustrations are given for how minerals are named, such as aragonite for the Aragon Province in Spain, rooseveltite for Franklin Delano Roosevelt, and at one point: "There is even a skinnerite, which is named after Brian J. Skinner (one of the authors) as well as a dietrichite which is not named for R. V. Dietrich but for G. W. Dietrich, the 19th century Bohemian chemist who first analyzed the mineral. (In any case these two names seem appropriate – skinnerite is an ore mineral, and dietrichite is a vitriolic efflorescence.)"

Gems, Granites, and Gravels provides an excellent introduction for the layperson to the world of minerals.

RICHARD T. LIDDICOAT
Chairman of the Board, GIA
Santa Monica, CA

CRYSTALS

*By Ian F. Mercer, 60 pp., illus., publ. by the Harvard University Press, Cambridge, MA, 1990. US$9.95**

I was given this excellent little book to review while trying to find a text or two on crystals and crystal growth that my 11-year old daughter could use for a school mathematics project on the geometry of crystal forms. *Crystals,* by Ian F. Mercer, proved to be the type of introductory book she needed. That's not to say that this book is only for children. It is so beautifully illustrated and enjoyable to read that, even if you are not specifically interested in crystallography, mineralogy, or any of the related sciences, it is still hard to put down without at least leafing through and reading the figure captions.

This well-organized book is divided into three main sections. The first, titled "The Inside Story," addresses crystal form, structure, symmetry, and classification into crystal systems. Minerals, gem-quality crystals, crystalline perfection, and the micro-world of crystals are also introduced.

In the second section, "See How They Grow," the geologic formation of mineral crystals is illustrated with a line drawing that shows where various minerals may form in a cross-section of the earth's crust and upper mantle. Visual evidence of crystal growth in nature is presented by a series of color photos that illustrate "ghosts" (phantoms), color zoning, solution or etch pits, growth marks, and inclusions. This section also contains detailed instructions on how to grow your own crystals at home by vapor or from water solution.

The last section, "Crystals and You," introduces the reader to the various means used to study crystals, such as polarized light, X-ray diffraction, and light refraction. Two particularly interesting photos show the double image of a sewing needle when viewed through calcite and a brass contact goniometer being used to measure the interfacial angles of a crystal. The book concludes with condensed sections on collections, the growth of synthetics, crystal lore, crystal technology, and crystal wonders (including a photo of a baby sitting in an amethyst geode for size reference). Crystal facts and figures, an index, and a list of titles suggested for additional reading are also present.

This is an excellent book to introduce someone, regardless of age, to the beauty of the crystal world around us.

JOHN I. KOIVULA
Chief Gemologist, GIA
Santa Monica, CA

GEMOLOGICAL ABSTRACTS

DONA M. DIRLAM, EDITOR

COLORED STONES AND ORGANIC MATERIALS

Baotite—A new gemstone in Baiyun Ebo, Inner Mongolia. Sun Weijun and Yang Ziyuen, *Abstracts of the 15th General Meeting of the International Mineralogical Association*, June 28–July 3, 1990, Beijing, China, pp. 688–689.

Baotite is a brownish black to black translucent mineral with a semi-metallic luster and a Mohs hardness of 6 that could potentially be used as a gem material. It is newly discovered from the Baiyun Ebo rare earth–iron ore deposit in Inner Mongolia. Its chemical composition is $Ba_4(Ti,Nb,Fe)_8O_{16}(Si_4O_{12})$ Cl. A brief description of the occurrence of baotite is presented, although no information is included on its abundance. *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 her 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.*

Emeralds from Colombia (Part 2). G. Bosshart, *Journal of Gemmology*, Vol. 22, No. 7, 1991, pp. 409–425.

Part 2 of this trilogy on Colombian emeralds includes a review of crystal size and morphology, chemical composition, causes of color, physical and optical properties, and microscopic features. It is interesting to note that the author, contrary to one commonly held notion in Europe, acknowledges emeralds colored largely by vanadium. Colombian emeralds, with an average Cr:V ratio of 3:1, fall in the middle of the range of chromophore composition for emeralds in general. Iron content of Colombian emeralds is relatively low, and other possible chromophores are absent or insignificantly low. Optical absorption spectra, illustrated by unretouched spectrophotometer curves, are related to the chemical causes of color and to the renowned fine color of Colombian emeralds.

The discussion of microscopic features that concludes this article covers fluid inclusions, mineral inclusions, internal growth characteristics, and color zoning. Three pages of color photomicrographs illustrate the features discussed.

I found part 1 of Mr. Bosshart's three-part series to be commendable and readable, and I have not been disappointed by part 2. Moreover, the discussion in part 2 provides information on emeralds other than those of

Colombia, making the article of even broader interest and gemological value. It was, however, mildly frustrating not to have the bibliography printed with the article in hand (an editor's note advises that the full bibliography was published with part 1). *CMS*

An examination of chrysoprase from Goiás, Brazil. R. C. Kammerling, J. I. Koivula, and E. Fritsch, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 313–315.

The authors studied specimens of chrysoprase that were reported to have originated in a galena mine near Niquelandia, Goiás, Brazil. The gemological properties were found to be consistent with those previously reported for chrysoprase chalcedony. X-ray fluorescence spectroscopy revealed that silicon and nickel were the only elements present in significant amounts. Comparison of these samples with Australian chrysoprase indicated that features are similar except for the intense absorption in the Australian material, which correlates with its more saturated color.

Although the authors have observed that chrysoprase is typically inert to U.V. radiation, the Brazilian material fluoresced a moderate greenish blue to long-wave U.V., with a weaker reaction to short-wave U.V. There was no phosphorescence to either wavelength.

Maha Smith

Fossil mammoth ivory: A new choice for jewelers. R. Weldon, *Jewelers' Circular-Keystone,* Vol. 162, No. 8, August 1991, pp. 154–156.

Since the U.S. banned the import of elephant ivory in 1989, fossilized mammoth ivory has become a favored—and legal—alternative. The permafrosts of Alaska and the Soviet Union are sources for this ivory, which is thought to have lain preserved for 20,000 to 40,000 years.

This type of ivory has been used by the Athabascan Indians, Eskimos, and other Alaskans for thousands of years. According to Al Allen of Alaska Jade and Ivory Works, Soldotna, Alaska, 20,000 Indians currently make a living from fossilized ivory.

Depending on the minerals absorbed, fossilized ivory can occur in different colors: It has been found in dark blue, black, brown, and green, as well as in various shades of cream. Besides strength of color, the best way to distinguish between fossilized ivory and modern elephant ivory is from the engine-turn effect: The V-shaped crossing of lines in fossilized specimens forms acute angles of 90°, versus the angles of 120° or more seen in modern elephant ivory.

Other animal ivories and products exist such as walrus, narwhal, animal bone, horn, antlers, and chemically treated coral. For those uncomfortable about wearing ivory of any kind, doum palm, orozo nuts, and even plastic are available. *KBS*

Gemmology Study Club Lab Reports. G. Brown, S. M. B. Kelly, R. Beattie, and H. Bracewell, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 325–332.

This series of brief reports covers a number of interesting gem materials. First described is a 1.12-ct crystal fragment from central Queensland that consists of a ruby core surrounded by hexagonally banded grayish blue to bluish to purplish sapphire. Next covered is gem-quality stichtite, a rare, chromium-containing mineral from northwest Tasmania.

The next, and longest, of the entries covers a suite of jewelry set with emerald-cut stones that resemble "padparadscha" sapphires. According to the investigators, these stones were actually flame-fusion synthetic yellow sapphires "coated by a thin layer of surface diffused synthetic ruby." It is interesting to note that the owner of the jewelry had purchased it in Kashmir.

This is followed by an entry on two glass imitations, the first resembling aquamarine and the second composed of a photosensitive glass that changes from colorless to dark brown after a 15-second exposure to a 150-watt incandescent bulb.

Also covered are green beryls from Harry's Mine near Torrington, New South Wales (with a good description of their gemology and inclusions); an aventurescent quartz that reportedly originated from a site near Inverell, New South Wales, and resembles aventurescent feldspar; and pit glass from Sri Lanka. *RCK*

Editor's Note: Diffusion treatment actually diffuses a layer of color into the stone and is not a coating per se. However, recutting can remove the color.

Gemmological study on Eonyang amethyst from Korea. Won-Sa Kim, *Abstracts of the 15th General Meeting of the International Mineralogical Association,* June 28–July 3, 1990, Beijing, China, pp. 678–679.

Amethyst that occurs in geodes is found in the Eonyang Granite near the southern part of the Korean peninsula. The amethyst develops as an epitaxial overgrowth on earlier-formed smoky or colorless quartz. Fe, Mg, Ca, and Cu occur as trace elements in the amethyst in quantities up to 6 ppm. Various solid inclusions (hematite and perthite feldspar) and fluid inclusions (both liquid and gaseous) that occur in the amethyst were studied by several analytic methods to reveal the conditions of amethyst formation. *JES*

On the genesis of charoite rocks. N. V. Vladykin, *Abstracts of the 15th General Meeting of the International Mineralogical Association,* June 28–July 3, 1990, Beijing, China, pp. 689–690.

The geologic occurrence of this ornamental gem material in the Soviet Union appears to be unique. Charoite is found in the Murun massif, a large body of layered ultrapotassic-alkali rocks that have been age dated at 120–160 million years. A number of unusual rock types are represented in this layered sequence, among which is charoite. These unusual rocks are thought to have crystallized from an ultrapotassic lamproite magma. Inferences are presented on the temperatures and other conditions of crystallization. *JES*

Mineral associations of corundum-bearing marbles and the problem of ruby genesis. S. I. Konovalenko, *Abstracts of the 15th General Meeting of the International Mineralogical Association,* June 28–July 3, 1990, Beijing, China, pp. 679–680.

Most high-quality rubies are found in primary and secondary deposits associated with corundum-bearing calcite marbles. Much of the world's production comes from a series of deposits that occur along the Alpine-Himalaya fold belt that stretches from Afghanistan and the Hindu Kush in the west along the Himalayas into portions of Southeast Asia. Experimental data and the presence of certain mineral inclusions (such as phlogopite, feldspar, etc.) suggest that rubies are formed during the metamorphism of carbonate rocks under high-grade conditions (epidote-amphibolite or amphibolite facies). Ruby formation also involves recrystallization during which structural defects and inclusions are often removed from the growing crystal. *JES*

Perestroika gems—natural & not. R. Weldon, *Jewelers' Circular-Keystone,* Vol. 162, No. 8, August 1991, pp. 142–145.

The Soviet Union has long been known for its natural gem materials—among them Siberian diamonds, emeralds from the Ukraine, spinels from the Pamir Mountains, and demantoids from the Urals. Today, the Soviet Union is making inroads in the production of synthetic gems, including synthetic diamonds, synthetic malachite, flux synthetic spinel, "pearl" cubic zirconia, and hydrothermal quartz. This article gives a concise report on the past and present situation of the Soviet Union's production of natural and synthetic gems. It is a must-read for anyone interested in Soviet economics and how they affect the gem industry in the Soviet Union. The article is accompanied by nine photos of various USSR-produced gems. *KBS*

A rare baler shell pearl. G. Brown and S. M. B. Kelly, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 307–308.

Baler shells are large, spiral-shaped univalves found in the shallow waters off Australia's northern coasts, from Shark Bay in Western Australia to southeast Queensland. This nicely illustrated Gemmology Study Club Report describes the authors' examination of a rare, nonnacreous "pearl" that was recovered from a baler shell dredged off the coast from Noosa, some 100 km north of Brisbane, Queensland.

The authors preface their description of the "pearl" with a detailed description of the host shell, *Melo amphora.* The "pearl" itself weighs 68.97 ct, measures 22.8 mm × 20.6 mm, and is slightly pinkish orange, nonnacreous, and slightly pointed on one end. It displays a distinctive "flame" pattern similar to that seen on so-called conch "pearls." Magnification reveals that the smooth porcelaneous external surface is covered with a pattern of yellowish "flames" as well as small brown spots due to subsurface conchiolin accumulations. Gemological properties include an S.G. of 2.83, a spot R.I. of 1.67, no reaction to both long- and short-wave U.V. radiation, and no identifying absorption spectrum. An X-radiograph revealed a concentric structure similar to that of *Pinctada* pearls.

The authors conclude that this "calcareous concretion" is composed predominantly of aragonite. *RCK*

Research on the mineralogy of the calcium chrome-garnet of gem grade at a district in Tibet. Yongxian Liu, *Abstracts of the 15th General Meeting of the International Mineralogical Association,* June 28–July 3, 1990, Beijing, China, pp. 680–682.

Small crystals of transparent uvarovite garnet have been found at a locality in Tibet. The garnet occurs as part of a skarn deposit at the contact of metamorphosed carbonate sediments (marble) and igneous rocks that are part of the Mesozoic-age Gangdise-Liangqing Tanggula fold belt. Two generations of garnet can be recognized and differ slightly in occurrence and geochemistry. Chemical composition and other mineralogic data on this gem material are cited. *JES*

Two strongly pleochroic chatoyant gems. R. C. Kammerling and J. I. Koivula, *Journal of Gemmology,* Vol. 22, No. 7, 1991, pp. 395–398.

Gemstones that are both chatoyant and pleochroic are relatively uncommon. In this note, the authors describe samples of two such gems: two cat's-eye iolites (23.65 ct and 8.25 ct) and a 2.69-ct cat's-eye tanzanite. Gemological properties for the stones described are typical for their respective gem varieties, with the exception of their phenomenal features. In the iolites, the chatoyancy was found to be caused by minute, whitish-appearing parallel fibers. The tanzanite's chatoyancy was observed to be the result of parallel, whitish, light-reflecting channels. The authors note that, in both materials, cutting for the best optic effect resulted in poor face-up color, because the best pleochroic color was oriented to a different axis from that of the chatoyancy. This disparity between good color and chatoyancy, which is almost universal in pleochroic materials, is undoubtedly why more such stones are not cut. Six color photographs illustrate the note. *CMS*

DIAMONDS

The Lewis and Clark diamond. J. C. Zeitner, *Lapidary Journal*, Vol. 45, No. 5, August 1991, pp. 79–88.

This article provides some details of the July 1990 discovery of a light yellow, transparent, 14-ct diamond along a road near Craig, Montana, by local "rockhound" Darlene Dennis. The stone was first identified by a local faceter; the identification was then confirmed by the owner of the Yogo Sapphire mine. According to the article, an additional large (8 ct) stone was allegedly recovered in late 1990 by another Craig resident. The 14-ct diamond was sold for $80,000 to New York gallery-owner Alexander Acevedo. The article includes a color photo of the stone, a discussion of the possible source and future prospects for diamonds from this area, and an insert on diamonds from the Great Lakes region of the U.S. *WRV*

GEM LOCALITIES

Gemstone [sic] of Malawi: Ruby, sapphire, padparadscha, and fancy corundums. O. Grubessi, *Abstracts of the 15th General Meeting of the International Mineralogical Association*, June 28–July 3, 1990, Beijing, China, pp. 676–677.

This abstract presents a brief summary of gemological data on various gem corundums from the Landanai region of Malawi. Chemical composition data (microprobe) along with optical properties and features seen by microscope examination are described for ruby and a range of colors of sapphire. The author notes that, except for green corundum, R.I. and S.G. increase with iron enrichment and decreasing aluminum. Considerable data are provided in this brief note. *JES*

INSTRUMENTS AND TECHNIQUES

The microscopic determination of structural properties for the characterization of optical uniaxial natural and synthetic gemstones. Part 2: Examples for the applicability of structural features for the distinction of natural emerald from flux-grown and hydrothermally-grown synthetic emerald. L. Kiefert and K. Schmetzer, *Journal of Gemmology*, Vol. 22, No. 7, 1991, pp. 427–438.

Using the techniques described in part 1 of this three-part series, the authors pursue their research into the distinction between natural and synthetic emeralds. The authors found that natural emeralds from metamorphic deposits usually do not have growth structures that can be used diagnostically. However, emeralds from deposits with lower temperatures of formation, including those from Colombia and Nigeria, reveal internal growth structures that are useful. These appear as striations parallel to the dominant growth planes. A variety of flux-grown and hydrothermally grown synthetic emeralds were also examined and revealed certain differences in growth features from those of natural emeralds. Flux-grown synthetic emeralds, for example, were never observed to exhibit structure parallel to the pyramidal faces *u*, *p*, and *s*, while such structural features were observed in both Colombian and Nigerian samples. Also commonly noted in flux-grown synthetics is the zoning of residual flux parallel to dominant growth planes, a feature not found in natural emeralds.

Hydrothermally grown synthetic emeralds revealed one dominant set of growth structures parallel to the orientation of the seed plate, forming an angle with the c-axis of 22°–40°—a characteristic never found in natural emeralds. Accompanying the growth striations in hydrothermal synthetics are distinct color zoning and subgrain boundaries.

The authors conclude that the structural characteristics they observed in natural and synthetic emeralds cannot be used alone to determine the origin of a sample. However, they do constitute a valuable source of information that, in conjunction with other features, can decisively identify natural or synthetic origin. Thirty photomicrographs clearly illustrate the features discussed in the text. *CMS*

Presidium® DiaMeter—System Berger. T. Linton and G. Brown, *Australian Gemmologist*, Vol. 17, No. 8, 1990, pp. 301–303.

This Instrument Evaluation Committee report covers both the DiaMeter®—System Berger and Presidium's Electronic Gemstone Gauge. The former is a specialized slide rule calculator used to estimate the weight of round brilliant-cut diamonds, calculate weight loss in recutting round brilliants, distinguish brilliant-cut diamonds from simulants of higher specific gravity, and identify poorly proportioned diamonds. The Gemstone Gauge is an electronic measuring device that resembles the conventional analog Leveridge gauge but uses instead a digital LCD read-out.

The investigators used the two instruments to measure and then estimate the weights of 10 well-made round brilliants, ranging from 0.05 ct to 1.4 ct. The electronic gauge was found to be easy to use and accurate to within 0.01 mm, while the DiaMeter® proved to be, on average, within 1% of the exact weights of the stones (compared to their actual weights as determined on an electronic balance). The DiaMeter® also proved to be successful in detecting deviations from "ideal make" in 10 other round brilliants of moderate to poor make. No indication was given of what criteria were used for "ideal make."

The investigators conclude that these two instruments used together will speed weight and girdle diameter estimations, although accuracy is limited by how much the make of the stones varies from "ideal" proportions. *RCK*

Presidium® Diamond MiniMate™. T. Linton and G. Brown, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 318–320.

After reviewing the working principle behind this and similar instruments, the authors of this Instrument Evaluation Committee Report describe in detail the components and use of the Presidium® Diamond MiniMate™.

On the basis of their evaluation, Messrs. Linton and Brown found the instrument to distinguish accurately both mounted and unmounted diamonds (either gem or industrial quality) from an extensive range of simulants. They also identify a number of critical precautions that must be observed when using the instrument. *RCK*

JEWELRY MANUFACTURING ARTS

The composition and structure of a Byzantine torc [sic]. M. Hockey, *Jewellery Studies,* Vol. 3, 1989, pp. 33–39.

In 1984, the British Museum received an early Byzantine gold torque that had passed through several collections and had been restored many times. At the time the museum received the neckpiece, both the original work and the restored areas were deteriorating badly. This article describes the original methods and materials used in making the torque, and documents the museum's restoration process in great detail.

The torque, which is estimated to date from the sixth or seventh century A.D., is made of gold foil over a magnetite, sand, and glue filler; the whole length is threaded with a copper core wire attached to lion's-head finials. The core wire itself had swollen from corrosion and was missing in places, and repairs to it had broken; gold foil had flaked off the body and filler had been lost.

To restore the torque, sheathed copper dowling was soft-soldered to the remaining core wire; the missing filler was replaced with polyester resin, which also provided a base to which the gold foil was attached with adhesive. Areas missing the original gold were infilled with an easily removable adhesive-resin mixture and covered with gold leaf or gold-powder color.

The author provides details of the composition of the various components, and of experiments she performed to determine the exact method of the torque's assembly. She also describes the means of shaping, soldering, and burnishing its parts; it is readily apparent that the methods of manufacture were extremely sophisticated for their day. *LES*

From Oroide to Platinageld: Imitation jewellery in the late nineteenth century. J. Rudoe, *Jewellery Studies,* Vol. 3, 1989, pp. 49–71.

In an exhaustive study, the author discusses the enormously popular costume jewelry of the late 1800s. The first part of the article deals with the many alloys used to imitate gold and silver, as reported in the trade press of that period. The second part discusses the jewelry made by the firm N. C. Reading & Co., a major Birmingham, England, manufacturer, whose ledgers and sample boards from the period provided the author with documentary evidence.

The fanciful trade names used by 19th-century manufacturers make fascinating reading. Various combinations of copper, aluminum, and zinc create "Abyssinian Gold," "Oroide," "Orissus Gold," "Afghanistan Gold," and "Crazy Gold." This last prompted one writer to remark that perhaps the market would soon be subjected to "deranged electro-plate, delirious rolled plate, and slightly gone German silver."

In her discussion of N. C. Reading & Co., the author covers the trademarked alloys used by the company, as well as their registered designs, and offers many insights into the techniques of mass-manufacture in the late 1800s. For example, watch-chain swivels for pocket watches were hand assembled from die-struck parts in a process that required 36 steps.

It is interesting that the company, which specialized in chain, hired only women to make its chains. Several of these women survived, eyesight intact, into the mid-20th century. It would have been extraordinary to have had their views on working conditions and the like. *LES*

The golden age of designer jewelry. S. Menkes, *Connoisseur,* Vol. 220, No. 942, July 1990, pp. 48–53.

Jewelry produced during the 1940s and '50s has a distinctive look that has been repopularized in the last several years. This article briefly describes the influences that brought about the design style and, with broad strokes, paints a vivid picture of several important designers, their jewels, and the women who wore them (notably, the Duchess of Windsor). Among the designers mentioned are Cartier, Van Cleef and Arpels, Schlumberger, Verdura, Belperron, and Boivin. The article concludes with a list of the major dealers in jewelry of this period worldwide. Photos of jewels appear throughout the article. *EBM*

Medieval and Renaissance jewelry flowers at Christie's. R. Shor, *Jewelers' Circular-Keystone,* Vol. 161, No. 5, Heritage Section, May 1990, pp. 148–150.

JCK's senior editor gives a concise report on the December 1989 sale in London of British artist Phyllis Bray Phillips' important collection of Medieval and Renaissance jewelry. Although this is not a catalog of the 80 pieces offered at auction, several pieces are described and the characteristics that made them particularly significant are pointed out. The author also provides the hammer prices on those jewels he has singled out for discussion, and mentions the final offer ($108,000) on the only item that did not meet its reserve bid: a 14th-century rock crystal triptych of superior workmanship and rarity. Seven color photos augment the text.

EBM

Metall in Bewegung (Metal in motion). R. Ludwig, *Art Aurea,* No. 2, 1991, pp. 55–60.

Jewelry designer Birgit Laken has long been active in Holland's artistic avant-garde. Drawing her inspiration from the Haarlem shore, 18 km west of Amsterdam, she uses the ancient technique of mokumé gane to recreate the textures of the sea in gold, silver, and other metals.

Mokumé was first developed in the late 17th century by Japanese armourers who used heat and pressure to weld several layers of metal into exceptionally resilient swords for the samurai. This labor-intensive process has only been used in the West since the 1970s.

The swirling patterns of mokumé are ideally suited to Birgit Laken's artistic vision. Stark and impressionistic, her jewelry echoes the 17th-century work of painter Frans Hals, but has the timelessness and energy of the ocean itself, as can be seen in the five illustrations. This article is printed in both German and English. *LES*

More than elegant, ravishing, and chic—Schlumberger. A. F. Collins, *Connoisseur,* Vol. 220, No. 942, July 1990, pp. 54–55 and 105.

Jewelry design underwent a transformation in the 1940s from the tailored, two-dimensional geometrics of the Art Deco period to the vigorous, three-dimensional shapes derived from nature that characterized one aspect of the "Retro" style. French designer Jean Schlumberger was at the forefront of this evolution, and his vibrant, distinctive jewels were trend setters among the international *haute monde.* In the mid-1950s, he was invited to join Tiffany & Co. as one of their designers. This proved to be a successful collaboration that continues to benefit Tiffany to the present day. Although Schlumberger died in 1987, Tiffany still produces jewels based on his "elaborate, chimerical designs."

The article traces Schlumberger's career, touching on the factors that influenced his creative genius and mentioning many of his associates, particularly his partner Nicolas Bongard. Colorful descriptions for several pieces of his fantastical jewelry are presented in the text, making up for the paucity of illustrations. *EBM*

Neillo [sic] jewellery in major renaissance. *Bangkok Gems & Jewellery,* Vol. 3, No. 12, July 1990, pp. 34–41.

Niello is a decorative technique for silver and, infrequently, gold, wherein the metal is engraved with a design and the indented areas are filled with a black alloy to produce a contrast with the polished metal. This article discusses a recent revival of interest in Thai-produced niello items and expresses the concern that this craft is dying out. The text mentions the oldest nielloware company in Thailand, Thai Nakon R.O.P., and Simon Callai, an Italian artist who makes niello jewelry for Rose Tattoo Jewelry in Thailand; articles that describe their work immediately follow this one in the issue. Historically, niellowork in Thailand is speculated to have come from Persia, although "its origin has yet to be found with definitive accuracy." The technique of producing niello is described in equally vague terms, with "skill, patience, and precision" as qualities to be emphasized. Two examples of Thai nielloware illustrate this article, and niello items produced by Thai Nakon and by Callai are shown in the two articles that follow. *EBM*

Schönheit ist eine Geschichte (Beauty is a story). G. Staal, *Art Aurea,* No. 2, 1991, pp. 72–77.

Stories come in many forms and can be told through many media. The "Beauty Is a Story" exhibition in Belgium last spring showcased the work of 13 American and European artists who use jewelry to tell their stories.

With such diverse materials as gold, pearls, gem crystals, bits of fabric, and tea leaves, these jewelers take us through their private landscapes. Sometimes obscure, sometimes eloquent, this jewelry is deeply personal: a meditation on the artists rather than the design.

Although it is difficult to imagine that anyone but the designer would wear some of these pieces, several of which are illustrated, it is fascinating to see the conventions of jewelry design being challenged. This article is printed in both German and English. *LES*

JEWELRY METALS

A comparison of recent analyses of British Late Bronze Age goldwork with Irish parallels. D. R. Hook and S. P. Needham, *Jewellery Studies,* Vol. 3, 1989, pp. 15–24.

In trying to determine whether Britain had a goldworking tradition separate from that of Ireland in the Late Bronze Age, the authors compared stylistic details with the chemical compositions of 31 British bracelets of the period.

To determine the composition of these historic artifacts, the authors used X-ray fluorescence (XRF) testing because it is nondestructive. The XRF results were confirmed by data from hydrostatic weighing. This allowed the authors to correct for depletion gilding caused by the years of burial to which the bracelets had been subjected. Data for this correction were obtained by electron microscopy of one bracelet that had broken in antiquity. Calculated S.G.'s based on the corrected XRF results seemed close to the measured S.G.'s, but, unfortunately, no statistical analysis is presented.

No systematic compositional differences were found to correlate with the stylistic differences seen between the two sets of bracelets. This article is of interest particularly for its combination of two testing methods. *Meredith E. Mercer*

SYNTHETICS AND SIMULANTS

ESR spectrum of Australian synthetic Biron emerald. D. R. Hutton and G. J. Troup, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 299–301.

This report, originally presented at the Australian Bicentennial Physics Conference in 1989, describes the use of electron spin resonance (ESR) spectra in the examination of various types of emeralds.

First described is the use of this method to determine the iron content of emeralds. Examination of a "known hydrothermal emerald" revealed an appreciable iron content. Similar examination of a "New Chatham" synthetic emerald revealed little iron present, while the ESR spectra of a Biron synthetic emerald also showed little iron present.

The ESR spectra can also be interpreted to provide information on the perfection of an emerald's lattice. Based on ESR spectra, the authors deduce that the Biron synthetic emerald has an extremely well-ordered lattice that approaches, if not reaches, laser quality. *RCK*

Imitation chicken-blood stone. G. Brown, S. M. B. Kelly, C. Sutherland, and P. Callaway, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 311–313.

Following a description of the appearance and gemological properties of chicken-blood stone, a natural ornamental material from China, the authors describe a rather convincing imitation that is being sold to unwary tourists in China and Hong Kong.

A representative sample of this imitation is then discussed. A polished seal blank, measuring 4 × 4 × 11.5 cm, was sawed in half, revealing a central core of opaque, dark gray talc-like material and a 1-cm-thick cap of a similar material at one end (where the seal would be carved). All surfaces except the cap were coated with a layer 2–5 mm thick of translucent, yellow-brown plastic that contains red streaks of imitation cinnabar. The streaky texture of the underlying talc-like material was visible through the translucent coating, adding to the realism of the deception.

The core material was cool to the touch with a soapy feel, had a Mohs hardness of 1–2, a spot R.I. about 1.55, and peeled readily to yield a fibrous peeling. The coating was warm to the touch and had a waxy feel, a Mohs hardness of 1–2, a spot R.I. about 1.57 to 1.58, bubble inclusions, and peeled readily to yield a "clean" peeling. The imitation cinnabar streaks fluoresced bright red to long-wave U.V.

The authors conclude that the imitation was produced by coating a steatite core with a layer of thermosetting epoxoid resin that had been included with streaks of imitation cinnabar. *RCK*

Russian flux-grown synthetic spinel. G. Brown, S. M. B. Kelly, and R. Sneyd, *Australian Gemmologist,* Vol. 17, No. 8, 1990, pp. 315–317.

The authors begin with a review of the gemological properties already reported in the literature for Russian flux-grown synthetic red spinel, and proceed to describe their investigation of a 14.69-ct octahedral crystal of this material.

The gemological properties of this flux-grown synthetic are virtually identical to those previously reported. Magnification revealed a number of diagnostic features, which are well illustrated with 10 photographs in the report, among them: (1) etch trigons on octahedral faces; (2) dissolution microlamellation along octahedral edges and polycentric development of octahedral faces; (3) clusters of small, colorless to light pink, spinel octahedra attached to external crystal faces of the host crystal; (4) irregular, rounded masses of opaque, dark-colored flux; (5) highly reflective flat triangular platinum "flakes" (some partly resorbed); (6) curving internal fractures; and (7) a single flattened triangular inclusion decorated by tufted dendrites.

The authors conclude that if no inclusions were present this material could not be identified as synthetic by conventional gemological testing. *RCK*

TREATMENTS

Anomalous behaviour of certain geuda corundums during heat treatment. S. I. Perera, A. S. Pannila, and R. N. Ediriweera, *Journal of Gemmology,* Vol. 22, No. 7, 1991, pp. 405–407.

Heat treatment of the "ottu" variety of geuda sapphire (i.e., light blue or colorless with dark blue patches) has resulted in the production of a nontransparent white coating on much of the material. In an attempt to discover why some "ottu" sapphires heat well and others do not, the authors performed chemical analyses on some 50 samples of treated material. They found that stones of good blue final color contain Fe of 0.03%–0.15% and Ti below 0.03%, with few other trace elements present. Material that clarified but resulted in only pale color contained both Fe and Ti in the range 0.03%–0.15%, with a few additional trace elements present. The "dead milk" coating of the third group of stones proved to have significantly more Fe (0.15%–0.3%) and Ti (more than 0.3%), with Ti always greater than Fe, as well as significantly more trace elements—including vanadium—present. The chemical composition of the blue areas in the treated stones of this third group were found to be similar to that of stones in the first and second groups, except for the presence of vanadium. The authors conclude that the presence of additional minor impurities, including vanadium, may prevent the formation of the Fe-Ti pairs necessary for the production of blue color. *CMS*

Radioactive and radiation treated gemstones. C. E. Ashbaugh, III, *Radioactivity and Radiochemistry,* Vol. 2, No. 1, 1991, pp. 42–57.

This well-illustrated report appears in a journal whose audience is primarily scientists and engineers who deal with radioactivity and its measurement. Mr. Ashbaugh first discusses naturally radioactive gems such as zircon and ekanite and then describes gems that are irradiated in the laboratory, e.g., tourmaline, diamond, and topaz. This portion of the article is enhanced by an up-to-date table on radiation-induced color alterations in various gem materials and the color centers responsible for the colors so produced.

The report also includes a discussion of the radioactive nuclides encountered in gems and the mechanisms by which they are produced. Finally, there is a small treatise on how to calculate radiation exposure from radioactive gemstones over various periods of time.

Well documented with 58 references, this report is recommended for those interested in irradiated gemstones and radiation doses from various radionuclides. *RCK*

Two types of historical traps: On "Diamond Softening" and the "Antiquity of Emerald Oiling." K. Nassau, *Journal of Gemmology,* Vol. 22, No. 7, 1991, pp. 399–403.

The author opens this article by pointing out that readers of ancient gem "recipes" should watch out for two "traps": either outright scoffing of seemingly outrageous statements, or ready acceptance of reasonable-sounding statements. Dr. Nassau describes two examples of these problems. The process of "diamond softening" described by Pliny proved, through new translations of original texts and reference to older texts from which Pliny derived information, to refer neither to diamond nor to softening for the purpose of easier cutting. The misunderstood process, in fact, referred to the quench-crackling of quartz in preparation for dyeing.

The example provided for the second "trap" involves emerald oiling. Pliny has often been cited to prove the antiquity—and, thus, venerability—of this treatment. However, closer examination and retranslation of Pliny's original descriptions revealed that the oiling he described was that of either turquoise or poor-grade malachite. In fact, further investigation by the author revealed no clear reference to emerald oiling before 1962, when it appeared in Liddicoat's *Handbook of Gem Identification* described as a "longstanding" process. *CMS*

MISCELLANEOUS

Frederick H. Pough. J. Sinkankas, *Lapidary Journal,* Vol. 45, No. 4, 1991, pp. 18–24.

This article provides a detailed and interesting account of Dr. Pough's career. After receiving his M.S. in geology at the University of St. Louis in 1930, he subsequently studied at the University of Heidelberg before receiving his doctorate in mineralogy from Harvard University. Dr. Pough then acquired a position at the American Museum in New York, where he became Curator of Mineralogy and Physical Geology in 1943. After retiring from that position in 1952, he worked for a short time at the Santa Barbara Natural History Museum before leaving to become an independent consultant. During his long career, he has authored and co-authored numerous articles and books on mineralogy, vulcanology, altering the color of minerals with irradiation, and pearls. In 1990, Dr. Pough was awarded the Carnegie Mineralogical Award. Also included in the article is a one-page compilation of highlights of the rare mineralogy books in Dr. Pough's collection. Four other fascinating articles concerning the life of Fred Pough are included in this issue. Now in his 80s, Fred Pough continues to be actively involved in the gem and mineral community. *RT*

Old books, old maps, and the gem connoisseur. W. J. Sersen, *JewelSiam,* Vol. 1, No. 5, 1990, pp. 102–105.

For the gem connoisseur, Sersen provides a brief overview of important literature and where to find it. He discusses three rare (late 19th to early 20th century) books: *Ivory and the Elephant* by G. F. Kunz, *Mani-Mala* by S. M. Tagore, and *Precious Stones and Gems* by E. W. Streeter. Also of value are early British colonial government publications that contain maps and photographs. One such publication was the *Burma Gazetteer,* which focused on different areas in Burma and sometimes detailed that area's gem deposits and mining techniques. Two editions of the *Gazetteer* detail the Ruby Mines District and the Myitkyina District. British Ceylon also published gem-related documents. As for how and where to find these treasures, Sersen points to specific libraries, sellers that specialize in rare and out-of-print books, and book publishers. *RT*

SUGGESTIONS FOR AUTHORS

The following guidelines were prepared both to introduce you to *Gems & Gemology* and to let you know how we would like a manuscript prepared for publication. No manuscript will be rejected because it does not follow these guidelines precisely, but a well-prepared manuscript helps reviewer, editor, and reader appreciate the article that much more. Please feel free to contact the Editorial Office for assistance at any stage in the development of your paper, whether to confirm the appropriateness of a topic, to help organize the presentation, or to augment the text with photographs from the extensive files at GIA.

INTRODUCTION

Gems & Gemology is an international publication of original contributions concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments and identification techniques, gem localities, gem enhancements, gem substitutes (simulants and synthetics), gemstones for the collector, jewelry manufacturing arts, jewelry history, and contemporary trends in the trade. Manuscripts may be submitted as:

Original Contributions—full-length articles describing previously unpublished studies and laboratory or field research. Such articles should be no longer than 6,000 words (24 double-spaced, typewritten pages) plus tables and illustrations.

Gemology in Review—comprehensive reviews of topics in the field. A maximum of 8,000 words (32 double-spaced, typewritten pages) is recommended.

Notes & New Techniques—brief preliminary communications of recent discoveries or developments in gemology and related fields (e.g., new instruments and instrumentation techniques, gem minerals for the collector, and lapidary techniques or new uses for old techniques). Articles for this section should be approximately 1,000-3,000 words (4-12 double-spaced pages).

Gems & Gemology also includes the following regular sections: *Lab Notes* (reports of interesting or unusual gemstones, inclusions, or jewelry encountered in the Gem Trade Laboratories), *Book Reviews* (as solicited by the Book Review Editor; publishers should send one copy of each book they wish to have reviewed to the Editorial Office), *Gemological Abstracts* (summaries of important articles published recently in the gemology literature), and *Gem News* (current events in the field).

MANUSCRIPT PREPARATION

All material, including tables, legends, and references, should be typed double spaced on 8 1/2 × 11" (21 × 28 cm) sheets with 1 1/2" (3.8 cm) margins. It is preferable, but not essential, that the article be submitted (preferably in Microsoft Word or in ASCII format) on an IBM-compatible floppy disk (either 3 1/2" or 5 1/4") as well as in hard copy form. Please identify the authors on the title page only, not in the body of the manuscript or figures, so that author anonymity may be maintained with reviewers (the title page is removed before the manuscript is sent out for review). The various components of the manuscript should be prepared and arranged as follows:

Title page. Page 1 should provide: (a) the article title; (b) the full name of each author (first name, middle initial, surname), with his or her affiliation (the institution, city, and state or country where he/she was working when the article was prepared); (c) acknowledgments of persons who helped prepare the report or did the photography, where appropriate; and (d) five key words that we can use to index the article at the end of the year.

Abstract. Page 2 should repeat the title of the article followed by an abstract. The abstract (approximately 150 words for a feature article, 75 words for a note) should state the purpose of the article, what was done, and the main conclusions.

Text. Papers should follow a clear outline with appropriate heads. For example, for a research paper, the headings might be: Introduction, Previous Studies, Methods, Results, Discussion, and Conclusion. Other heads and subheads should be used as the subject matter warrants. Also, when writing your article, please try to avoid jargon, to spell out all nonstandard abbreviations the first time they are mentioned, and to present your material as clearly and concisely as possible. For general style (grammar, etc.) and additional information on preparing a manuscript for publication, *A Manual of Style* (The University of Chicago Press, Chicago) is recommended.

References. References should be used for any information that is taken directly from another publication, to document ideas and facts attributed to—or facts discovered by—another writer, and to refer the reader to other sources for additional information on a particular subject. Please cite references in the text by the last name of the author(s) and the year of publication—plus the specific page referred to, if appropriate—in parentheses (e.g., Kammerling et al., 1990, p. 33). The references listed at the end of the paper should be typed double spaced in alphabetical order by the last name of the senior author. Please list only those references actually cited in the text (or in the tables or figures).

Include the following information, in the order given here, for each reference: (a) all author names (surnames followed by initials); (b) the year of publication, in parentheses; (c) for a *journal*, the full title of the article or, for a *book*, the full title of the book cited; and (d) for a *journal*, the full title of the journal plus volume number, issue number, and inclusive page numbers of the article cited or, for a book, the publisher of the book and the city of publication. Sample references are as follows:

Kammerling R.C., Koivula J.I, Kane R.E. (1990) Gemstone enhancement and its detection in the 1980s. *Gems & Gemology,* Vol. 26, No. 1, pp. 32–49.

Armstrong J.T. (1988) Accurate quantitative analysis of oxygen and nitrogen with a Si/W multilayer crystal. In D. E. Newbury, Ed., *Microbeam Analysis—1988,* San Francisco Press, San Francisco, CA, pp. 301–304.

Liddicoat R.T. (1989) *Handbook of Gem Identification,* 12th ed., 2nd rev. printing. Gemological Institute of America, Santa Monica, CA.

Tables. Tables can be very useful in presenting a large amount of detail in a relatively small space, and should be considered whenever the bulk of information to be conveyed in a section threatens to overwhelm the text.

Type each table double spaced on a separate sheet. If the table must exceed one typewritten page, please duplicate all headings on the second sheet. Number tables in the order in which they are cited in the text. Every table should have a title; every column (including the left-hand column) should have a heading. Please make sure terms and figures used in the table are consistent with those used in the body of the text.

Figures. Please have line figures (graphs, charts, etc.) professionally drawn and photographed. High-contrast, glossy, black-and-white prints are preferred.

Submit black-and-white photographs and photomicrographs in the final desired size if possible. Where appropriate, please use a bar or other scale marker on the photo, not outside it.

Use a label on the back of each figure to indicate the article's title (or a shortened version thereof) and the top of the figure. Do not trim, mount (unless one figure is composed of two or more separate photos), clip, or staple illustrations.

Color photographs—35 mm slides or 4 × 5 transparencies—are encouraged. Please include three sets of color prints with the manuscript package submitted for publication consideration.

All figure legends should be typed double spaced on a separate page.

In each legend, clearly explain any symbols, arrows, numbers, or abbreviations used in the illustration. Where a magnification is appropriate and is not inserted on the photo, please include it in the legend.

MANUSCRIPT SUBMISSION

Please send three copies of each manuscript (and three sets of figures and labels) to the Editorial Office, in care of:

Alice S. Keller, Editor
Gems & Gemology
P.O. Box 2110
1660 Stewart Street
Santa Monica, CA 90407

In view of U.S. copyright law, we must ask that each submitted manuscript be accompanied by the following statement, signed by all authors of the work: "Upon publication of (title) in *Gems & Gemology,* I (we) transfer to the Gemological Institute of America all rights, titles, and interest to the work, including copyright, together with full right and authority to claim worldwide copyright for the work as published in this journal. As author(s), I (we) retain the right to excerpt (up to 250 words) and reprint the material on request to the Gemological Institute of America, to make copies of the work for use in classroom teaching or for internal distribution within my (our) place of employment, to use—after publication—all or part of this material in a book I (we) have authored, to present this material orally at any function, and to veto or approve permission granted by the Gemological Institute of America to a third party to republish all or a substantial part of the article. I (we) also retain all proprietary rights other than copyright (such as patent rights). I (we) agree that all copies of the article made within these terms will include notice of the copyright of the Gemological Institute of America. This transfer of rights is made in view of the Gemological Institute of America's efforts in reviewing, editing, and publishing this material.

As author(s), I (we) also warrant that this article is my (our) original work. This article has been submitted in English to this journal only and has not been published elsewhere."

No payment is made for articles published in *Gems & Gemology.* However, for each article the author(s) will receive 50 free copies of the issue in which their paper appeared.

REVIEW PROCESS

Manuscripts are examined by the Editor, the Editor-in-Chief, and at least three reviewers. The authors will remain anonymous to the reviewers. Decisions of the Editor are final. All material accepted for publication is subject to copyediting; authors will receive galley proofs for review and are held fully responsible for the content of their articles.