

# GEMS & GEMOLOGY

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# GEMS & GEMOLOGY

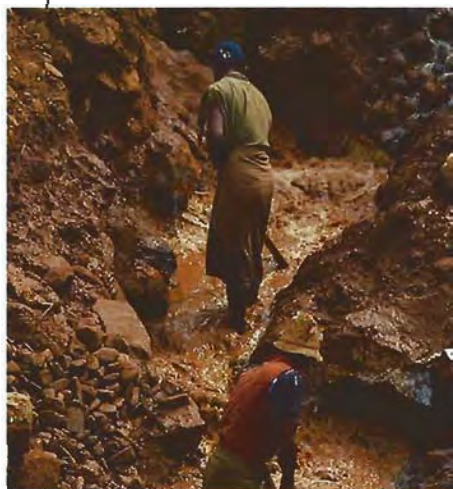
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*ABOUT THE COVER: Perhaps the most enigmatic and exciting of all ruby sources, the Mogok Stone Tract of Burma (now Myanmar), has been off-limits to Westerners for almost three decades. Yet today this area may be producing more rubies and sapphires than ever before. In the lead article in this issue, two prominent gemologists describe the mining activities they observed in the course of two visits to Mogok, and provide a fascinating update on this locality. The rubies in this unique suite represent some of the superb material that has emerged from Mogok in recent years. The necklace contains a total of 138.12 ct of ruby, with the largest stone 16.69 ct; the earrings contain a total of 34.34 ct of ruby, with the drops 10.15 and 9.97 ct, respectively.*

*Jewelry courtesy of Harry Winston, Inc. Photo by Michael Oldford.*

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*Gems & Gemology* welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in the Winter 1991 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.

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# LETTERS

## "MISNOMERS" IN AMERICAN GEMOLOGY

I am dismayed to see what I regard as misnomers being used by GIA, and even published in *Gems & Gemology*, while there are either clear names issued by CIBJO or already much better sounding names in use for certain gemstones. I am referring to misnomers and misleading names like malaia garnet, green tanzanite, and sunstone labradorite, which are the most important, among others.

*Malaia garnet* (correctly spelled with an "i") is an obscene name which should never be applied to this noble category of gemstones. *Umbalite*, which has been accepted in Europe, is a much better sounding, more correct name that simultaneously points to the garnet's cradle in the Umba Valley of Tanzania.

*Tsavorite* is orthographically completely wrong. The ending "-rite" has absolutely no justification in connection with the name *Tsavo*. In Europe, the correct name *tsavolite* has been generally accepted and is being used. Europeans by writing it correctly demonstrate their cultural background of ancient Greek. It is a mistake for Americans not to do the same. GIA should promote gem names with a Greek etymological base, such as "-lite," which originates from *lithos*, meaning stone.

About green tanzanite, I wrote to you in my last letter to the editor [*Gems & Gemology*, Summer 1992, p. 140].

In the Winter 1991 issue of *Gems & Gemology* there was a paradoxical title that read "Sunstone Labradorite" on p. 220. *Sunstone* is a definitely established name of long standing for an oligoclase feldspar. Thus, the combination *sunstone labradorite* is an impossible paradox. Why not accept Dr. F. Pough's excellent suggestion to call these red and green labradorites from Oregon *heliolite* (from the Greek words *helios*, meaning sun and *lithos*, meaning stone)? This means the same as sunstone, but is a different-sounding name altogether; it could very well and easily be given to these labradorites without causing confusion and violating traditional nomenclature.

E. GÜBELIN, Ph.D., G.G., F.G.A.  
Lucerne, Switzerland

## In Reply

Much as we would relish the opportunity, we know that *Gems & Gemology* is not the arbiter of terminology in the gem world. When Henry Platt of Tiffany, within a year or two of their discovery, coined the two now-familiar terms *tanzanite*, for beautiful blue zoisite from Tanzania, and *tsavorite*, for the vibrant green grossular from East Africa, they were widely accepted in the American trade. Today,

both the brown zoisite that is transformed by heat treatment and the blue or purple material that results are usually referred to as tanzanite by American and European jewelers alike. Personally, I do not like the term *green tanzanite*, but neither do I like the proliferation of separate names for each color variety of a gem material. I feel that a case can be made for that term, since it also is gem zoisite from Tanzania.

By the time Dr. Gübelin had pointed out to the gem industry the fact that *tsavolite* is orthographically preferable to *tsavorite*, the term was well established both in America and elsewhere. We at *Gems & Gemology* did not feel that we could impose this or any other term on the trade, and thus we accepted it as publicized.

Whether it is spelled *malaya* or *malaia*, this term, too, is in common usage in the trade. Since this stone is actually a mixture of garnet species, the question is really whether a separate name is needed. If one is, I personally agree that *umbalite* would technically be much preferable to *malaia*.

Dr. Gübelin refers to sunstone as the aventurescent variety of oligoclase feldspar. The Shipley *Dictionary of Gems and Gemology* defines *sunstone* as "albite (or other) feldspar." True, many of the early sunstones found had the properties of oligoclase, but since labradorite is also a member of the plagioclase feldspar family, aventurescence in another member of the same family should hardly justify an entirely new name. We felt that it was important for the sake of clarity to call attention to the difference in properties by using the labradorite designation, but not by creating a new name. If there is a need to have a separate name for the red and green labradorite from Oregon, *heliolite* has a nice ring and logic behind it. Again, though, do we really need a new name for this material?

Unlike many sciences, terminology in gemology is often driven by market forces. Since there is no single governing body, terms used in commerce commonly enter the gemological literature before adequate study can be undertaken as to their efficacy. Actually, there is no body with the power to enforce the discontinuance of a term, unless it is illegal in a given country because it clearly misrepresents the nature of the material. We appreciate your feeling that, as a well-known and respected publication in gemology, we should act as an arbiter in matters of new terms, and exercise restraint in the use of old ones. However, unless a term is blatantly misrepresentative, or clearly unneeded, we have generally accepted the common usage of a majority of our readers or, in the case of a new material, carried the article as the author intended.

—Richard T. Liddicoat, Editor-in-Chief

## IN DEFENSE OF FADE TESTING

There are several rapidly fading gemstones where conventional testing cannot establish light stability with certainty. Examples include several types of yellow sapphires, yellow to brown topaz, and green spodumene (not hiddenite).

A fade test consisting of a few hours in the sun is normally the only way to ensure that the color is stable enough that the stone can safely be shown in a jeweler's window or store display, or worn outdoors in jewelry by the ultimate consumer. It seems to me that any gemstone in the jewelry trade should be able to tolerate either of these exposures.

Heating is not always a reliable substitute for a fade test, because some yellow sapphire that has lost its color on quite gentle heating will return to yellow on exposure to light (see K. Nassau and G. K. Valente, *Gems & Gemology*, Winter 1987).

Although some of these materials may be in their original colored state, that is, as they came from the mine, in most such stones the color is usually gone by the time the material has been faceted. Irradiation is then used to produce the color seen in the faceted stone. Such a fade test is therefore not "destructive" of a natural color in the usual sense, but should be viewed as being "restorative" to the stable color it had before the irradiation step.

KURT NASSAU, Ph.D.  
*Nassau Consultants*  
*Lebanon, New Jersey*

## KOMOLO TSAVORITE PARTNERSHIP

I have just read your very interesting article on Tanzania in the Summer '92 edition of *G & G*.

I would, however, like to point out that I pegged the Komolo tsavorite deposit for a *partnership* that was formed between myself, Costas Lycos, and Costas Piperas, *not* for the Lycos family. Please correct this error.

C. R. BRIDGES  
*Bridges Exploration Ltd.*  
*Nairobi, Kenya*

## EARLY CRYSTALLIZATION OF PERIDOT AT KILBOURNE HOLE

Since I had never heard of Kilbourne Hole, I read with particular interest the paper, "Kilbourne Hole Peridot," in the Spring 1992 issue of *Gems & Gemology*. It is well written and the gemological properties of the peridot most thoroughly and carefully given. They should be, with the wealth of help that the author mentions in "Acknowledgments." Because of this galaxy of gemological stars as helpers, it is with considerable temerity that I write pointing out what I feel is a rather gross geological error.

On page 19, first column, it is stated that, "The peridot is an early crystallization, formed during the solidification of igneous rocks from the liquid magmatic phase."

Quite true, it formed *early* deep within the earth's crust. Also true is, "...when the volcano erupted" (the final phase) "it threw liquid magma into the atmosphere." The eruption also ejected crystals of the *early crystallized olivine* (peridot) that had aggregated together into nodules. When they were erupted, the nodules were coated with a thin skin of molten lava that cooled quickly. The peridot did not form after the eruption but long before. Olivine nodules are not uncommon and have been found in many places as volcanic "bombs."

Even though I find something now and then in *Gems & Gemology* that I think is wrong, yours is a great journal, the best!

CORNELIUS S. HURLBUT, Ph.D.  
*Harvard University*  
*Cambridge, Massachusetts*

## In Reply

Editors and author alike agree that Dr. Hurlbut is indeed correct. The first part of the paragraph in question should have read:

Peridot is one of the early minerals that forms from the liquid magmatic phase during subsurface crystallization of an igneous magma. During this crystallization stage, the peridot crystals aggregated into nodules along with certain other early-formed minerals, particularly augite and diopside (and occasionally enstatite and bronzite). When the volcano erupted, it threw the still-liquid magma, as well as the predominantly peridot-containing nodules, into the atmosphere. As the nodules spun through the air, the adhering lava solidified on their surfaces. This resulted in basalt-covered "xenolith bombs" (figure 4). . . .

We thank Dr. Hurlbut for bringing this to our attention.

—Alice S. Keller, Editor

## ERRATA

Two errors occurred on p. 108 of the article "Gamma-Ray Spectroscopy to Measure Radioactivity in Gemstones," which appeared in the Summer 1992 issue.

In figure 7, the bottom of the spectrum display is cropped off. This portion of the figure gave the total "net area" counts (678) under the peak marked by the cursor. This number is used in the discussion in Box A. The number (205) shown is the peak height at the cursor and, as such, has no meaning in the discussion, except to indicate the height of the peak.

In figure 6, two red dots on the left of the 150 KeV cursor were not drawn in as were the others. Thus, it incorrectly appeared that the computer-calculated quadratic equation does not pass through any data points.

# 1992 "PERFECT" CHALLENGERS

The sixth annual *Gems & Gemology* Challenge appeared in our Spring 1992 issue. Once again, hundreds of readers participated. Those who earned a score of 75% or better received a GIA Continuing Education Certificate recognizing their achievement. Our heartiest congratulations go to the respondents listed below, who each received a perfect score (100%).

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Wyatt, Mesa, AZ; Monique Zander, Sao Paulo, Brazil; Deanna Zino, Haddonfield, NJ.

Answers [see pp. 68 and 69 of the Spring 1992 issue for the questions]: (1) A, (2) B, (3) B, (4) D, (5) A, (6) C, (7) B, (8) C, (9) D, (10) D, (11) B, (12) A, (13) A, (14) B, (15) C, (16) D, (17) D, (18) D, (19) D, (20) question stated incorrectly—all answers accepted, (21) B, (22) B, (23) C, (24) C, (25) A.

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# STATUS OF RUBY AND SAPPHIRE MINING IN THE MOGOK STONE TRACT

By Robert E. Kane and Robert C. Kammerling

*Burma, now named Myanmar, has for centuries been considered the world's preeminent source of fine rubies. Today, after nearly three decades of limited gem production, there is a resurgence of mining activity at the famous Mogok Stone Tract. New developments include mechanized government mines and joint-venture mining operations with Myanmar nationals. This article, based on two recent visits to Mogok, briefly reviews the mining history and geology of this extraordinary locality, and describes the current status of mining and the methods used to recover rubies and sapphires in the Mogok area. Limited statistics on gem production are also presented, as is a map of the area showing many of the active mine sites.*

## ABOUT THE AUTHORS

*Mr. Kane, former manager of identification at the GIA Gem Trade Laboratory, Inc., Santa Monica, California, is currently on leave of absence to research and write a book on gemstones.*

*Mr. Kammerling is director of identification and research in the GIA Gem Trade Laboratory, Inc., Santa Monica.*

*Acknowledgments are listed at the end of the article.*

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**F**or centuries, the finest rubies in the world have been associated with the Mogok mining region of upper Burma (now Myanmar). In the 20th century especially, rubies and sapphires from Mogok have played an important role in jewelry of every design (figure 1). Although production in Mogok has historically been sporadic, it appears to have been even more so after all gem mining was nationalized in 1963. Today, however, Mogok is experiencing its greatest mining activity in decades, and perhaps the greatest production of rubies and sapphires ever recorded from this locality.

With nationalization, few non-Myanmar nationals were permitted to visit the Mogok area; as a result, essentially no firsthand information on mining developments appeared in the Western literature for over two decades. Nearly all of the recently published reports are based on information and photographs obtained in the late 1950s (e.g., Ehrmann, 1957) and early 1960s; the last detailed firsthand reports of mining activity in Mogok were issued by Meen (1962) and Gübelin (1963, 1965, 1966a and b, 1977). A. Chikayama recently published several very informative reports, based in part on his visits to Myanmar (Chikayama, 1987a-f); he did not, however, visit the Mogok area.

At the invitation of the Myanmar government, the senior author (REK) visited Mogok in February 1991 and again in March 1992, accompanied on the second visit by the coauthor (RCK). As the first research gemologists to visit Mogok since Dr. Gübelin last traveled there in 1963, we used these opportunities to document the current status of gem mining and production in this famous region. We visited 11 of the more than 165 authorized mining operations active in 1991 and 1992. These included five of the seven government ruby and sapphire mines and six joint ventures. We also saw a number of apparently unlicensed operations.

What we encountered was an exciting mixture of traditional methods of mining that had been used in Myanmar for centuries, together with highly efficient, mechanized open-

Figure 1. This suite of predominantly early-20th-century jewelry is set with fine-quality rubies and sapphires, for which Myanmar (Burma) is renowned. Photo by Shane F. McClure; jewelry from the collection of Donald K. Goodman, Frank Goodman and Sons, Los Angeles, California.



pit and tunneling operations to remove the rubies and sapphires.

Following a brief review of the history and geology of this area, this article examines the different entities—primarily government and joint venture—responsible for the heightened activity at Mogok, and describes the types of mining operations observed there. Also reported are production statistics for the major government operations, observations on cutting factories at Mogok and Yangon (formerly Rangoon), and information on the distribution of many of the stones mined. For information on the known gemological properties of Mogok rubies, the reader is referred to Gübelin (1977), Keller (1983), and Schmetzer (1986).

For a discussion of famous rubies from Mogok, see Keller (1983, 1990).

#### HISTORY

Burma is one of the oldest recorded sources of fine rubies. Although it is not known exactly when mining began there, ancient legends refer to a deep valley in "Old Cathay" that was covered with beautiful red gems. According to one story, natives would throw pieces of meat onto the valley floor. Some of the gems would stick to the meat, which was then eaten by vultures. When the vultures flew up from the valley, the natives would kill them to retrieve the gems (Scott, 1935). The earliest record of actual mining in





Figure 2. The 196.1-ct Hixon ruby, shown here on a locality map from E. C. S. George's 1915 Burma Gazetteer — Ruby Mines District, is from the historic Mogok Stone Tract. Ruby crystal courtesy of the Los Angeles County Museum of Natural History. Photo by Shane F. McClure.

this part of the world appeared in the 6th century, when a son of Kun-Lung, founder of the Shan dynasty of Chinese emperors, governed a state that was near a ruby-mining area. Records show that he sent an annual tribute of "2 viss" (approximately seven pounds!) of rubies to the central government (Chhibber, 1934).

In the 15th century, European travelers published two separate accounts of rubies from this area; the first report was by Nicolo de Conti (c. 1430) and the second by Ludovico di Varthema, who visited the land of Pegu (Burma) in 1496. A more direct reference to gems was made by Caesar Fredericke in 1569, who reported on the busy, established trade in rubies at that time and described the King of Pegu as "Lord of the

Mines of Rubies, Safires and Spinels." In fact, the court of this king was so rich that the idols were embellished with rubies and sapphires (Chhibber, 1934).

The Burmese monarchy took control of the ruby-mining areas in 1597, and leased the mines to individual operators at a fixed annual rate. Any stones above a certain size were the property of the king, who also had the right to take control of any mine that showed a high yield of gems. It is believed that, because of this dictum, large stones were often broken up to avoid royal intervention (Wynne, 1897).

During the 17th and 18th centuries, under the demanding rule of the Burmese kings, the mines became synonymous with exile. Unrelenting pressure to produce more and more gems took its toll, and miners were literally worked to death. A rebellion in the early 19th century ended this servile system, and the mining areas were deserted until 1863, when they were declared open for any to work. Conditions for the miners might have improved, but the output of gems remained under strict royal supervision, and taxes were levied on both buyers and sellers (Scott, 1935).

After the British took control of the region in 1886, following the Third Burmese War, they set regulations to monitor gem mining and trade. In 1887, a concession was granted to London jeweler Charles Streeter, who formed Burma Ruby Mines, Ltd. (BRM). This company paid £30,000 a year, plus 30% of the profits, for the sole rights to mine the area using heavy machinery. Their contract further stated that the local miners would be allowed to continue to mine using the same methods they had employed since antiquity, but that they must pay BRM 30% of the value of the gems they recovered. Smuggling and theft escalated, and competition among districts and mines made it impossible for BRM to regulate prices. Ultimately, this system was abandoned for one in which miners were required to obtain a license from BRM for a 20-rupee monthly fee. The miners could then sell any gems recovered on the open market (Scott, 1935).

Burma Ruby Mines was in operation from 1887 through 1925 (figure 2). They worked throughout much of what is known today as the Mogok Stone Tract. The company brought hydroelectric power to Mogok to run washing plants, pump water out of waterlogged mine sites, and operate tunneling equipment. Wynne (1897) reported on the costs involved in cutting three drainage tunnels to make areas more accessible for mining. Such mechanized mining was lucrative only from 1890 through 1908, when the

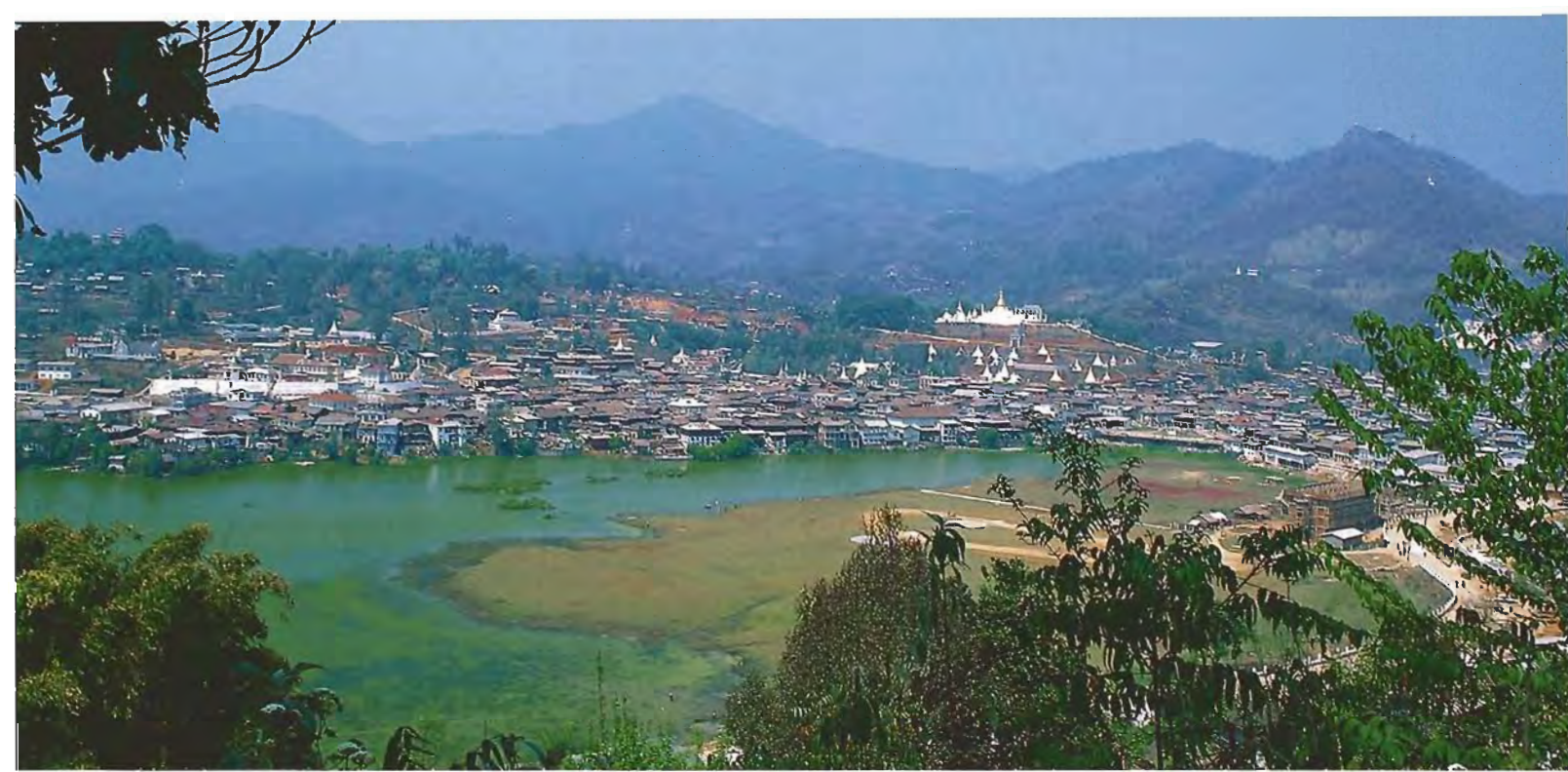


Figure 3. The township of Mogok has been a center of gem mining activity for hundreds of years. In fact, many homes line the shores of an artificial lake that was created by the flooding of an early 20th-century Burma Ruby Mines, Ltd., open-pit operation. Photo by Robert E. Kane.

price of rubies dropped in Europe due to the arrival of synthetics on the market. Prices for top-quality rubies plummeted to one-third of their previous value, and prices for inferior grades fell even further. The outbreak of World War I further depressed the ruby market and, in 1925, Burma Ruby Mines went into voluntary liquidation. BRM continued to mine on a very small scale for another five years until the Great Depression forced the company to disband completely, surrendering its leases to the government on June 30, 1931 (Scott, 1935).

The British did not realize how costly it would be to mechanize mining in Burma. Most of the European methods of hard-rock mining, designed for products like coal, were poorly suited to the geology of the area. Wynne (1897) reported "very hard rock" that "changed to a soft micaceous schist, containing volumes of water, in the presence of which it became almost as soft as mud, and required close and careful timbering," for which it was difficult to get suitable wood. Eventually, the largest drainage tunnel collapsed in places and the mining excavations filled with water. The original town of Mogok, moved in the late 1800s as the main area was turned over to ruby mining, is now covered by a beautiful lake (figure 3).

Following the departure of the British in 1931, mining reverted almost entirely to the native meth-

ods that had been effectively used since antiquity (Iyer, 1953; Gübelin, 1965; Nordland, 1982). Only very recently, due to the active participation of the Myanmar government, has modern, mechanized mining returned to the Mogok Stone Tract.

#### LOCATION AND ACCESS

The town of Mogok is located almost 100 air km north-northeast of the city of Mandalay (figure 4). We traveled by plane from Yangon (formerly Rangoon) to Mandalay (about 500 air km, or 312 mi.), and by four-wheel-drive vehicle along 200 km of rough and twisted paved road to Mogok (six hours in good weather). For the last 25 km, the road ascended sharply in a pattern of severe twists and turns.

The government provided an armed escort to accompany us throughout the duration of our stays in Mogok. Non-Myanmar nationals are rarely allowed in the area, and we strongly advise against travel to or within Mogok without proper authorization.

The actual area encompassed by the "Mogok Stone Tract" has been variously described, with reports from "170 square miles" (442 km<sup>2</sup>; Iyer, 1953) to "1,040 km<sup>2</sup>" (Keller, 1983; Myanmar officials, pers. comm., 1991). Iyer, who published in 1953 what is considered the definitive geologic work on the Mogok Stone Tract, indicated latitude 22°50'45"N to

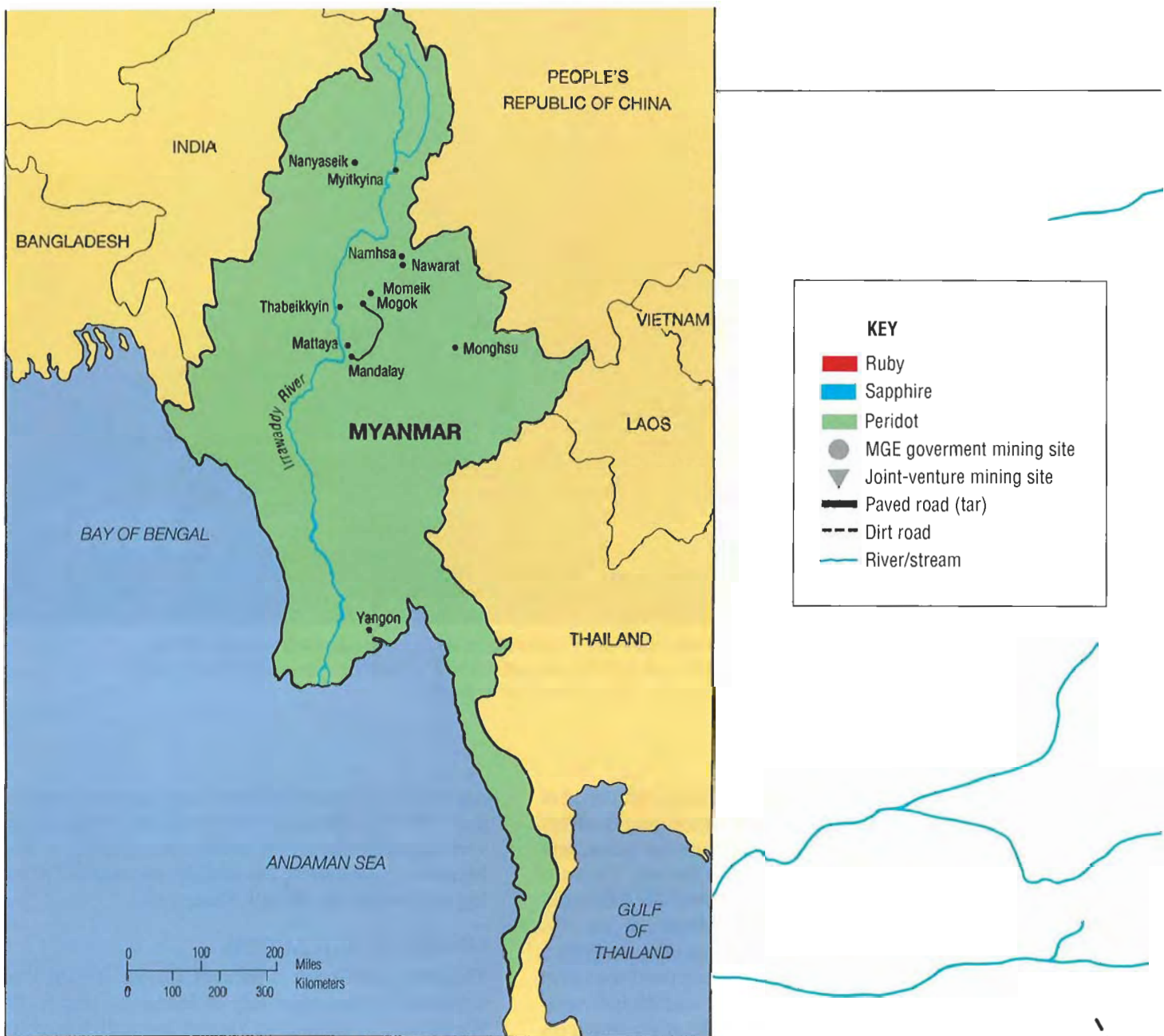


Figure 4. Rubies and sapphires are found at several localities throughout the immediate area surrounding Mogok in the Mandalay District of Myanmar (Burma). Peridot is mined only in the Pyaung Gaung Hills, north-northwest of the Mogok Township. This map shows the approximate locations of all MGE mines and several joint-venture mines in the Mogok Stone Tract. Indicated here are the major gems mined, with red and blue used together to show both ruby and sapphire. Note that significant quantities of spinel are found at virtually all of the corundum mines, as are limited quantities of other gem materials. Unauthorized mining sites are not shown. Map compiled by Robert E. Kane based on information provided by the MGE.







Figure 5. At Mogok, the primary (in situ) occurrence of rubies is in a coarse-grained marble. Here at Dat Taw, the white marble tailings cover a large portion of the hillside. Photo by Robert E. Kane.

23°5'5"N and longitude 96°19'E to 96°35'E for the area. According to the Myanma Gems Enterprise (MGE), the Mogok Stone Tract is bounded on the south by the Nam Pai River, on the north by the foot of the Momeik Scarp, on the east by the town of Momeik, and on the west by the town of Thabeikkyin on the Irrawaddy River ("Role of Gems Mining Department," 1991).

The region is mountainous, with peaks higher than 2,150 m (7,000 ft.); the town of Mogok sits at an altitude of 1,500 m. Mogok receives annual rainfall of more than 350 cm (140 in.). The rainy season is typically from mid-May to mid-October. Malaria is always a concern, but particularly during the rainy months. Small farming villages dot the region amid "forests" of teak, bamboo, and bananas.

Senior MGE employees reported that the indigenous population of Mogok Township is approximately 200,000, with another 200,000 people who have come from other areas of Myanmar.

### GEOLOGY OF THE MOGOK AREA

Many regional geologic studies were made of the Mogok area in the late 19th and early 20th centuries (as reviewed in Keller, 1983, 1990). Yet none is more recent, or more authoritative, than that of Iyer (1953), which was based on months of surveying over three years.

Geologic mapping is particularly difficult in this part of the world, because the dense vegetation and a thick cover of residual weathered material (soil, etc.) result in a lack of rock outcrops. Nevertheless, Iyer (1953) produced a geologic map of the Mogok area, which was reproduced in modified form in Gubelin (1977) and Keller (1983). This geologic map shows the distribution of several types of common high-grade metamorphic rocks, that is, gneiss and marble (the latter is referred to as "crystalline limestone" by Iyer and others, but current terminology for "crystalline [metamorphosed] limestone" is marble), as well as intrusive igneous rocks (granite and minor amounts of syenite). Alluvium (unconsolidated material transported and deposited by running water) of Quaternary age has accumulated particularly in valleys and other low-lying areas. Iyer's report and map also revealed gem-bearing pegmatites, peridot-bearing ultramafic intrusives (dikes and sills), quartzites, and several varieties of gneiss (e.g., garnet, scapolite), as well as structural features such as faults, which indicate that the area has been subjected to several major tectonic processes over extended periods of time. The granites are particularly noteworthy because of their abundance (they comprise the western one-third of the map area), the presence of gem materials (e.g., topaz and tourmaline) in the associated pegmatites, and the fact that they may have produced contact metamorphic mineral assemblages in appropriate rocks (e.g., marbles; figure 5), resulting in the formation of corundum and spinel under special conditions. Keller (1990) suggests that regional, rather than contact, metamorphism may have played a major role in the origin of the primary ruby deposits at Mogok. It is also possible that there are actually two generations of ruby at Mogok, one formed by regional metamorphism and the other by subsequent contact metamorphism (A. A. Levinson, pers. comm., 1992).

In areas with tropical climates and high rainfall,

rocks are especially susceptible to chemical weathering; this has been the situation in this part of Southeast Asia for millions of years. As a result, the major rock-forming minerals are altered to clays, iron oxides (e.g., goethite), and other minerals that are stable in the surface environment. These materials accumulate in the form of soils or even laterites (highly weathered red soils rich in iron and aluminum oxides that typically develop in tropical climates) if the weathering process is sufficiently long and efficient. Certain minerals, such as corundum and spinel, that are inherently resistant to chemical weathering, may accumulate within the soils or laterites, frequently concentrating into layers or beds of gravel resting on soft, decomposed rocks. Such gem-bearing beds—which are characteristically brown or yellow and contain clays, iron oxides, and at times sandy material—are locally known as *byon*.

Until recently, only minor amounts of gem minerals have been recovered from their primary (*in situ*) occurrences. Most have been recovered from secondary deposits, the *byon* (figure 6). Gem minerals within the *byon* may be classified into two types: (1) *eluvial* (gem concentrations essentially in place that result from decomposition of the host rock), and (2) *alluvial* (gem concentrations that occur following transportation by water, which implies significant movement from the source). As a practical matter, distinction between the two types frequently is not possible.

#### MINING ENTITIES AT MOGOK

From the nationalization of gem mining in 1963 until April 1990, all legal mining activity in the Mogok Stone Tract was conducted by the Myanmar government. The Myanmar Ministry of Mines still controls all legal mining and exploration in the Union of Myanmar. The Ministry founded the Myanmar Gems Corporation on April 1, 1976, to oversee the Mogok Gems Project, the Pharkant Jade Project of the Mineral Development Corporation, and the Trade Corporation No. 19 (Gems) of the Ministry of Trade. In 1989, the Myanmar Gems Corporation was renamed the Myanmar Gems Enterprise ("Role of Gems Mining Department," 1991).

Today, in addition to MGE mining, there are also government-authorized joint ventures between the MGE and private individuals or groups, as well as illicit mining activities. Although both the MGE and joint-venture operations (and even some unautho-

rized concerns) now mine a small number of primary deposits, most of the mining by all entities at Mogok today continues to be in secondary (*byon*) deposits.

*Figure 6. Historically, most of the rubies and sapphires found in the Mogok Stone Tract have been recovered from alluvial or eluvial gem gravels called byon in Myanmar. These are frequently covered by a thick (up to 25 m) overburden of soil, laterite, etc. Here, miners in the trench push the byon into a stream of water that carries it downward for processing. Photo by Robert E. Kane.*

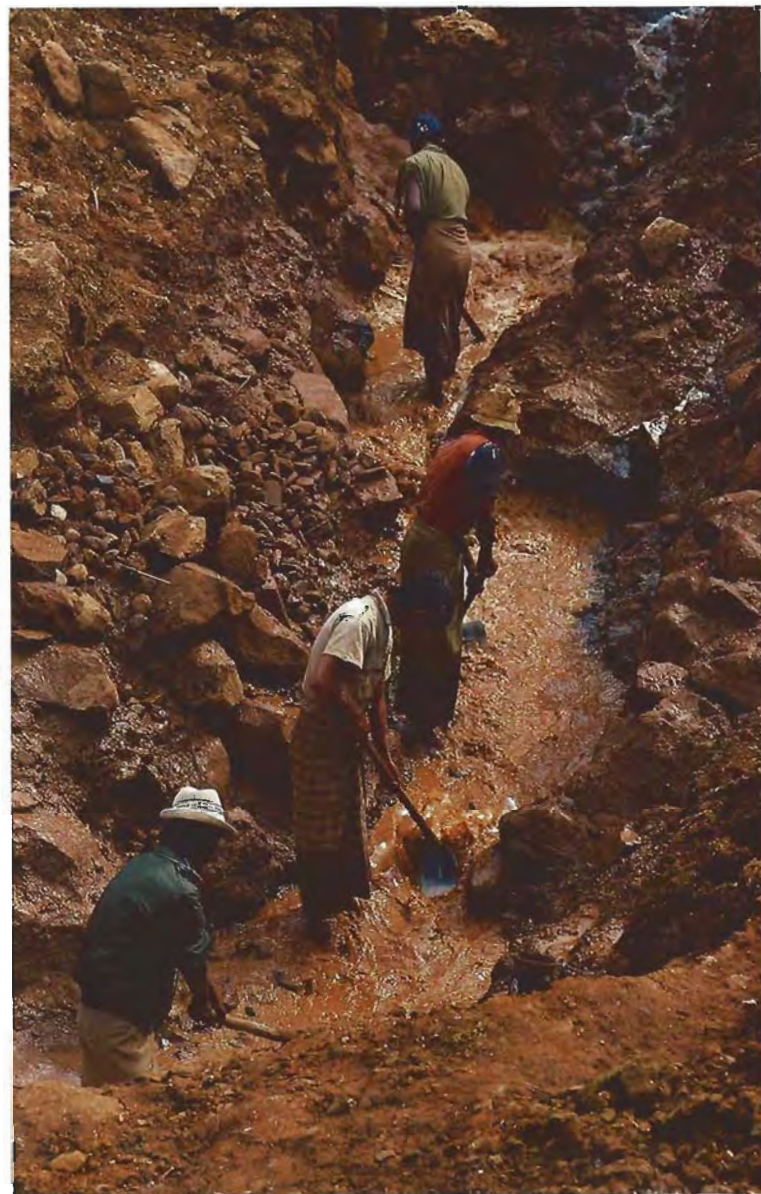




Figure 7. The Myanmar government receives 51.4% of the sale price on all "first-quality" stones recovered from joint-venture operations in the Mogok Stone Tract. The faceted ruby shown here weighs 11.55 ct; the rough crystals, ranging from 16.65 to 278.50 ct, have a total weight of 733.65 ct. Photo by Robert E. Kane.

**MGE Mogok Gems Mining Department.** All government mining in the Mogok Stone Tract is handled by MGE's subsidiary, the Mogok Gems Mining Department, which has several geologists and mining engineers on staff. Eight mines are currently being worked exclusively by the government: one for peridot and seven for ruby and/or sapphire. All are well-organized, mechanized operations that use various methods of mining such as ground sluicing, open pit, and underground tunnels into the host rock, depending on the type and nature of a particular deposit. The number of MGE-operated mines is limited only by budgetary constraints—additional deposits have been identified (MGE officials, pers. comm., 1991).

**Joint-Venture Mining Contracts.** On March 9, 1990, in an attempt to drastically curtail illegal gem mining, the Myanmar government announced the availability to Myanmar nationals of joint-venture mining leases in both the ruby and sapphire districts and the jadeite mining areas (*Working People's Daily*, November 20, 1990). All proposals, complete with the exact location to be mined and the amount of money being offered, had to be submitted by April 27, 1990.

From this initial offering, the government allowed 159 joint-venture projects to begin mining in June and July 1990. According to Yong (1990), the one-acre plots were all located within a total of 230 acres in the areas of Mogok, Momeik, Mattaya, and Thabeikkyin. Each approved operator reportedly paid at least "a six figure" amount (in Myanmar kyats). The highest price paid for a one-acre plot was 21 million kyats, or approximately US\$3.5 million at the official

exchange rate (*Working People's Daily*, November 20, 1990). Joint-venture mines range from the traditional techniques described below to more sophisticated open-pit and tunneling operations. Like the MGE mines, some of the joint-venture mines are mechanized and well organized.

All gems found at a joint venture must be turned over to the MGE for quality grading. First-quality rough must be sold through the MGE at jewelry shops or at the Gems, Jade, and Pearl Emporium held annually (in recent years, every February; in 1992, in February and October) in Yangon; lesser-quality stones are returned to the joint-venture operator after 10% of the value is charged as a mineral tax, and 50% of the value is paid to the MGE (*Working People's Daily*, November 20, 1990). From the sale of first-quality stones (see e.g., figure 7), the Myanmar government receives 32.4% for the Myanma Gems Enterprise, 10% for mineral fees, and 9% for handling charges; the joint-venture operator retains the remaining 48.6% (*Working People's Daily*, November 20, 1990; Yong, 1990). Before the sales are completed, the government will pay joint-venture operators in need of cash 30% of the value of their first-quality stones in Myanmar kyats. When the stones are sold for foreign currency, the joint-venture operators can repay the borrowed money and open foreign-exchange accounts at the Myanma Foreign Trade Bank (*Working People's Daily*, November 19 and November 20, 1990). No mining joint ventures between the MGE and non-Myanmar nationals are presently in operation, but MGE officials we spoke with in March 1992 said they were being considered.

**Independent (Illicit) Mining.** In Mogok, citizens have found gems even while digging water wells, leading to the mandate that anyone in the area who wants to dig in the earth must first seek approval from the government (*Working People's Daily*, November 20, 1990). Yong (1990) estimated, before the first joint ventures were established, that the government of Myanmar may have controlled as little as 5% of the total gem production, with the rest being smuggled to Thailand and India. MGE officials believe that the many joint ventures now in operation have greatly reduced the amount of illegal mining. On a small scale, however, simple washing of gem gravels with rattan baskets is still common in the streams and rivers in and around Mogok. Illicit miners also use the age-old mining methods described below to reach the gem-bearing gravels. Although we did not witness any unauthorized tunneling operations, we were told they do exist. Presumably, because of the noise the explosives generate, illicit mining of this type takes place in more outlying areas, away from government scrutiny.

#### MINES AND MINING TECHNIQUES

The mining techniques we observed include some that match descriptions written decades ago, others that involve contemporary variations on these traditional techniques, and a number that use new, more sophisticated, mechanized methods to extract the gems from deposits that may be deeply buried. It is some of the newer, larger operations that are successfully working the primary deposits.

**Traditional Techniques and Modern Variations.** The simplest method of mining throughout Myanmar, if not all Southeast Asia, is the washing of gravels along local streams and rivers (figure 8). However, a number of basic mining techniques are also used to remove or penetrate the overburden and reach the gem-bearing byon. Several reports have described the classic mining methods used at Mogok (see, e.g., George, 1915; Chhibber, 1934; Iyer, 1953; Gübelin, 1963; Keller, 1983; Hughes, 1990). According to Iyer (1953), three types of operations have traditionally dominated mining in the Mogok Stone Tract: (1) *twinlons*—small round pits, (2) *hmyawdwins*—open trenches through which gravels are washed, and (3) *loodwins*—the recovery of gravels from caverns produced by the chemical weathering of marble. The loodwins represent the richest deposits, with concentrations of gem rubies in the byon as high as 25% (Chhibber, 1934).

*Twinlons.* The twinlons described by Iyer (1953) were generally small round pits, just wide enough for a man to descend by putting his feet in niches on the sides. These might be as deep as 30 m, depending on where the miners encounter the gem-bearing byon layer or the water table. They are typically lit by mirror-like materials (some as simple as aluminum foil or a tin pan) strategically placed at the surface to direct sunlight into the vertical shaft. Once the byon is reached, the miners tunnel laterally into the gravel layer until air and light are no longer adequate, usually no more than 30 or 40 m. Commonly, more than one tunnel

Figure 8. The centuries-old method of washing gem gravels in and along streams and rivers is still commonly used to recover gems throughout the Mogok region. Photo by Robert E. Kane.

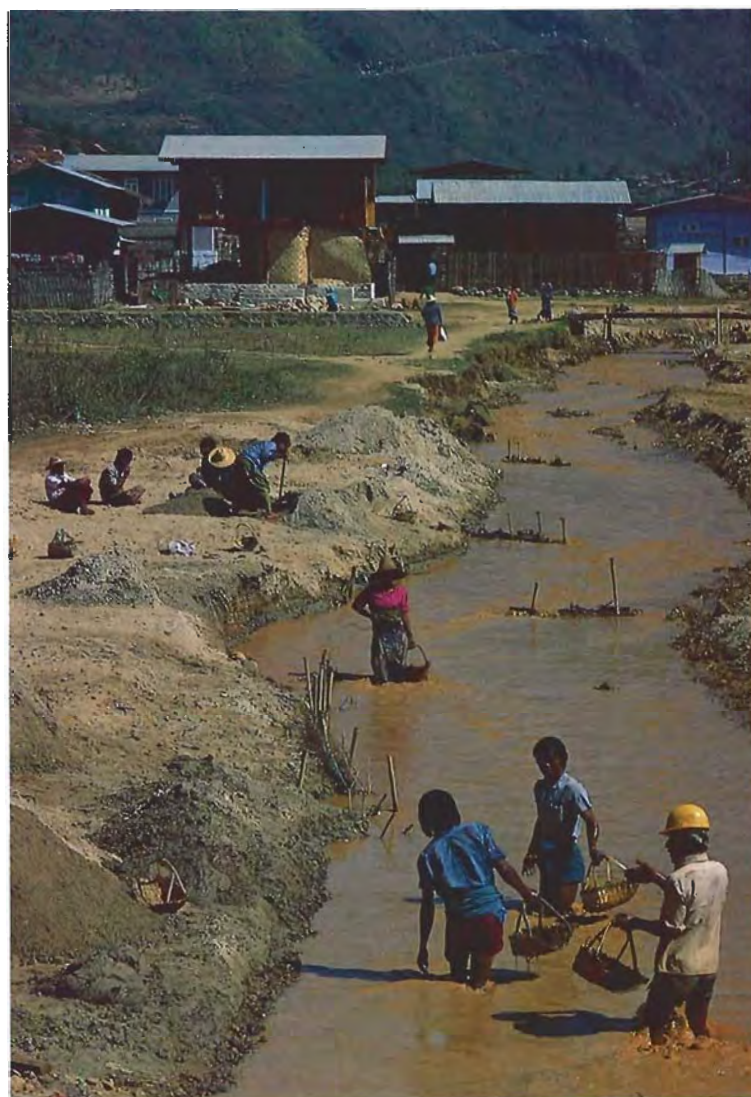






Figure 9. A variation of the classic twinlon mining method, a lebin is a square pit reinforced with timber and large leaves. Note the use of aluminum foil to reflect light into the mine and of a hand-cranked winch to hoist dirt and gem gravel to the surface in tightly woven bamboo buckets. Photo by Holly Kane.

will be dug into the byon from the main shaft to remove the gem-bearing gravels. Flooding usually forces a halt to mining during the rainy season.

Once gems have been found at any twinlon, miners will descend on the area and dig dozens of pits often quite close to one another. Typically each pit is operated by only three people—two who dig and a third who hauls up the overburden and byon.

We did not visit any circular twinlons but, around some of the joint-venture mines we visited, we saw a variation—a *lebin* (Halford-Watkins, 1932; Iyer, 1953). Although both twinlons and lebins are vertical shafts and have similar “lighting” systems, a lebin is square and reinforced by timber and large leaves (fig-

ure 9). Our guide explained that twinlons are used only in areas where the soil is compact enough to allow simple excavation; lebins are used where the soils are less cohesive.

Earlier reports (Halford-Watkins, 1932; Iyer, 1953; Gübelin, 1965) described the use of long bamboo levers or cranes to lift the dirt- or gravel-filled buckets. The miners we observed used a hand-hoist operation (again, see figure 9). The same reports also described and illustrated a clever indigenous hand pump that was used to remove water from the bottom of the vertical shafts. At the mines we visited, however, modern pumps—powered, for the most part, by diesel engines—were used to move water.

*Hmyawdwins*. Chhibber (1934) and Iyer (1953) describe *hmyawdwins* as “cuttings” or trenches dug into the sides of hills and steep valleys to expose the byon layer. After the overburden has been removed, the gem-bearing gravels and soil—which may lie more than 10 m below the original surface—are tossed into the trenches and water is used to force them down the slope to a flat circular “floor” or pit. Some of the trenches may require years to make when dug by hand. The critical water supply is obtained from various sources (streams, reservoirs, etc.) in the area through carefully engineered channels.

We visited a large open-cast mine that used what appeared to be the mechanics of a *hmyawdwin* at Yadanar Kaday-kadar (meaning “billions of precious stones”), approximately 23 km by road southwest of Mogok Township, just north of Kyaukpyatthat Village. The site is a natural basin approximately 200 m in diameter, with an area approximately 30,000 m<sup>2</sup>, situated near the base of two hills, Thurein Taung and Katheyaike (Yadanar Kaday-kadar Camp, 1991).

MGE mining began at this locality on May 14, 1985. Before 1962, local miners had worked the basin, then known as Loke Khat Inn (meaning “difficult to work”) because considerable overburden had to be removed to reach the gem-bearing gravels. In addition, the basin would fill with water during the rainy season.

Although excavation still takes place primarily by hand, the MGE now uses a truck as well as manual labor to move the larger rocks. They solved the problem of flooding by excavating a drainage tunnel—approximately 275 m (900 ft.) long and 1.5 m square—through the marble hillside to a valley beyond. Between visits in 1991 and 1992, the size of the mining operation had increased significantly.

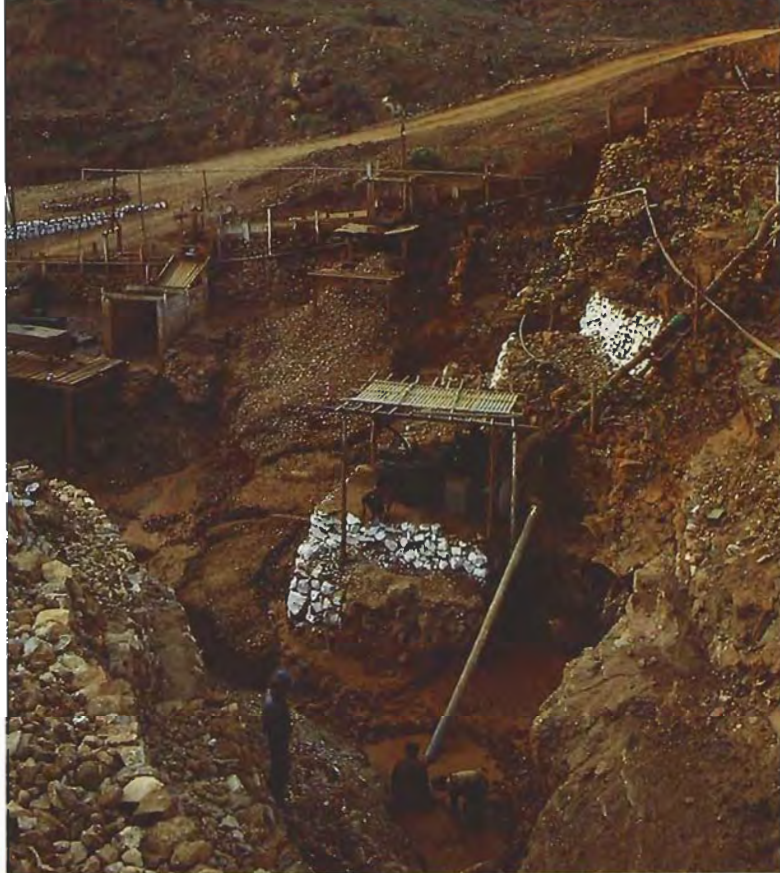


Figure 10. At a hmyawdwinn, as shown here at the Yadanar Kaday-kadar mine, the water and gravel that are collected are subsequently pumped upward for processing. The gravels are then washed and large rocks removed before they are sent through a series of sluices (shown running diagonally at top center) in which the denser materials are trapped and hand sorted. Photo by Robert E. Kane.

Consistent with descriptions of hmyawdwinn mining, a sloping trench had been cut into the side of the large open pit. Water was transported by pipe to the top of the trench, through which it flowed downward until it reached a smaller, flatter pit. Workers positioned along the slope used hand tools to attack the byon at the sides of the trench, forcing it into the flowing water (again, see figure 6), which softened the earth and separated some of the clay particles from the gem-bearing gravels. The water and gravels that collected in the pit at the bottom of the trench (figure 10) were then pumped into a hexagonal holding tank, where the gravels were washed with clean water and any remaining large rocks were removed by hand. The recovery process then followed a standard sluicing operation (again, see figure 10), and the remaining gem gravels were sorted by hand on site.

In both the 1990–91 and 1991–92 fiscal years, Yadanar Kaday-kadar was the most productive MGE

mine (see table 1). Although the production is primarily blue sapphire, ruby and pink sapphire are also recovered (figure 11). Our hosts reported that, shortly before our 1992 visit, a 384-ct blue sapphire of “very good quality” was recovered from this mine, and even larger stones have been found in the past.

*Loodwins.* Gems are also recovered from “holes,” often large and cavernous, in the marbles in which pockets of byon concentrate. As the main component (calcite) of the marble was dissolved by the action of groundwater, the heavy minerals—including corundum and spinel—in the marble were resis-

Figure 11. The combined open-cast/hmyawdwinn operation at Yadanar Kaday-kadar produces blue and pink sapphires as well as lesser amounts of ruby and other gem materials, as shown by the loose stones here. The two specimens of sapphire in matrix are from the nearby Thurein Taung hard-rock mine. Photo by Robert E. Kane.





Figure 12. At the bottom of a 100-m-deep shaft at Than Ta Yar, workers use a hand winch to haul out buckets of waste material. The wide plastic tube to their left carries water and gem-bearing gravels to the surface for processing. Photo by Robert E. Kane.

tant to dissolution and movement, and tended to settle at the bottom of the cavern or in crevices or other natural cavities. Some of these marble caverns have been described by Iyer (1953) and others as running as deep as 60 m. To reach and remove the byon is often laborious and may be quite dangerous.

The joint-venture ruby mine Than Ta Yar, located about a kilometer from the Kyauk Saung mine (see below), appeared to be a variation of loodwin mining in which explosives were used to widen some areas of the naturally occurring marble openings. We entered the mine through a downward-sloping tunnel that led to a vertical shaft approximately 100 m deep, which we then descended on damp wooden ladders and scaffolding. At the bottom of the shaft, which contained about a meter of water, workers used a hand winch to haul out buckets of what appeared to be waste rock and debris (figure 12). A wide plastic tube carried water and gem-bearing gravels from a nearby concentration to a washing plant at the surface.

Within approximately 50 m of the mine entrance was a small but efficient recovery plant surrounded by bamboo and barbed-wire fencing for security. The

water and gravel pumped from the mine shot out of the pipe and showered into a sluice. As the gravels traveled down the inclined trough, workers raked the larger waste rock over the side. The gravels were then processed in the sluicing/sorting operation typical of this area (see, e.g., the discussion of the MGE Central Washing Plant below).

The joint-venture leaseholder showed us two days' production that consisted of what appeared to be several thousand carats of predominantly rubies with some red spinels, moonstones, and undoubtedly other minerals. As noted above, deposits of this type in marble cavities are naturally concentrated and typically very rich. However, they are also very dangerous: A few days before our 1992 visit, we were told, several workers died in a cave-in at Than Ta Yar.

**Contemporary Mechanized Mining at Mogok.** Today, some mines are far more mechanized and efficient than any previous operations in the history of this famous mining area. Open-pit mining that was once done entirely by hand is now accomplished with bulldozers and backhoes, resulting in the removal of many tons of overburden and byon in a few weeks or even days. Historically rare at Mogok, tunneling operations are now being conducted at a number of primary occurrences.

*Open-Pit Mining.* This form of mining, also known as open cast, involves the removal of large amounts of overburden over a wide area to reach the layer of gem-bearing gravels. It is used for gem mining the world over, as well as in many areas of the Mogok Stone Tract. At some Mogok operations, like Yadanar Kaday-kadar, open-cast mining is used in conjunction with other methods such as hmyawdwins.

We visited another open-pit mine, Shwe Pyi Aye, that is located within the township of Mogok, approximately 1 km north of the MGE headquarters and adjacent to the Mogok ("Rubyland") Golf Club. The site is known for the high-quality rubies it has produced since it opened on December 11, 1987 (Shwe Pyi Aye Camp, 1991, 1992). A superb 5.56-ct oval faceted stone, known as the Crown of Mogok, was cut from a 10.95-ct crystal found at Shwe Pyi Aye.

At the time of the March 1991 visit (figure 13, inset), Shwe Pyi Aye—a secondary deposit—was being mined predominantly by hand. The 12- to 25-m-thick overburden had been removed from one area by bulldozer, and laborers were working the exposed byon layer, which was about 2–3 m thick. In addition to the mine manager, three engineers, and a geologist, 36



Figure 13. In 1991, the MGE open-pit mine at Shwe Pyi Aye was being worked by hand (inset); through the use of heavy earth-moving equipment, many tons of overburden had been removed by the time of the 1992 visit (main photo). The backhoe shown was removing byon, which was subsequently taken by truck to the Central Washing Plant. Photo by Robert E. Kane.

miners and other personnel were at the site. At the time of this visit, the bulldozer was not working in this area and mechanization consisted entirely of pumps for transporting gravel and water to the on-site processing operation.

The site had changed dramatically by the 1992 visit (figure 13). Significantly more overburden had been removed, expanding the diameter of the pit, and the bulldozer was working above the original site, stripping additional overburden. The recent earth-moving had exposed some old timbers, the remnants of pre-MGE mining in the area. According to the mine manager, military personnel had worked the site from 1965 to 1987.

Heavy equipment was also being used in the recovery of the gem-bearing gravel. A large backhoe removed the byon and loaded it onto a truck for shipment to the MGE's Central Washing Plant, as washing was no longer done on site. Gravels are transported from Shwe Pyi Aye to this recovery plant only during the dry season (mid-October to mid-May). During the rains, when this facility is not in operation, the gravels are stored on site in a holding pen. Because of

the additional mechanization, 10 fewer men were working the mine during the 1992 visit (Shwe Pyi Aye Camp, 1991, 1992).

We also visited the MGE open-pit operation at Pan Sho, approximately 1.5 km north of central Mogok Township and about 500 m from the Central Washing Plant (see below). A bulldozer and excavator were used to remove first the overburden and then the byon. Dump trucks carried the byon to the Central Washing Plant for processing. In the 1990/1991 fiscal year (see table 1), Pan Sho was the second most productive ruby mine run by the MGE; it also produced significant amounts of blue sapphire and other gems.

*Tunneling.* The MGE is currently mining hard rock at two locations: Lin Yaung Chi is presently worked primarily for ruby, whereas Thurein Taung is mined strictly for sapphire. We also visited two joint-venture tunneling operations, Dat Taw and Kyauk Saung, both of which produce rubies. Pointed out, but not visited, was another joint-venture tunneling operation approximately 30 m from Thurein Taung.

MGE-operated Lin Yaung Chi is situated just

north of Mogok Township, on the east side of the Panlin Bernard road. The site is surrounded by the Lot Nye, Shwe Taing, Min Phaya, and Ye-kan Mountains. It has been worked for many years: Before MGE involvement, local miners recovered rubies by removing the topsoil and processing the gem-bearing gravels found in the weathered faults and fractures in the marbles. Rubies were first found *in situ* at Lin Yaung Chi in 1970, by local miners. Government mining began on April 18, 1977 (Lin Yaung Chi Camp, 1991, 1992).

At the mine, we were told that rubies are found in brecciated marble associated with veins in a fault zone. The veins are undoubtedly igneous; hence, the rubies associated with them would be of contact metamorphic origin. The brecciated fault zone in which the veins occur lies between a massive marble and a diopsidic marble. The tunnel runs in the fault zone between the two rock types. The area around Lin Yaung Chi is in a zone characterized by many faults, and the tunnel intersects at least one minor fault plane.

The main tunnel, which was started at a vein outcrop high on the hill, was about 150 m long in 1992; the slope distance from top to bottom was about 50 m. At the time of our visit, ruby was found only in the main-tunnel workings. A secondary shaft,

called lateral cut number 2, ran perpendicular to the main shaft. It was wide enough to accommodate several people in places, was illuminated by electric lamps, and had steps cut into the ground for ease of access. Forty-seven people were directly involved in working the mine, in addition to the site manager.

The deposit was worked by conventional tunneling, using drilling and blasting. Holes were made with a jackhammer, loaded with explosives, sealed with mud, and then the explosives were detonated (figure 14). After blasting, rock was collected in baskets and taken by wheelbarrow from the mine to the sorting operation, just at the entrance to the main shaft. The broken pieces of rock were first sorted with screens of different-size meshes (figure 15), and then the rubies and other gems were picked out by hand and placed in a sealed metal cannister with a small, one-way opening. Three generator-powered water pumps were used to keep the tunnels from flooding and to supply water for the washing operation.

We were told that a ruby recovered from Lin Yaung Chi was cut into a 4.70-ct stone that sold at the February 1992 Emporium in Yangon ("Lot 1") for US\$282,000 (\$60,000 per carat). MGE officials reported that a secondary mine on the other side of this hill produced large sapphires exhibiting good habit

**TABLE 1.** Production<sup>a</sup> of ruby, sapphire, and other gem rough at the seven Mogok corundum mines currently operated by the Myanmar Gems Enterprise (MGE), 1989–1992.

Name of mine	Year that MGE first started mining	Occurrence	1989–90 <sup>b</sup> Actual production in carats <sup>c</sup>				1990–91 Actual production in carats <sup>c</sup>				1991–92 Actual production in carats <sup>c</sup>			
			Ruby and pink sapphire	Blue sapphire	Other gems	Total	Ruby and pink sapphire	Blue sapphire	Other gems	Total	Ruby and pink sapphire	Blue sapphire	Other gems	Total
Yadanar Kaday-kadar	1985	Secondary	2,113	34,463	1,139	37,715	17,098	185,735	30,005	232,838	17,746	102,116	3,184	123,046
Pan Sho	1989	Secondary	811	2,228	4,771	7,810	11,156	15,387	15,829	42,372	2,275	1,534	2,771	6,580
Lin Yaung Chi	1977	Primary	835	188	6,065	7,088	1,536	1,241	10,298	13,075	2,446	102	1,247	3,795
Shwe Pyi Aye	1987	Secondary	1,360	28	2,836	4,224	4,150	133	3,290	7,573	8,435	583	4,738	13,756
Pinku Taung	1989	Secondary	1,668	NR <sup>d</sup>	NR <sup>d</sup>	1,668	362	NR <sup>d</sup>	NR <sup>d</sup>	362	2,008	35	30	2,073
Thurein Taung	1987	Primary	NR <sup>d</sup>	134,209	NR <sup>d</sup>	134,209	NR <sup>d</sup>	24,111	NR <sup>d</sup>	24,111	NR <sup>d</sup>	17,653	NR <sup>d</sup>	17,653
Padamyar	1985	Secondary	3,739	11	1,435	5,185	3,921	58	830	4,809	6,188	60	220	6,468
Total			10,526	171,127	16,246	197,899	38,223	226,665	60,252	325,140	39,098	122,083	12,190	173,371

<sup>a</sup>Statistics provided by the Myanmar Gems Enterprise (MGE), Mogok Gems Mining Department, Mogok, Mandalay Division, Myanmar (Burma). The production figures provided here represent only a portion of the total gem rough produced annually in the Mogok Stone Tract. See text for a discussion of the many other mining activities in the Mogok area.

<sup>b</sup>Fiscal year ends March 31.

<sup>c</sup>Carat weight figures are approximate. No distinction is made between non-gem and facet- or cabochon-grade materials.

<sup>d</sup>NR = No production reported during this period.



Figure 14. A major tunneling operation underway at the MGE Lin Yaung Chi mine involved the extensive use of explosives to reach the gem-bearing fault zone, that is, the primary occurrence of the gems. A jackhammer was used to drill holes, which were then packed with explosives, sealed with mud, and the fuse lit. Photo by Robert E. Kane.

as well as spinel, garnet, apatite, and green tourmaline (Lin Yaung Chi Camp, 1991 and 1992).

The second tunneling operation visited, the Thurein Taung mine, is located approximately 23 km west of Mogok Township. To reach the site, we first drove to the Yadanar Kaday-kadar mine and then walked approximately 1 km over a rough footpath. At this locality, where mining began on December 12, 1987, alkali-rich mafic igneous rocks (technically, urtites) have been intruded into marble. The sapphires are found *in situ* in these unusual igneous rocks and biotite-bearing gneiss. At the time of the 1991 visit, a staff of 25 were employed at this site. Drilling and blasting were used to tunnel into the rock along the sapphire-bearing vein (Thurein Taung Camp, 1991; "Role of the Gems Mining Department," 1991).

Located about 5 km northeast of Mogok Township, the joint-venture Dat Taw mine is reached by driving along a narrow dirt road, followed by a steep climb by foot that takes approximately one hour. The bright, white marble tailings are visible from quite a distance (again, see figure 5). Some of this very white marble is also exposed on the face of the mountain itself, where several tunnels are located at various elevations.

Figure 15. Just outside the entrance to the Lin Yaung Chi mine, the broken marble is passed through a series of screens. The large pieces are removed and sorted by hand in the screens on the left, while the smaller fragments continue downward through a series of sluices on the right, from which the gems are also recovered by hand. Photo by Robert C. Kammerling.





Figure 16. The 496.5-ct Nawata, later rechristened the SLORC, ruby is an example of the exceptionally large crystals recovered from Dat Taw. Photo by Robert E. Kane.

We entered through an excavated tunnel that leads into a natural marble cave that is as high as 10 m (about 30 ft.) in some areas. Tunnels have been excavated from this natural cavern, one of which we followed to an area that was being prepared for blasting.

This locality is known to produce exceptionally large rubies. Among these is the 496.5-ct crystal (figure 16) that was originally named the Nawata but was later rechristened the SLORC ruby (after the acronym for State Law and Order Restoration Council, the ruling government body). This crystal, recovered in early 1990, weighed 504.5 ct and measured 43 mm × 37 mm × 33 mm before it was trimmed (MGE catalog, 1990). It is considered a national treasure, and was depicted on a Myanmar postage stamp (Koivula and Kammerling, 1991). While at this mine, we were shown another unusually large crystal, although of lesser quality than the Nawata/SLORC ruby. According to the leaseholder, this crystal weighed 560 ct and was recovered March 19, 1992 (figure 17).

A number of joint-venture mines operate in the Kyauk Saung area, on the northwestern outskirts of Mogok Township. These mines, all of primary deposits, are located on one side of the access road, stretched out along approximately 1.5 km of a ruby-rich marble contact zone. Again, explosives were used to remove the hard rock and reach the gem-bearing zone. On the other side of the road, secondary, mostly lebin, mining was in progress.

## RECOVERY

**Kanase.** We observed a variety of recovery operations at Mogok. The most rudimentary of these are performed by the *kanase*—traditionally women, although

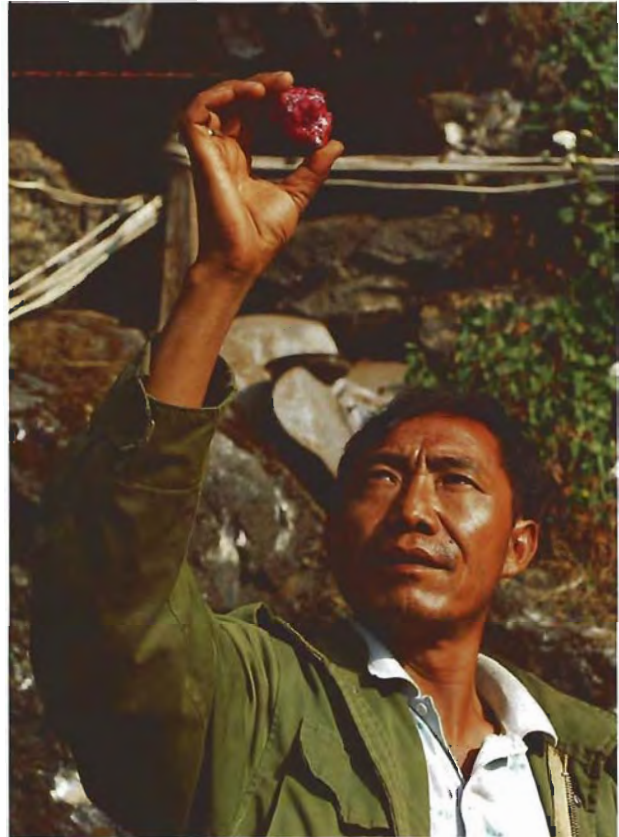


Figure 17. This 560-ct ruby crystal was found at Dat Taw on March 19, 1992. Photo by Robert C. Kammerling.

For decades, if not centuries, *kanase* women have searched the discarded gravels at Mogok (here, at Than Ta Yar) for rubies and other fine gems overlooked in the original recovery operation. Photo by Robert C. Kammerling.





Figure 19. Processing at the Central Washing Plant begins with trucks unloading byon from MGE-operated mines onto a large metal grate. Photo by Robert E. Kane.

we saw men as well, who work the discarded gravels and mine tailings in search of gems that were overlooked. At Than Ta Yar and throughout the gravel workings, the *kanase* could be found rewashing the discarded gravels (figure 18). At Kyauk Saung and other primary mines, they could be seen hammering on marble in the tailings piles. The "right" of the *kanase* to work the abandoned rocks and gravels in Mogok and keep any gems they find is centuries old and continues to the present day (see, e.g., O'Connor, 1907; George, 1915; Halford-Watkins, 1932; Iyer, 1953; Hughes, 1990).

**Joint-Venture and Unlicensed Operations.** As described above, the primary deposits are processed via a very simple method whereby the host marble is broken down and passed through screens of different-size meshes, where they are hand sorted.

In most of the secondary deposits, the gravels are either washed in baskets or, more commonly, processed in a series of sluices placed along an incline (see, e.g., figure 10). The heavier materials are trapped in the sluices, while the lighter materials pass downward. At each sluice, the gravels are checked for gems and then discarded.

**Central Washing Plant.** The most sophisticated recovery operation at Mogok is the Central Washing Plant, an MGE facility used to process gem-bearing gravels

from the government mines. The plant, which began operation in 1989, has the capacity to process 100 tons of material a day (Central Washing Plant, 1991, 1992). From November 1989 through December 1990, the plant recovered a reported 7,471 ct of ruby, 7,851 ct of sapphire, and 8,054 ct of spinel. The largest ruby recovered at the plant weighed 21 ct, and the largest sapphire weighed 155 ct, before faceting.

Processing begins with the unloading of trucks filled with byon that has been removed from various MGE mine sites. During our 1992 visit, the Central Washing Plant was processing gem gravels from both the Pan Sho and Shwe Pyi Aye mines. A truck backs up to a concrete slab and dumps its load of byon onto a large metal grate (figure 19). High-pressure water cannons are then directed at the byon, washing the smaller, gem-bearing gravels into a concrete pen (figure 20). Large rocks are trapped by the grating and discarded by laborers. From platforms on either side of the pen, additional water cannons attack the gravels and wash the lighter soil down a wastewater chute, while the gravels pass through a series of vibrating screens and cement chutes. One of these screens separates out all stones over 2 cm, which are then collected and hand sorted on a nearby table.

The smaller gravels continue downward until, near the end of the operation, they reach a large cement holding tank with a drain pipe. From this pipe, the gravel is collected into shallow, circular





Figure 20. High-pressure hydraulic cannons are next directed at the off-loaded material. Large rocks are trapped by the metal grating while the smaller, gem-bearing gravels are washed into a concrete pen. Photo by Robert C. Kammerling.

pans with fine-mesh-screen bases. These pans are then placed in a small vibrating jig for several minutes. The vibrating action causes the corundum and spinels (as well as other heavy minerals) to settle to the bottom center of the pans (figure 21). The pans are then taken to a sorting table, where they are skillfully and rapidly turned over so that the heavy minerals lie at the top center of the pile, from which they are sorted by hand (with either fingers or tweezers). The sorted gems (figure 22) are then placed in locked metal containers.

Although the different types of gems were mixed when placed in the locked containers on site, the sorters displayed for our benefit their skill in rapidly distinguishing the corundum from spinel on the basis of crystal morphology and nuances of color. This is in dramatic contrast to a practice used in Myanmar in the earlier part of the 20th century: immersion of the gem rough in a solution of thallium silver nitrate (specific gravity just under 4.00). In this solution, the spinels would float to the surface (Calhoun, 1929).

## PRODUCTION, MANUFACTURING, AND DISTRIBUTION

**Production.** MGE officials provided statistics for the production of ruby, sapphire, and other gem rough from their seven current corundum mines at Mogok for the last three fiscal years (1989–90, 1990–91, 1991–92; see table 1). The MGE also reported total production of gem rough at all of the joint ventures from the beginning of joint-venture mining in June 1990 to February 1991 as 432,909 carats (pers. comm., 1991).

Figure 21. The vibrating action of the jig causes the denser minerals, including corundum and spinel, to settle in the bottom center of the pans. Photo by Robert E. Kane.

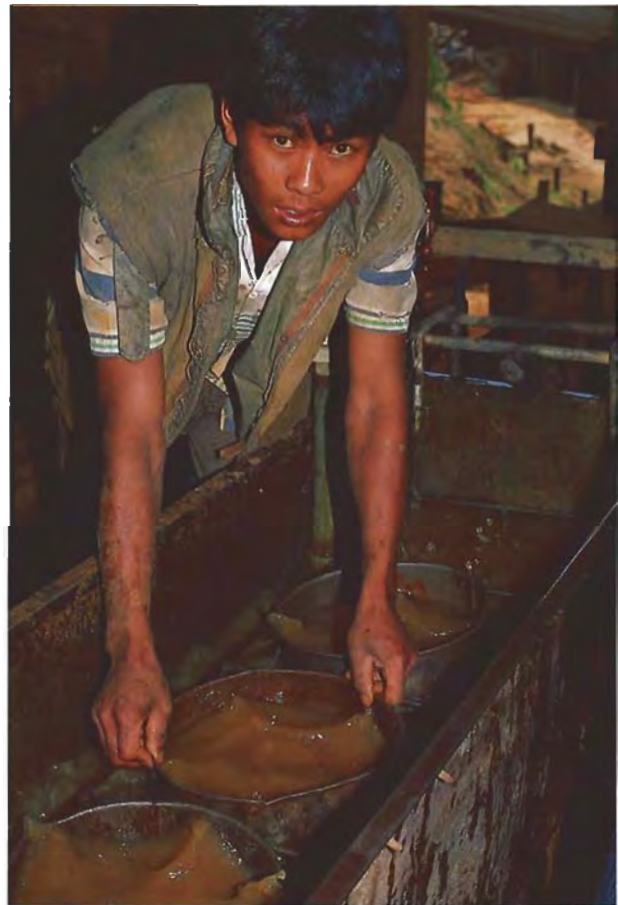




Figure 22. After processing in the vibrating jig, the gem materials are removed by hand. Here, the mine manager displays some of the production for that day in a metal tray. Photo by Robert E. Kane.

They indicated that the Dat Taw, Than Ta Yar, and Kyauk Saung operations were the most productive joint ventures in terms of total carats of gem rough. Specific information regarding the percentage of material that was facet or cabochon grade was not available.

**Manufacturing.** During the 1991 trip, a visit was made to a small cutting factory/school at the MGE headquarters in the town of Mogok. The 13 people who did the cutting were reportedly relatives of MGE mine staff. At the time of this visit, they were fashioning cabochon sapphires (some asteriated). The stones were first preformed on a motorized grinding wheel. The apprentices then finished the sapphires entirely by hand, using a series of wooden boards—some coated with silicon carbide (figure 23), others with diamond powders #120 and #320.

There are also many unauthorized cutting operations in Mogok. Reportedly, most of these operations still use the traditional pedal-driven benches described by Gübelin (1963, 1966b). Some rubies as well as sapphires (see, e.g., figure 24) are fashioned at a more modern factory in Yangon, where motorized grinding wheels and other types of modern equipment are used throughout the cutting process (figure 25).

**Distribution.** Thousands of carats of fine rubies, sapphires, spinels, and other gems are offered at the Gems, Jade, and Pearl Emporium in Yangon. At the 1991 Emporium, total sales of US\$11,030,128 were reported (\$6,925,251 in jade, \$2,828,806 in pearls, and \$1,276,071 in “gems”—primarily ruby, and sapphire, as well as spinel, with lesser amounts of stones such as diamond, peridot, zircon, aquamarine, garnet, and amethyst). At the February 1992 Emporium, total sales of \$8 million were recorded (\$4.5 million for jade, \$800,000 for pearls, and \$2.7 million for other Myanmar gems (Clark, 1992). The October 1992 Emporium produced more than \$8.9 million in sales (\$6.37 million for jade, \$470,000 for pearls, \$1.76 million for other “gems” and \$300,000 for jewelry and jade carvings). Sales at the two 1992 Emporiums exceeded the single 1991 Emporium by almost \$7 million.

*JewelSiam* reports that other sales are made by special arrangement with the government (“Neigh-

Figure 23. Some of the gem materials recovered from MGE-operated mines are fashioned at a small cutting factory/school within the MGE headquarters compound in Mogok. This young woman is using a traditional method—a wooden board coated with silicon carbide—to polish a sapphire cabochon. Photo by Robert E. Kane.





Figure 24. The end result of the MGE's operations: exceptional rubies and sapphires from the Mogok Stone Tract. Shown here are faceted rubies of 9.36 ct and 11.55 ct and sapphires ranging from 6.68 ct to 142.20 ct (the largest is the partially fashioned stone in the calipers). Photo by Robert E. Kane.

borly Burma," 1990). Dealers in Bangkok confirm that large numbers of gems continue to cross the Myanmar borders illegally. We observed Myanmar gem materials openly traded at the town of Mae Sot, on the Thailand side of the border with Myanmar.

#### OTHER RUBY OCCURRENCES IN MYANMAR

Known and as-yet-undiscovered ruby and other gem deposits are believed to extend far beyond what is commonly called the Mogok Stone Tract. Ruby is known to occur, and has been mined, in several other areas. In 1934, for example, Chhibber identified two important stone tracts in upper Burma in addition to Mogok—Nanyaseik (Myitkyina District) and the Sagyin Hills (Mandalay District)—and reported the existence of corundum-producing stone tracts in the districts of Kengtung and Mongmeik.

Based on conversations with various Myanmar Government officials at the 1986 Emporium in Yangon, Chikayama (1987e) reported that ruby min-

Figure 25. Traditional as well as more modern techniques are used to fashion gems at MGE headquarters in Yangon. The latter includes the use of motor-driven grinding wheels. Photo by Robert E. Kane.



ing was also taking place at Tha Fain Pin and Inyyauk. He noted as well the "new" locality of Blin-Thandaung in Karen State between Yangon and Mandalay, at about 19°N.

One of the more recent and potentially most important new ruby sources is the Nawarat Stone Tract, also referred to as Pyinlon, in Shan State (*Working People's Daily*, November 8, 1990; Aye, 1992). Immediately after the 1991 Emporium, one of us was shown a ring-set 5.25-ct faceted ruby of exceptional color and clarity that was subsequently christened the "Nawarat Tharaphu." This gem was reportedly cut from a 9.70-ct piece of rough that was recovered in the Nawarat Stone Tract on April 23, 1990 (Aye, 1992).

Another recent discovery is at Namhsa, in the northern section of Shweli and approximately 15 km north of the Nawarat Stone Tract. Rubies and other gem materials are being recovered from this area. Exploration and mining are being jointly carried out by the Geological and Mineral Exploration Department and the Myanmar Gems Enterprise; actual mining began on September 26, 1990. Both of the above two sites—Nawarat and Namhsa—are near the border with the People's Republic of China (*Working People's Daily*, November 8, 1990; Aye, 1992).

An even more recent, and also very promising, discovery is the Monghsu Stone Tract. In an official notification dated July 16, 1992, the boundaries of this new locality in the Saihlian region of Monghsu Township, southern Shan State, were delineated in detail (*Working People's Daily*, July 18, 1992). In a subsequent press conference, MGE officials stated that exploratory extractions were being carried out by the government in a "one square mile block" of the new deposit. Among the materials recovered to date and displayed at the press conference were 1,162 rubies with a total weight of 1,181 carats. The exploratory production included facet- and cabochon-grade material as well as asteriated stones. The MGE also announced that 200 additional blocks would be designated in the new tract for joint-venture mining

## CONCLUSION

The historic Mogok Stone Tract has long been known as the premier source of fine-quality rubies. During the 20th century, Burmese rubies became a staple of jewelry fashioned in the finest jewelry houses in the world, including Tiffany's, Cartier, Van Cleef and Arpels, and Harry Winston (figure 26). Not since Burma Ruby Mines ceased mining in 1931 has there been such a high level of organized activity at Mogok.



Figure 26. This diamond-and-ruby bracelet, once owned by the late Mrs. Harry Winston, is an example of the exquisite jewelry in which gems from the Mogok Stone Tract have been set. The total weight of the 40 cushion-shaped rubies is approximately 81.25 ct. Jewelry courtesy of Harry Winston, Inc.; Photo by Michael Oldford.

The Myanmar government's renewed interest in developing this national resource has led to the use of new techniques (and new variations on old techniques) to recover the gem gravels, or byon. Pneumatic drills and explosives are now employed in the extensive working of hard-rock deposits. Recent advances include the establishment of a Central Washing Plant to process material from a number of mines.

In addition to modernizing mining techniques at MGE operations, the Myanmar government has initiated a more open development policy in licensing joint-venture operations with Myanmar nationals, making further resources available. All these factors, combined with recent discoveries of additional ruby and sapphire deposits, indicate that greater amounts of these highly desirable gems will be reaching the international markets.

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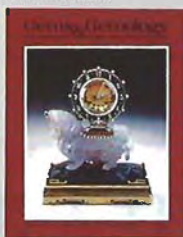
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Spring 1985



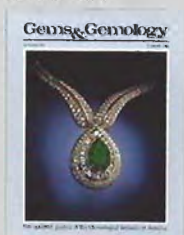
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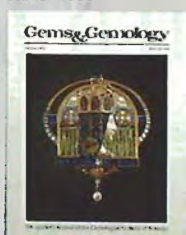
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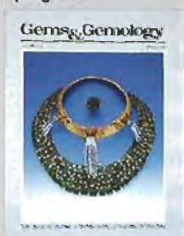
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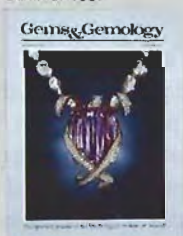
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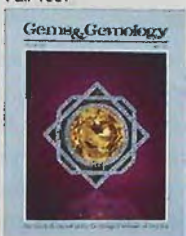
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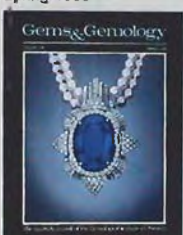
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# IDENTIFICATION OF BLEACHED AND POLYMER-IMPREGNATED JADEITE

By Emmanuel Fritsch, Shun-Tien Ten Wu, Thomas Moses, Shane F. McClure, and Mike Moon

The "bleaching" treatment of jadeite jade has become prevalent in higher- as well as lower-quality material. "Bleaching" is actually a two-step process whereby a brown or gray color component (probably iron compounds filling the fractures) is removed chemically, followed by impregnation of the resulting white to green material with some type of polymer. The treatment product is commonly referred to as "bleached jadeite" or "B jade" in the Orient. Although several gemological tests are useful in detecting this treatment, infrared spectroscopy is the only method found thus far that provides conclusive evidence of polymer impregnation in all cases.

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**A** new type of jadeite treatment, often referred to in the trade as "bleaching," has become prominent in the 1990s (figure 1). It is seen worldwide, but particularly in Taiwan, Hong Kong, and Japan. The appearance of this treatment prompted several reports in the trade press. Of special concern was the fact that the treatment initially went undetected by some gemological laboratories; this reportedly led to a 50% decrease in jadeite sales in Japan over a three-month period ("Green jadeite bleached then dyed emerald green," 1991; "New filler threatens jadeite sales in Japan," 1991).

The process reportedly consists of two steps—first bleaching and then polymer impregnation. The bleaching enhances the appearance of the jadeite primarily by removing a brown component from the gem's overall color. The polymer impregnation fills any voids left by the bleaching, thus enhancing the clarity appearance of the stone and stabilizing it. The change produced by this two-part treatment may be relatively minor or quite significant (figure 2); the material that results is called "grade B jade" or simply "B jade" by many dealers in the Orient. So far, this treatment has been reported only for green and white jadeite (not for other colors of jadeite, such as "lavender," or for nephrite jade). However, it has been identified in all qualities of jadeite, as dealers seek to improve the appearance (and, therefore, the salability) of even the finer materials (see figure 3).

The expression *bleached jadeite* is misleading because it refers only to the first half of this two-step treatment process. In this article, we will use the word *bleached* alone to mean that the piece of jadeite has only been bleached. If the piece has also been impregnated, we will indicate so and identify the impregnation material—typically some type of polymer, such as a wax or a resin. In accordance with the practice in Hong Kong and Taiwan, we will occasionally refer to the process by which jadeite is both bleached *and* polymer impregnated as "bleaching" treatment. Note, however, that jade that has only been bleached rarely appears on the market because the



Figure 1. Jadeite that has been bleached and polymer impregnated is appearing with great frequency in the gem trade. In these attractive pieces of jadeite jade jewelry, all of the cabochons in the bracelet, as well as the cabochon in the large (15.19 × 10.12 × 4.30 mm) ring on the left, have been subjected to "bleaching" treatment, whereas the cabochon in the ring on the right has not. Photo by Shane F. McClure.

resulting voids are too visible (figure 4) and the material may be unstable.

#### AN OVERVIEW OF JADE TREATMENTS

Because fine jadeite is highly prized, a number of enhancements have been used. For at least 30 years, for example, most jadeite jade has been coated with a thin film of paraffin or wax to improve its luster and fill fractures and pits (Ehrmann, 1958; Crowningshield, 1972). Material that has received only a superficial waxing is often called "grade A jade" (F. Ho, pers. comm. to P. Yurkiewicz, 1991) or simply "A jade" in the trade.

Some jadeite is dyed. Green dye mixtures were reported first (see, e.g., Ehrmann, 1958), then purple

and other colors (Liddicoat, 1971; Fryer, 1983). The detection of dyed green and dyed lavender jadeite—often called "C jade"—is discussed in several texts (see, e.g., Koivula, 1982; Liddicoat, 1987).

The treatment discussed in this article should not be confused with another treatment, which appears to be a simple resinous coating ("Coating on jadeite," 1990; "Resinous coating reported on jadeite," 1991), that has been known for several years but reportedly is not very common in the market (Wu, 1991b). Although resins are used in the impregnation process for bleached and impregnated jade, our experiments showed that the material usually is found only at the openings of the voids or fractures, not forming a uniform coating on the surface.

On May 2, 1988, a Taiwan newspaper reported that a jadeite bangle purchased for US\$400,000





Figure 2. These two jadeite pieces, which weigh 10.32 and 7.69 ct, illustrate the effectiveness of the treatment discussed in this article. They represent two halves of the same sample, one before treatment (left) and the other after bleaching and polymer impregnation (right). Photo © GIA and Tino Hammid.

changed “color” (actually luster) after one month. Closer examination revealed that the bangle was jade that had been bleached and polymer impregnated (Wu, 1989). One of the authors (S-TTW) saw this type of treated jade as early as 1984. In 1989, impregnation of jadeite jade with a polymer believed at the time to be a mixture of polyacrylates was first reported in English (Hurwit, 1989). Today, significant amounts of jadeite treated in this fashion are believed to have entered the market via treatment facilities in Hong Kong and Taiwan. In the experience of one of the authors (S-TTW), as much as 90% of the jadeite sold in Taiwan has been treated in this fashion; dealers report that large amounts of this material are being sold in Hong Kong as well (e.g., D. Kay, pers. comm., 1992).

## DESCRIPTION OF THE BLEACHING/ POLYMER-IMPREGNATION TREATMENT PROCESS

The first step is bleaching: The jadeite pieces, rough or fashioned, are immersed in chemicals to remove brown, iron-containing compounds present in the fractures and at grain boundaries. According to various sources (e.g., D. Mok, C. J. Ko, and F. Ho, pers. comms., 1992), hydrochloric acid is the most common bleaching agent, but nitric acid or a sodium compound may also be employed, depending on the type of jadeite and the personal experience of the treater. (One of the authors [S-TTW] observed that early treaters sometimes used the acidic juice of a sour plum from mainland China.) The jadeite is then immersed in these various chemicals for a few hours to a few weeks, depending on the porosity of the stone and the severity of the staining.

Not all jadeite responds to treatment, and treaters claim that it takes a trained eye to determine whether the treatment will be effective on a given piece. When the color appearance is deemed sufficiently improved, the jadeite is repeatedly rinsed with water. A solution of caustic soda may also be used to neutralize the acids.

If bleaching has been successful, the fractures and grain boundaries will have lost all or most of the brown coloration but will now appear as white or pale green veins (again, see figure 4) that are quite noticeable and unattractive. The bleached jadeite may also be very brittle because the material removed by bleaching leaves voids; bleached stones of the lowest quality can sometimes be completely crushed by finger pressure alone. In addition, over time, it is likely that the voids would become filled by dirt and grease—thus discoloring the stone—if subjected to normal wear in jewelry.

Therefore, bleached jadeite is typically impregnated with some kind of polymer to fill the open fractures. Occasionally, only wax is used (C. J. Ko and J. Ng, pers. comm., 1990). In most cases, a resin is injected into the piece, reportedly under pressure (“New filler threatens jadeite sales in Japan,” 1991), to replace the material lost in the bleaching process. In the experience of one of the authors (S-TTW), a vacuum pump is sometimes used to pull gas bubbles out of the fractures before they are filled. In addition, the stones may be exposed to the heat generated by a microwave oven to facilitate the injection process. Some treaters use a green dye before the impregnation or mix a dye with the impregnation material (C. J. Ko and J. Ng, pers. comm., 1990). Once impregnation is

completed, the stones are wiped to removed any residual polymer.

### MATERIALS AND METHODS

Because jadeite jade is a rock (frequently jadeite mixed with other minerals), some of its gemological properties may vary significantly from one sample to the next. It is, therefore, particularly important to study a range of samples of different color and appearance in order to ascertain that any difference in properties seen between untreated and treated samples is a consequence of the treatment, not of the natural variability of this gem material. Thus, to document the effects of this new type of jadeite treatment, we examined 42 samples of jadeite jade: 27 known to be natural and untreated, and 15 known to have been treated by "bleaching." The set of natural, untreated samples (small, approximately 1–3 cm) covers a range of colors from white to dark green, with several mottled white and green. Small areas of brown or black were present on some of these samples. Eighteen of these untreated pieces were polished, in a variety of shapes, and nine were unpolished slabs. Five jadeites with lower-than-normal specific gravities were deliberately incorporated into this sample.

Among the treated pieces, four were bleached but not impregnated, two were bleached and impregnated with wax, and the remaining nine were



Figure 3. Virtually all qualities of jadeite are being subjected to the bleaching/polymer-impregnation treatment, including finer pieces like this bangle bracelet. Photo by Shane F. McClure.

Figure 4. The bleaching part of the treatment removes iron staining from small fractures and grain boundaries, leaving whitish or lighter color veins instead. As illustrated by the sample on the left (1.20 ct), jadeite that has only been bleached rarely appears on the gem market because the resulting voids detract from the appearance of the stone and may produce a "cracked" effect. Impregnation with a polymer that has a refractive index close to that of the jadeite (right, in this case wax) makes these unattractive features less prominent. Photo by Shane F. McClure.



bleached and all impregnated with the same type of polymer. We also obtained four paired samples that represent the same piece of jadeite before and after treatment (see, e.g., figure 2).

We documented the gemological properties of all samples, placing particular emphasis on specific gravity, ultraviolet luminescence, thermal reaction testing, and appearance with high magnification. We used the hydrostatic method to measure specific gravity, and confirmed the results by observing the behavior of the samples in 3.32 S.G. liquid (methylene iodide).

Because infrared spectroscopy has proved useful in the detection of polymer impregnation (Arnould and Poirot, 1975; Lind et al., 1983; Fritsch and Stockton, 1987; Hurwit, 1989; Shida, 1991), we recorded the infrared spectra of all samples using a Nicolet 60SX Fourier Transform Infrared (FTIR) spectrophotometer. Spectra were taken in both the mid-infrared (400 to 4900  $\text{cm}^{-1}$ ) and near-infrared (3700 to 10500  $\text{cm}^{-1}$ ) regions of the electromagnetic spectrum, because organic polymers are known to display strong absorptions in these regions, and these are the regions in which jadeite itself is at least partially transparent. All spectra were collected in the transmission mode, by passing the infrared beam through the jadeite sample.

To investigate potential differences in chemistry between unbleached and bleached jadeite, especially differences in iron content, we used an energy dispersive X-ray fluorescence spectrometer, the Tracor X-ray Spectrace 5000. Because this instrument cannot detect the light elements (such as C, H, O, N) that form most polymers, we did not expect it to detect the presence of the impregnation material.

## GEMOLOGICAL PROPERTIES

**Index of Refraction.** The index of refraction—measured by the spot method on all samples, untreated and treated, that had a polish good enough to obtain a reliable measurement (33 total)—was either 1.65 or 1.66. This is typical for jadeite jade.

**Spectrum Seen with a Handheld Spectroscope.** All samples showed the 437-nm line typical of jadeite, and 31 samples, both untreated and treated, showed “chromium lines” in the red.

**Appearance.** Most of the untreated jadeites in our sample showed the compact, polycrystalline, aggregate structure with a granular texture that is typical of jadeite (a pyroxene). A few, however, displayed more elongated crystals in a fibrous structure.

In the experience of one of the authors (S-TTW), initially only “apple green” or “flower green” material was found to be treated. Now, however, other shades of green jadeite show evidence of treatment, including the “old mine” or “imperial” color (*Jade Master Stone Chart*, 1981).

Because the presence of an impregnation material can often be detected by dissolving the polymer in an organic solvent, thereby noticeably reducing the luster of the material, we tested two samples of bleached/impregnated jade for their reaction to acetone. Even after total immersion for approximately 30 minutes, there was no visible change in appearance. Nor was any effect observed after immersion in alcohol for five minutes. However, other, stronger solvents might produce a different reaction.

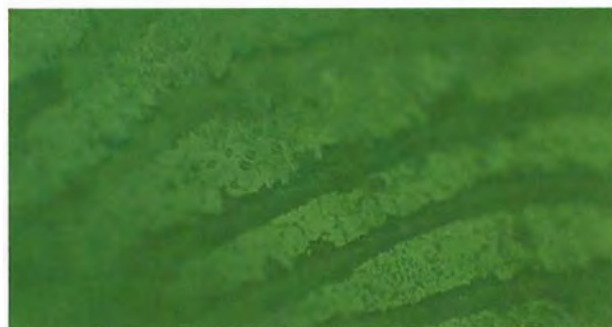


Figure 5. A drop of concentrated hydrochloric acid will produce “sweating” and beading on a natural (untreated) piece of jadeite. Photomicrograph © A. Hodgkinson; magnified 12 $\times$ .

Using information supplied by Alan Hodgkinson of Glasgow, we experimented with a new testing procedure. We placed a small drop of pure hydrochloric acid on a piece of natural (untreated) jadeite and watched for several minutes (Mr. Hodgkinson reports that the desired reaction will take from less than a minute to as long as 20 minutes), until we saw a “sweating” or beading of the acid at the surface of the stone, in the area immediately surrounding the droplet (figure 5). This reaction is due to capillary action in small fractures and minute spaces between the crystal grains of the jadeite. When the same test is performed on a piece of jadeite that has been bleached and polymer impregnated, no such beading or “sweating” is observed because the polymer has filled these minute spaces, thus preventing the acid

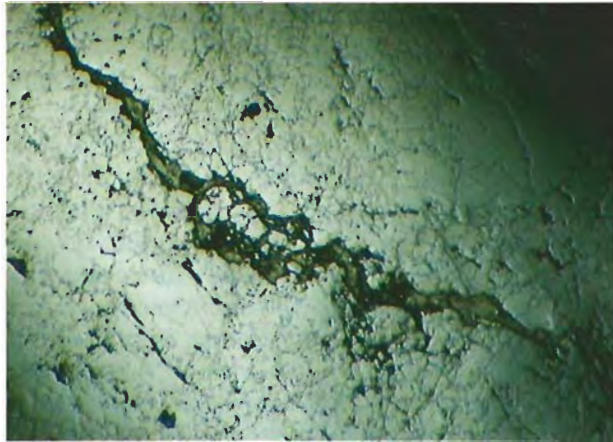


Figure 6. In reflected light, the filling material is clearly visible in this large fracture. Photomicrograph by Shane F. McClure; magnified 30 $\times$ .

from traveling through them. Note, however, that this test is more difficult in hot, dry areas, especially when air conditioning is used, because the HCl will evaporate before the desired reaction is achieved. Often the droplet will have to be replenished several times.

As noted earlier, fractures are more noticeable in samples that have been bleached but not polymer impregnated, and they may even give the overall piece a "cracked" appearance (again, see figure 4). With magnification and reflected light, the presence of a filler can be seen in some surface-reaching fractures (figure 6). Also, the poor luster typical of low-quality jadeite may be seen on some jadeite pieces, and white spots were evident on some pieces that did not respond well to treatment. In a small number of the filled fractures, we observed bubbles or lint trapped in the transparent impregnation material (figure 7). On occasion, shallow, concave "puddles" of residual impregnation material, reminiscent of those seen in some plastic-impregnated turquoises, were observed on the polished surface of a sample (R. C. Kammerling, pers. comm., 1991).

**Reaction to the Thermal Reaction Tester (TRT).** Four of our 27 samples of untreated jadeite showed "sweating" under the microscope near the area where the TRT was applied; subsequent infrared-spectroscopy testing (see below) showed that these four samples did, indeed, contain residual wax, which is a common final step in the polishing process in much of Asia.

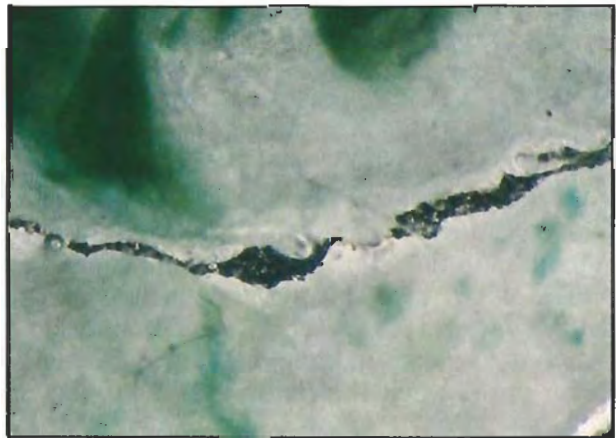
The remaining untreated samples showed no reaction. The bleached-only samples did not show any reaction either, with the exception of one that displayed "sweating" near the edges of the cabochon, probably residual wax that was not removed by the bleaching treatment.

All the bleached/polymer-impregnated jades in the test sample revealed melting on contact with the TRT. This was typically accompanied by a small amount of smoke, a recognizable "plastic" odor, or a minor flow of melted material. It is important to note, however, that the impregnated jades sent through the GIA Gem Trade Laboratory generally show no reaction to the TRT. The finer-grade material that the laboratory has seen seldom has any residual polymer on the surface. The only exception is when there is a filled cavity or fracture that reaches the surface (again, see figure 6), but such features are not common in the high-quality material usually submitted to the lab.

It is also important to note that thermal-reaction testing must be performed in numerous spots on an inconspicuous area of the sample (because of the natural inhomogeneity of jadeite jade) and must be observed with a microscope. Because of the potential for damage to the stone, this test is not recommended.

**Specific Gravity (S.G.).** The specific gravity of natural jadeite is generally greater than 3.32; that is, most natural, untreated jadeites sink in the 3.32 liquid

Figure 7. We observed bubbles and lint trapped in the polymer in a small number of stones. Photomicrograph by John I. Koivula; magnified 6 $\times$ .



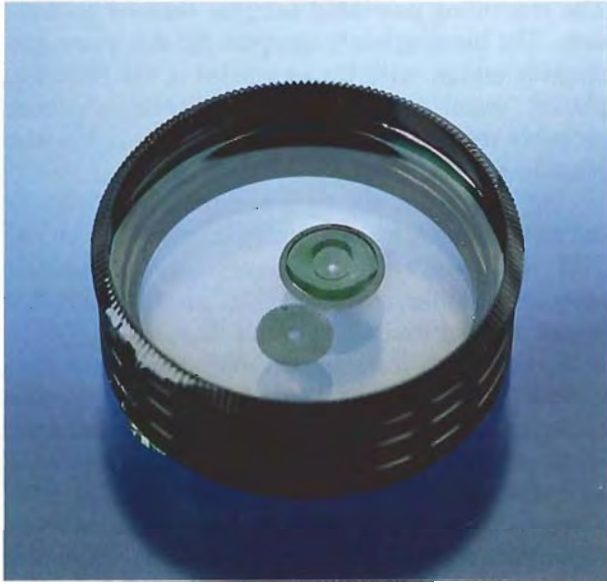


Figure 8. All of the bleached/polymer-impregnated samples in the original study floated in the 3.32 S.G. liquid. However, the authors have since examined three pieces of jadeite known to have been polymer impregnated that did not float in methylene iodide. Photo by Robert Weldon.

(Liddicoat, 1987). This was the case for 17 of our samples, with 3.44 the highest S.G. recorded.

However, some untreated, natural jadeite jades may be considerably lighter due to an admixture of amphiboles (Wu, 1991a) or feldspars (C. Fryer, pers. comm., 1992). Because we were aware of this problem, we specifically chose five low-S.G. pieces for our sample. Among the others in the sample of untreated stones, we identified an additional four with an S.G. below 3.32, and one that was only 3.15.

The specific gravities of the jadeites that had been bleached only ranged from 3.22 to 3.25. All of the samples in our test group that had been bleached and polymer impregnated floated in the 3.32 liquid (figure 8); they ranged in S.G. from 3.04 to 3.27. This lower S.G. range is attributed to the replacement of iron compounds by relatively lighter organic polymers.

After we completed our testing of the study samples, however, we examined three pieces of jadeite submitted to the GIA Gem Trade Laboratory and proved to have been polymer impregnated that did sink very slowly in the 3.32 S.G. liquid. We believe that a polymer different from that seen in the stones in our study sample (which came from a variety of

sources in Taiwan, Hong Kong, Japan, and the U.S.) was used (see "Infrared Spectroscopy" below).

Therefore, specific gravity provides a generally useful indication, but not proof, of "bleaching" treatment. In particular, a piece of jadeite that floats in 3.32 liquid (methylene iodide) should be regarded with suspicion. Such a low S.G. indicates that you may have: (1) untreated jadeite with a greater-than-normal amount of other minerals (in which case you might try to determine by careful microscopic examination if the piece contains fibrous amphiboles or other minerals that would lower the S.G. significantly, although this is difficult at best); (2) bleached-only jadeite (not often seen in the trade); or (3) jadeite that has been bleached and polymer impregnated.

**Ultraviolet Luminescence.** Most natural, untreated jadeites are inert to ultraviolet radiation, as was the case with 16 of our 27 natural samples. Some fluoresced a faint to moderate yellow in white areas when exposed to long-wave U.V. radiation, with a weaker (or no) reaction to short-wave U.V. The greener areas were inert.

All of the bleached and polymer-impregnated jadeites we tested fluoresced to long-wave ultraviolet radiation and had a duller (or no) reaction to short-wave U.V.. They generally showed a faint to strong bluish white to yellowish green luminescence, which is sometimes better seen in the whitish areas of the sample. This luminescence is most likely due to the impregnation material.

Therefore, a bluish white to yellowish green luminescence to long-wave U.V. radiation provides a useful indication of treatment. However, the reaction is sometimes faint and can easily be missed. Experience also demonstrates that ultraviolet lamps from different manufacturers produce slightly different reactions, and different individuals tend to see different colors when the luminescence is weak. For these reasons, this identification criterion alone cannot be considered conclusive.

As a footnote to this section on gemological testing, we learned that a less orthodox test is being used by some dealers. Larger pieces—such as bangles or small statues—of natural, untreated jadeite have a clear ring when tapped with a coin or like object. It has been reported that similar pieces fashioned from "B jade" emit a duller, more muffled sound when the same procedure is followed. This observation has a basis in science: The polymer present in the structure of a piece will dampen the sound waves that nor-

mally go unattenuated in untreated jadeite jade. For this unusual test to be of any significant help, though, reference samples and/or a great deal of experience with the sound emitted by both treated and untreated jade is essential. At best, this test might provide an indication of treatment and of the need for testing by the more conventional procedures described in this article. Note that this "test" is not useful with smaller pieces such as cabochons, because the treated and untreated materials will not produce noticeably different sounds.

From the preceding paragraphs, it is clear that classic gemological testing—in particular specific gravity, luminescence, and microscopic examination—can be helpful in determining whether or not a piece of jadeite is "B jade." However, none of these tests, even combined, will provide an answer in all cases. Only when the thermal reaction tester produces abundant melted wax or plastic in several areas of a sample can the piece be identified as polymer impregnated; this is not likely for most of the higher-quality treated jades that are of the greatest concern to the trade. Therefore, we proceeded to seek a method of identification with a higher degree of reliability.

#### ADVANCED TESTING

**Energy-Dispersive X-Ray Fluorescence (EDXRF) Chemical Analysis.** Because iron compounds are removed in the bleaching process, we used an analytical procedure optimized to detect iron to ascertain if the bulk iron concentration of treated samples was significantly lower than that of their untreated counterparts. We found no systematic difference in chemistry between bleached/polymer-impregnated and untreated jade. Even the two halves of the same sample, one treated and the other untreated, did not show meaningful variations. We believe that our results reflect the inhomogeneous distribution of iron in jadeite, with some of the iron dispersed in the crystal lattice (a partial cause of the green coloration in some jades), and only a portion of the brownish compounds in the cracks being close enough to the surface to be detected by EDXRF.

**Infrared Spectroscopy. Untreated Jadeite.** As expected, the infrared spectra of the untreated jadeite samples showed some variability, which reflects the variation in mineral composition that is typical of this rock. Most of the jadeite samples tested were opaque from 400 to about 2300  $\text{cm}^{-1}$ . They all showed

a broad, asymmetric absorption band centered roughly between 3400 and 3550  $\text{cm}^{-1}$  (figure 9a and b, black spectra). This band may be fairly smooth in shape, or it may show a number of narrow accessory peaks, for example, at 3580 or 3725  $\text{cm}^{-1}$  (figure 9b, black spectrum). In eight of our 18 samples, we found two moderately sharp bands at 4320 and 4250  $\text{cm}^{-1}$ , which were accompanied by an absorption at 3725  $\text{cm}^{-1}$  (again see figure 9b, black spectrum). In the mid-infrared, almost all samples showed absorption at about 5230  $\text{cm}^{-1}$  (figure 9c and d, black spectra), and six of them showed a sharp band at approximately 7295  $\text{cm}^{-1}$ .

All of our untreated samples showed two sharp bands at approximately 2920 and 2850  $\text{cm}^{-1}$ , accompanied by less intense, sharp peaks at approximately 4320 and 4250  $\text{cm}^{-1}$  (which were difficult to see in some of the spectra, e.g., figure 9a). The intensity of this series of bands varied widely from sample to sample, from extremely weak to—at 2920  $\text{cm}^{-1}$ —a peak height approximately one-quarter that of the 3400–3550  $\text{cm}^{-1}$  broad band. This spectrum is due to residues of wax used after polishing, as can be seen by comparing these bands with the spectrum of a typical wax used on jadeite (figure 10). It should be noted that although all of these samples were presented to us as not having been treated, virtually all such material—rough as well as polished—is waxed before it enters the market.

*Bleached-Only Jadeite.* All four jadeites that had only been bleached showed accessory shoulders or peaks at 3695 and 3620  $\text{cm}^{-1}$  on the 3500  $\text{cm}^{-1}$  broad band. We observed both of these peaks in the spectra of the untreated jadeites we examined and believe, therefore, that they are unrelated to the bleaching.

*Bleached and Polymer-Impregnated Jadeite.* The infrared spectra of the two samples that had been bleached and wax impregnated showed little difference from the spectra of the bleached samples, only that the bands at 2920 and 2850  $\text{cm}^{-1}$ , which are due to wax, were very strong (again, see figure 10).

In addition to the features described for untreated and bleached jadeites, the other nine polymer-impregnated jadeites tested showed a strong absorption centered around 2900  $\text{cm}^{-1}$  (again, see figure 9 a and b, green spectra). This absorption is composed of three sharp peaks at approximately 2965, 2930, and 2875  $\text{cm}^{-1}$ . There is also a weaker, companion feature at about 3035  $\text{cm}^{-1}$ .

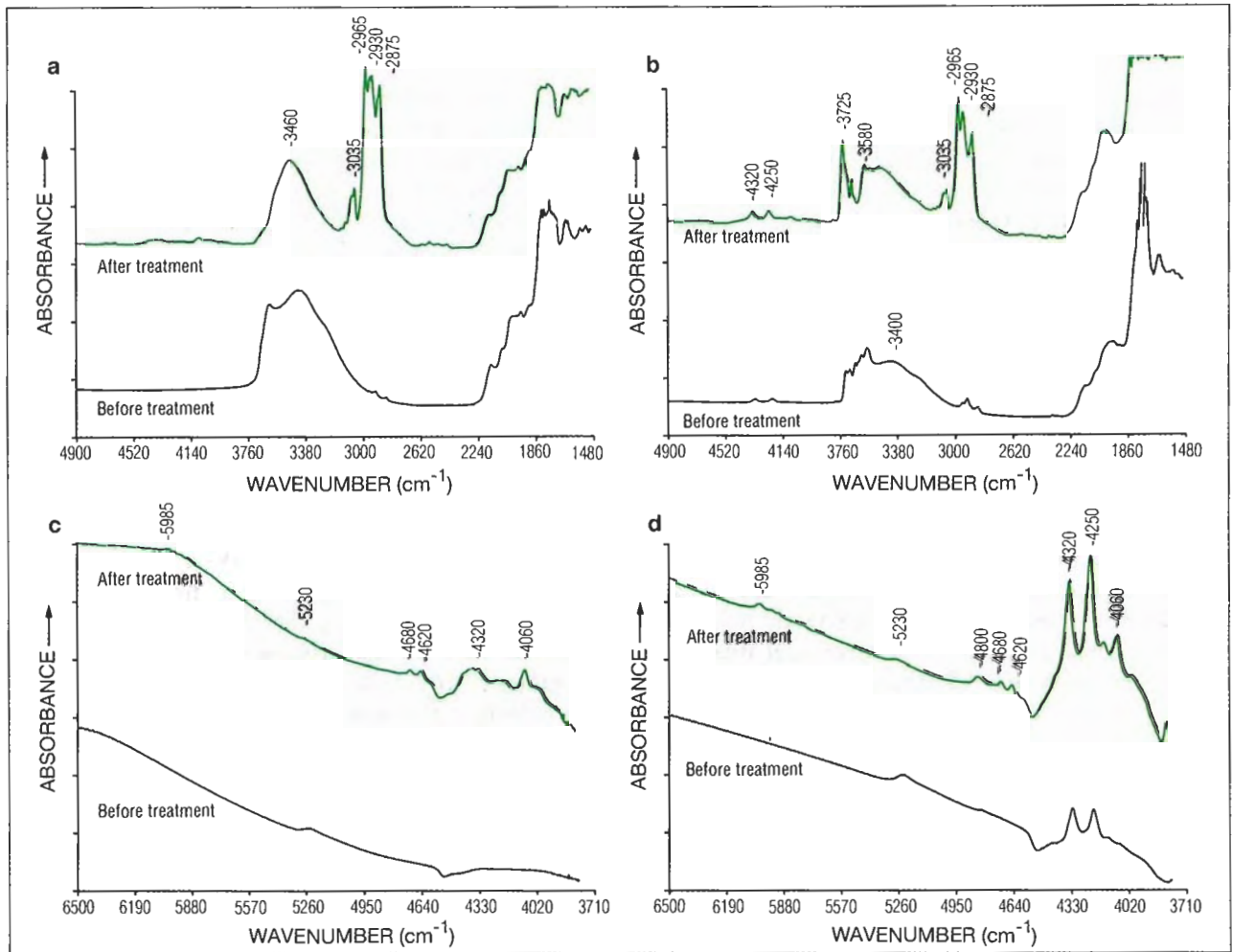


Figure 9. Shown here are the mid-infrared (a and b) and near-infrared (c and d) absorption spectra of two jadeite samples before (black) and after (green) bleaching and impregnation with a polymer. The strong absorption at about 2900  $\text{cm}^{-1}$  in the mid-infrared and a series of sharp bands in the near-infrared regions of the treated specimens provide proof of polymer impregnation.

In the near-infrared, weak but sharp additional bands are seen at approximately 4060, 4620, 4680, and 5985  $\text{cm}^{-1}$ , the last one with some structure on its low-energy side (figure 9c and d, green spectra). These features are identical to those described in 1989 by Hurwit.

The pattern of infrared absorptions observed in these nine impregnated jadeites is representative of those measured for organic polymers. This spectrum is remarkably similar to that of Opticon (figure 11), a polymer commonly used in the fracture filling of emeralds and suitable for that purpose in a range of other gems (Kammerling et al., 1991). Therefore, we believe that Opticon or an Opticon-like polymer is probably used most commonly to impregnate bleached jade. The broad absorption around 3500  $\text{cm}^{-1}$  is due primarily to jadeite.

We recently detected a new type of infrared spectrum in two jadeite samples (figure 12) that were not part of our study sample. These samples cannot be distinguished from other types of "B jade" on the basis of their appearance alone (figure 13). Their spectra showed a number of absorptions between 2900 and 3100  $\text{cm}^{-1}$ , with apparent maxima at approximately 2940, 3025, 3060, and 3080  $\text{cm}^{-1}$ , and two broader bands at about 3440 and 3530  $\text{cm}^{-1}$ . This pattern corresponds exactly to the spectrum between 2800 and 3100  $\text{cm}^{-1}$  of a piece of polymer given to us as one of the possible impregnation materials (again see figure 12). The best match (but not a perfect match) found in the Nicolet computer library of infrared spectra was for a family of phthalates (poly-diallyl- and diethyl-phthalates). The refractive index of this polymer is approximately 1.57, its specific gravity is about

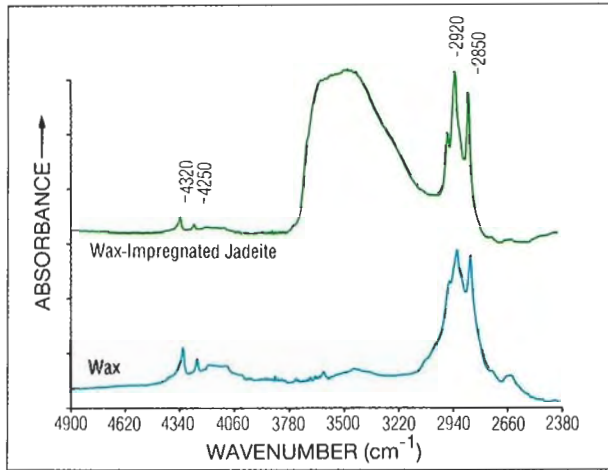


Figure 10. The mid-infrared absorption spectrum of the type of wax (bottom) commonly used to improve the luster of jadeite pieces after they are polished was seen in jadeites examined for this study that had been bleached and wax impregnated (top). In jadeites that have not been polymer impregnated, the key features are usually very weak (e.g., figure 9a and b, black spectra).

1.20, and it luminesces a weak bluish white to long-wave ultraviolet radiation, with a weaker reaction to short-wave U.V. The two stones we studied sank very slowly in the 3.32 S.G. liquid. They luminesced a faint yellowish green to long-wave U.V. radiation and were inert to short-wave U.V.

Figure 11. These mid-infrared spectra of a typical bleached/polymer impregnated jade (middle), liquid Opticon (top), and solid Opticon (bottom) suggest that Opticon or an Opticon-like resin is often the impregnation material used.

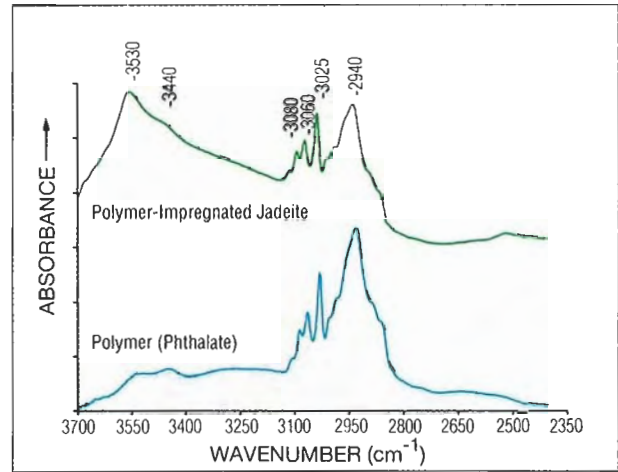
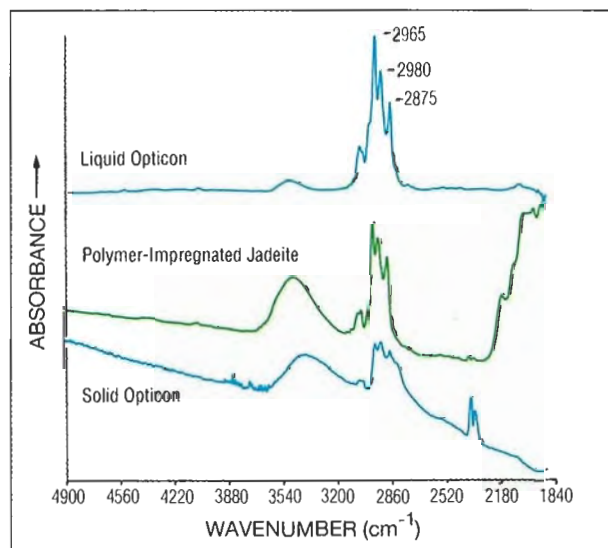


Figure 12. This mid-infrared spectrum of a new class of polymer-impregnated jadeite (top) shows absorptions significantly different from those seen in figure 9. These absorptions closely match those of a piece of polymer in the 3700–2800  $\text{cm}^{-1}$  range (bottom). The best match found for this polymer was a family of phthalates.

This study demonstrates that the presence of a strong absorption around 2900  $\text{cm}^{-1}$  and its accompanying features, which were seen in all of the test samples that had been bleached and impregnated, is conclusive proof of impregnation by a polymer.

The infrared spectra of the before-and-after specimens also indicate that the bleaching treatment results in a reduction of the overall absorption in the broad band centered at about 3400–3550  $\text{cm}^{-1}$ . Thus, we suspect that the absorption in that band might be due to some of the compounds removed by bleaching. However, because a pre-bleaching reference samples is needed to see that reduction in absorption, this technique cannot be used to detect bleaching per se for the routine testing of jadeite samples of unknown origin.

Characteristic absorptions of Opticon-like polymers can also be found in the near-infrared portion of the spectrum. This range is primarily useful when the stone is too thick to transmit in the mid-infrared, but still transmits in the near-infrared.

#### DURABILITY OF THE “BLEACHING” TREATMENT

Although most bleached/polymer-impregnated jades have not shown evidence of any change in appearance, durability problems have been reported with the “bleaching” treatment (Wu, 1989). In particular, after as short a period as six months to as long as a few years, pieces that had been bleached by boiling in





Figure 13. The use of a polymer other than one like Opticon was not evident in the visual appearance of these pieces. The spectrum shown at the top of figure 12 was taken from the carved Buddha; the other jadeites were all found to have been treated with a polymer that had a close spectral match to Opticon. Photo by Shane F. McClure.

acid have been known to exude some yellow residues of the acid treatment (C. J. Ko, pers. comm., 1990). Sometimes, in the course of normal wear, the treated jadeite will turn dark and its color will look gray-er (F. Ho, pers. comm. to P. Yurkiewicz, 1991). Because most such problems are evident only after relatively long periods of time, we did not attempt to document them experimentally for this study. Note, however, that any polymer or polymer-treated product is likely to be damaged by exposure to high heat, such as that produced by a jeweler's torch. Because it appears that an Opticon-like polymer has been used in many instances, the same cautions regarding care in cleaning, setting, or repairing other Opticon-treated stones should be exercised (see, e.g., Kammerling et al., 1991).

#### ATTEMPT TO MASK THE "BLEACHING" TREATMENT

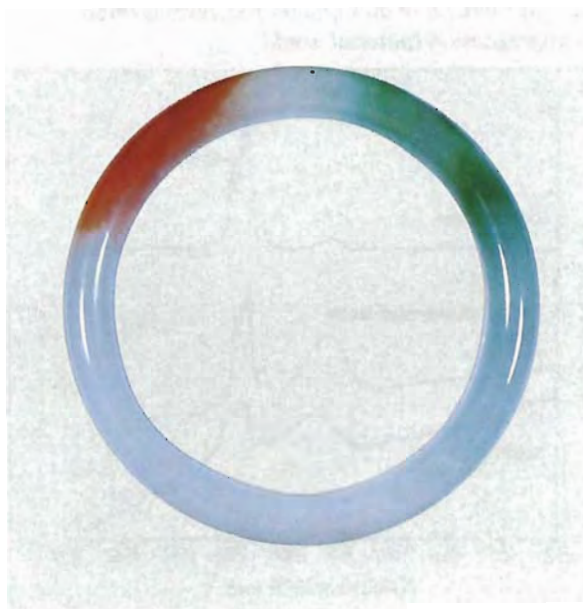
Because the purpose of the "bleaching" is to remove brown stains, most of the material that has been

bleached and polymer impregnated does not show such stains. As a consequence, it is often assumed that the presence of brown stains on a piece of jadeite is proof that it has not been treated. However, one of the authors (S-TTW) recently examined a jadeite bangle that had been bleached, partly stained reddish brown, and then impregnated with a polymer (figure 14). Therefore, jadeite pieces that show brown staining cannot be assumed to be untreated.

#### CONCLUSION

Classic gemological examination is useful to identify jadeite that may have undergone bleaching and subsequent polymer impregnation. In particular, pieces that show a specific gravity below 3.32, a reaction to the thermal reaction tester, and a bluish white to yellowish green luminescence to long-wave ultraviolet radiation are likely to have been treated in this fashion. The only definitive test, however, is infrared spectroscopy: The presence of a very intense group of peaks around  $2900\text{ cm}^{-1}$  and accompanying features in the mid- and near-infrared regions is characteristic of polymer impregnation. We know of three different

Figure 14. This jadeite bangle was bleached, partly dyed brown, and later impregnated with a polymer. Therefore, the presence of brown stains is not necessarily an indication that the piece is not "B jade." Photo by S.-T.T. Wu.



types of polymers with slightly different spectra that are being used at this time: one is wax, another appears to be a type of phthalate, and the most common observed thus far has characteristics similar to Opticon.

In recent years, impregnation processes have been used on a variety of gem materials to enhance apparent clarity. The most prominent are diamond (Koivula et al., 1989), emerald (Kammerling et al., 1991), and now jade. The purpose of such treatments is to match the index of refraction of the impregnation material to that of the gem to be enhanced, thereby minimizing the visibility of fractures. Diamond is the most difficult material to treat in this fashion, because potential filling substances with an index of refraction of 2.4 are not plentiful. In contrast, many polymers have indices of refraction in the 1.55–1.65 range, close to the indices of beryl or jadeite.

The case of “bleached” jade also illustrates the limitations of classic gemological testing when faced with relatively sophisticated new treatments. The definitive identification of polymer impregnation, as with a growing number of identification challenges (e.g., separation of inclusion-free samples of natural from synthetic ruby [Muhlmeister and Devouard, 1992] or natural from flux synthetic spinel [Muhlmeister and Fritsch, in preparation]), often requires advanced instrumentation to obtain conclusive results. These techniques are too expensive, or require too much technical expertise, to be practical for use in jewelry stores. In this sense, we have firmly entered a new era for gemology, where detection of sophisticated treatments or synthetics in many cases will require the use of expensive and technically sophisticated laboratory equipment that has no alternative in classic gemological testing.

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# UNSTABLE RADIATION-INDUCED YELLOW-GREEN COLOR IN GROSSULAR GARNET

By Kurt Nassau, George R. Rossman, and Darwin L. Wood

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*Although conventional wisdom has been that irradiation will not alter the color of garnets, exposure of some colorless to pale-hued African grossulars to either  $^{60}\text{Co}$  or  $^{137}\text{Cs}$  gamma rays turns them light yellow-green. The resulting color is unstable and fades within hours to days in sunlight, and within weeks in the dark. The spectra of the radiation-enhanced garnets differ from those of similar-appearing naturally colored grossulars. In the dark, the irradiation-related absorption features undergo two stages of fading: an initial period of relatively rapid fading, followed by a longer period of slow fading. In daylight, a single rate of even faster fading is observed.*

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The colors of various gemstones can be changed by irradiation procedures. Some irradiation-enhanced materials, such as blue topaz and certain colored diamonds, are significant items of commerce. Other gems, including garnets, are considered to be unaffected by irradiation. We now report that some pre-

dominantly colorless to pale yellow-green grossular specimens from various sources in East Africa turn light yellow-green on exposure to gamma rays. The colors produced in these garnets by irradiation are unstable, fading after some hours to days in daylight, or after days to weeks in the dark.

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### MATERIALS AND METHODS

In our initial survey, more than 100 colorless to pale-colored grossular specimens were exposed to 20 Mrads (million rads) of cobalt-60 ( $^{60}\text{Co}$ ) gamma rays to determine if radiation would produce a significant change in color. The samples consisted of both (1) crystal fragments and rough pebbles 3-10 mm in longest dimension, and (2) faceted stones 3-10 ct in weight. Canadian, African, and unknown sources were represented in the samples, which ranged from colorless to pale shades of yellow, brown, green, and orange. Samples from only a few localities, all in Africa (reportedly Kenya, Tanzania, and Zimbabwe), were changed from predominantly colorless to pale yellow-green to a light yellow-green (as determined using ISCC-NBS color terminology; Kelly and Judd, 1976).

Subsequently, we chose an additional 33 radiation-sensitive grossular garnets that were reportedly from the Lelatema Hills, Tanzania, for detailed examination. These samples were originally colorless to pale yellow-green pebbles as large as 1 cm in diameter. They were selected from lots of rough provided by a number of dealers in 1986 and 1987. The same lots contained other pale yellow-green to light yellow-green, as well as pale orange-yellow to moderate orange, garnets that did not change color on irradiation. Twelve of the 33 samples were irradiated with gamma rays from cesium-137 ( $^{137}\text{Cs}$ , at 7 to 130 Mrads) and the rest with gamma rays from  $^{60}\text{Co}$  (20 Mrads).

All radiation-sensitive samples changed to light yellow-green, and all showed essentially the same optical absorption spectrum, regardless of the type of radiation. However, all of these stones faded back to their original colors after some hours to days in daylight. In fact, fading occurred even in the dark, but required several days to weeks.

A search of the literature and inquiries with gemologists turned up no previous instances of radiation-induced change in the colors of any types of garnets, and only one report of heat-induced change in color in some rhodolite garnets (Nassau, 1984). Therefore, the radiation-induced change in color we observed in these grossulars appears to represent the first challenge to the generally accepted view that all members of the garnet group are color stable. To learn more about this new phenomenon in grossular, we proceeded to conduct additional experiments to establish the spectroscopic and fading properties of these stones.

### COLOR, SPECTROSCOPY, AND IRRADIATION BEHAVIOR

Detailed spectroscopic examinations were performed on a 12-mm-long, 1.52-gram yellowish gray specimen from Kenya (M40868, Royal Ontario Museum [ROM], Toronto, Ontario, Canada; figure 1, left) that had one of the greatest changes in color on irradiation (as represented by figure 1, right). Additional spectra were obtained from four radiation-sensitive grossulars (two colorless, one greenish white, and one yellowish white) from the Lelatema Hills. We recorded the ultraviolet, visible, and near-infrared spectra of these samples before and after irradiation, as well as the spectra of four of the naturally colored pale yellow-green and light yellow-green grossulars that did not respond to irradiation.

Prior to irradiation, the spectra of the colorless gar-



Figure 1. The most extreme change in color produced by this irradiation experiment was observed in these grossular specimens from Africa. Left: a 12-mm-long, 1.52-gram crystal (ROM specimen M40868) in its naturally yellowish gray state. Right: a similar specimen after exposure to 20 Mrads of  $^{60}\text{Co}$  radiation.

nets showed essentially no absorption in the visible region. The light-colored garnets that did not respond to irradiation showed a weak feature due to vanadium ( $\text{V}^{3+}$ ) at 610 nm (figure 2). This feature is also found, at greater intensity, in the spectra of intense green vanadium grossulars (tsavorites) from the Tsavo region of Kenya and Tanzania (Schmetzer and Ottemann, 1979). In addition, three weak but sharp features at 409, 422, and 431 nm were superimposed on the poorly resolved 425-nm vanadium band of the unresponsive samples. These features are from manganese ( $\text{Mn}^{2+}$ ) substituting for calcium, and they correspond to the main  $\text{Mn}^{2+}$  features observed in spessartine garnet (Moore and White, 1972). The vanadium and manganese features were also present (but at much lower intensity) in the spectra of the weakly colored radiation-sensitive garnets. The spectra of all these garnets also showed narrow bands near 1400 nm attributed to  $\text{OH}^-$  groups in the crystal structure, which are commonly found in grossulars (Rossman and Aines, 1991). This particular grouping of narrow bands has only been observed in grossular garnets from East Africa.

After irradiation, the four garnets that changed to a light yellow-green exhibited features not found in the naturally colored light yellow-green samples (again, see figure 2). The radiation-induced color derives from a steeply rising absorption in the blue region of the spectrum that produces a yellow color, and a trans-

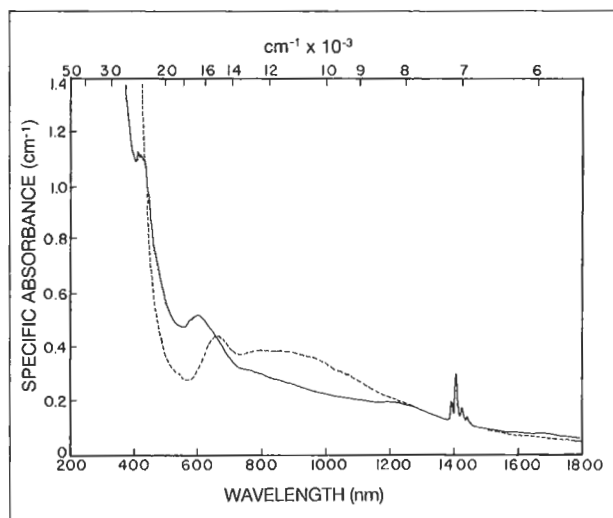


Figure 2. Significant differences can be seen in these spectra of two yellow-green grossulars, one of stable color and one that changed color on irradiation (plotted for 0.433 cm thickness). Solid line: a naturally pale yellow-green garnet with stable color. Dashed line: sample M40868 (ROM) from Kenya immediately after 20 Mrads of  $^{60}\text{Co}$  gamma ray irradiation. The spectra of  $^{137}\text{Cs}$  gamma-ray irradiated grossulars from the Lelatema Hills, Tanzania, are essentially identical to that shown by sample M40868.

mission window near 560 nm that adds the green component. We do not know the detailed origins of the absorption features at 654 and 926 nm that define the transmission window in the spectra of the garnets that responded to irradiation, but we recognize that they are distinctly different from those of tsavorite. Although several manganese-containing minerals owe their radiation-induced colors to oxidation of  $\text{Mn}^{2+}$  to  $\text{Mn}^{3+}$ , the spectra of our irradiated grossulars differ from the spectra of synthetic garnets prepared with known amounts of  $\text{Mn}^{3+}$  in the Al site (Frentrup and Langer, 1981).

The Lelatema Hills garnets occur in the crystalline limestones and gneisses of the Mozambique Belt (Key and Hill, 1989). The electron microprobe analysis of a representative colorless radiation-sensitive Lelatema grossular (table 1) indicates that its composition is close to pure end-member grossular. X-ray fluorescence (XRF) analyses revealed only minor differences between a colorless sample that became light yellow-green on irradiation and a naturally light yellow-green sample that did not change on irradiation. Unlike the radiation-sensitive colorless sample, the naturally light yellow-green garnet had a trace of

chromium, as well as twice as much Mn and 1.5 times as much Ti and Fe.

Schmetzer and Bank (1982) described a pale yellow-green grossular from this same locality. The chemical composition and optical spectrum of their garnet were similar to those of our specimens, as represented by the naturally light yellow-green sample in figure 2.

### FADING DYNAMICS

After irradiation, the spectrum of the initially yellowish gray ROM grossular from Kenya was measured at various times as the radiation-induced features (and related color) decayed in the dark. The same stone was then re-irradiated and its spectrum was again measured as it decayed in daylight while taped to an east-facing window in Murray Hill, New Jersey, in April. The dynamics of fading were then analyzed on the basis of the intensity of three features of the absorption spectra, specifically, changes in the absorption maxima at 926 nm and 654 nm and in the absorption edge at 454 nm.

When the results were plotted as a function of time, it was evident that, in darkness, the radiation-related absorption features first faded relatively quickly (short-term decay), but then graded into a longer period of slower fading (long-term decay; figure 3). Because the points lie fairly close to straight lines in these plots, it is possible to reduce the results to a mathematical formula from which can be determined the rates at which each of the radiation-induced

**TABLE 1.** Chemical composition of a representative nearly colorless grossular from the Lelatema Hills, Tanzania, that turns yellow-green on irradiation.<sup>a</sup>

Oxide	Weight %	Formula proportion
NaO	0.00	0.00
MgO	0.36	0.04
Al <sub>2</sub> O <sub>3</sub>	22.23	1.97
SiO <sub>2</sub>	39.76	2.99
CaO	36.75	2.96
TiO <sub>2</sub>	0.42	0.02
V <sub>2</sub> O <sub>3</sub>	0.07	<0.01
Cr <sub>2</sub> O <sub>3</sub>	0.08	<0.01
MnO	0.20	0.01
Fe <sub>2</sub> O <sub>3</sub>	0.13	0.01
Total	100.00	

<sup>a</sup>The formula proportions are based on 12 oxygens. Electron microprobe analysis conditions: 15 keV, 50 nA. David R. Bell (California Institute of Technology, Pasadena, California) analyst.

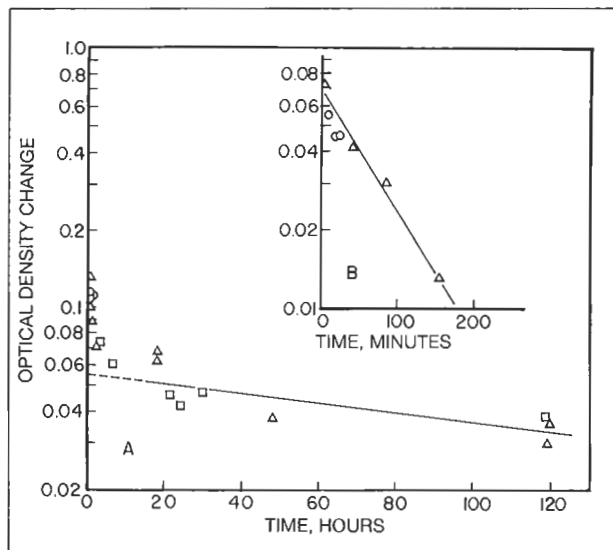


Figure 3. Experimentation revealed the dynamics of fading of the irradiation-induced color for the ROM (M40868) grossular specimen in the dark. Part A: the slow component of fading in the dark, with a scale of hours along the horizontal axis. Part B: the fast initial decay in the dark (with a scale of minutes for the horizontal axis), an expansion of the first portion of curve A which lies above the slow component straight line. The vertical axis is the change in absorbance at 926 nm during fading. The three different symbols are for three cycles of irradiation and fading; the consistency of the results throughout these three cycles demonstrates the reproducibility of this experiment.

absorption features decayed as the color faded. The time in which each related absorption feature decayed to half its intensity as the color faded in darkness was 172 hours for the slow component, and 74 minutes for the fast component. For each of the radiation-induced absorption features measured, approx-

imately 58% disappeared with the fast component and 42% with the slow component. In daylight, the rate of fading was considerably faster and involved a single component with a half-intensity-loss time of 12.6 minutes.

The values for the fading constants were approximately the same for the three wavelengths measured, which suggests that only one color center is involved in the radiation-induced color. Although the nature of the color center has not been determined, it is likely that it is present only at very low concentrations. After fading, either in the dark or in daylight, the intensity of absorption was essentially the same as before irradiation, so the coloration due to irradiation was completely reversed. Visual inspection indicated that the same reversibility of the radiation-induced coloring applied for all samples, but with different saturation and decay times characteristic of each particular crystal.

## CONCLUSION

It has been determined that some garnets, specifically some colorless to pale-hued garnets from various localities in East Africa, will turn light yellow-green when exposed to as little as 7 Mrads of gamma rays. Such stones, however, will fade to their original colors within hours to days in daylight and within two months in the dark.

Because they fade so rapidly, radiation-colored grossular garnets should not normally be encountered in commerce, since they would have to be offered for sale immediately after irradiation. Any confusion with similar naturally colored garnets could easily be eliminated by exposing the questionable material to strong light (e.g., sunlight or a 100-watt lamp placed about 25 cm from the sample) for a few hours, or merely by holding the stones in the dark for two to three weeks.

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# GEM TRADE LAB NOTES

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## ALEXANDRITE

Since a critical function of the GIA Gem Trade Laboratory is to detect and disclose treatments, we are diligent when examining all gemstones, even those not usually known to be subject to enhancement. Generally, one associates certain types of treatments with specific gem varieties, such as "oiling" or fracture filling with emeralds, heat treatment with corundum, and impregnation with porous gem materials such as turquoise. However, cavity filling—with a glass or resin—may be seen on any material.

The East Coast lab recently noted, for the first time, a filled cavity on the pavilion of a natural alexandrite. The stone, which was mounted in a ring, measured approximately  $9.20 \times 5.30 \times 3.68$  mm.

The filling in the large negative crystal that broke the pavilion surface was easily seen when the stone was viewed through the table (figure 1). A gas bubble was also evident in the filling material. Although the pavilion was not completely exposed (due to the mounting), the cavity was accessible. Therefore, we examined the stone with the microscope at  $10\times$  magnification while the hot tip of a thermal reaction tester (TRT) was carefully brought close to the filled area. In contrast to the glass-like material used to fill cavities in corundum, this material softened slightly and produced a puff of smoke when the TRT point came into contact, which suggests that some type of solid polymer was used. *TM*



Figure 1. Note the gas bubble in the filled cavity (as seen through the table) on the pavilion of this natural alexandrite. Magnified  $19\times$ .

## DIAMOND

### Fracture Filling Update

Since we first learned of the treatment whereby fractures or other voids in diamonds are filled with a material of similar refractive index to improve apparent clarity (see the article by Koivula et al., *Gems & Gemology*, Summer 1989, pp. 68–83), we have noticed several variations in the visual appearance of the filling material, especially the characteristic "flash effect" (e.g., *Gems & Gemology*, Summer 1991, p. 109). We know that some of these variations are due to differences in the original formula, but others probably represent different formulas used by competing fracture-filling services.

Staff members at the East Coast lab identified the presence of a filling

material in a light pink 1.22-ct pear-shaped diamond. Unlike the medium blue flash effect commonly associated with filled diamonds, the vivid blue flash color seen in this stone resembled a dark, "navy" blue ink splotch (figure 2). This "flash" also changed to orange as the stone was tilted. An X-radiograph verified that the filling compound in this second diamond contained elements, possibly lead, with high atomic densities. The filling mate-

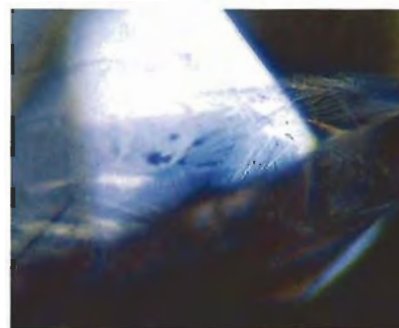


Figure 2. This filled fracture in a light pink 1.22-ct diamond showed a blue flash color that is darker and more vivid than the flash-effect color typically seen in filled diamonds. Magnified  $32\times$ .

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

*Gems & Gemology*, Vol. 28, No. 3, pp. 192–197

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Figure 3. A large fracture became noticeable on the table and pavilion of the "filled" 6.90-ct diamond in this ring after it had been inadvertently left in an ultrasonic cleaner for two hours. In some areas, the filling material had been removed; in others, it had shattered within the fracture.

rial in fractures and laser holes appears as less exposed gray areas on X-radiographs (again, see the article by Koivula et al.). DH

#### More on Damage to Fracture-Filled Diamonds: In Cutting and Cleaning

A prominent New York diamond cutter shared with the New York laboratory staff a surprising experience he recently had while fashioning an approximately 10-ct rough diamond. When the rough fractured on the wheel early in the cutting stage, he decided to submit the stone for fracture filling. The filling improved the stone's appearance, as expected, and he proceeded to finish it—producing a cut-corner rectangular modified brilliant. However, when he examined the finished stone, he saw that some of the filler had flowed out of the fractures, thus requiring a second filling treatment. This was apparently successful, but then the cutter decided to rework the diamond into a near-standard emerald cut. Again,

some of the filling was removed in the cutting process, and the finished 6.90-ct diamond was submitted for a third filling treatment. The newly filled diamond was then set in a lady's yellow metal solitaire ring. Subsequently, the ring was placed in an ultrasonic cleaner with household dishwashing detergent—and inadvertently left there for approximately two hours. When the ring was removed and the diamond examined, a large filled fracture breaking the table facet was very noticeable (figure 3).

Magnification revealed a number of alteration features. In surface reflected light, we noted that some of the filling material had been removed from the break near the surface on both the table and the pavilion. In darkfield illumination, the filling material itself appeared to have shattered, exhibiting a complex network of fractures. It was this system of breaks within the fill-

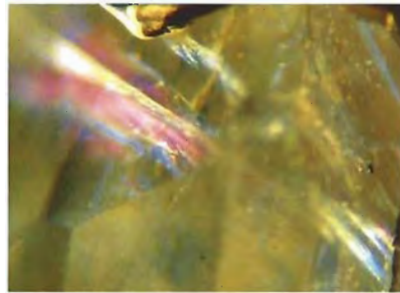


Figure 4. A flash effect can still be seen near the damaged filling in the diamond shown in figure 3. Magnified 36 $\times$ .

ing material that made the large fracture so noticeable to the unaided eye. Darkfield illumination also revealed some purplish pink and greenish blue flash effects (figure 4).

Ample warnings have appeared in the literature concerning the possibility of damaging the filling material in fracture-filled diamonds through various jewelry repair procedures. This is our first experience with durability problems during cutting. In addition, the treatment was generally believed to

hold up well to all but the most severe of cleaning procedures. As this account shows, however, prolonged use of an ultrasonic unit can damage the filling material, possibly making the original fractures even more obvious than before the treatment was undertaken.

GRC

#### Unusual Features in Diamond

The East Coast lab recently graded a 2.04-ct fancy light pink brilliant-cut pear shape that had eye-visible ribbon-like etch features (figure 5). On first examination, these features appeared to be laser drill holes that had gone astray. With magnification, however, we determined that the "entrance" points at the surface of the stone were square or rectangular in shape (figure 6), not round as laser drill holes would be. This shape proved that these cavities were inherent to the stone. Unlike the etch features reported in this section in the Fall 1991 issue (and the focus of a comment in the Spring 1992 "Letters" section), the twisted nature of these voids seemed to defy crystallographic orientation, since they did not follow straight paths.

Although the cause of these unusual features is open to speculation, we determined the clarity wholly on the basis of standard grading criteria. The large and numerous cavities, as well as their many reflections, set the grade on this stone. The fact that the voids were easily visible with the unaided eye contributed to the I<sub>2</sub> grade.

Ed Schwartz

#### Repaired JADEITE

A pair of ear clips set with an opaque green material were submitted to the East Coast laboratory for identification. Although the material resembled jade (figure 7), the jewelry was constructed in such a way that we could not conduct certain basic gemological tests, such as refractive index and specific gravity. However, a 437-nm absorption line visible in the handheld spectroscope proved them to be jadeite jade. Furthermore, the negative color-filter





Figure 5. At first glance, there appear to be numerous laser drill holes in this 2.04-ct fancy light pink diamond. Magnified 10×.

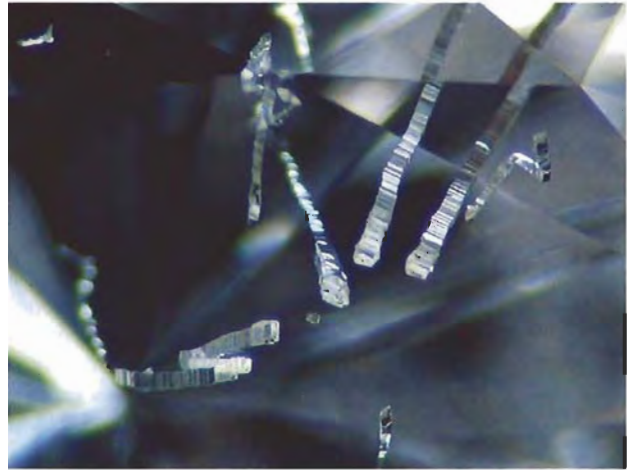


Figure 6. At 45× magnification, the features seen in figure 5 are revealed to be square or rectangular, which proves they are natural.

reaction and lack of a dye “band” in the visible spectrum proved these to be natural-color jadeite. The distinctive color, luster, and—on closer examination—coarse-grained nature of this material were reminiscent of jadeite from Guatemala (for more information,



Figure 8. The cement holding the repaired area shown in figure 7 fluoresces pale blue to short-wave U.V. radiation.



Figure 7. Note the repaired area at the top of the jadeite hololith in the ear clip on the left of this photo. Each jadeite hololith is approximately 35 mm in diameter.

see the article on jadeite from Guatemala by Hargett, *Gems & Gemology*, Summer 1990, pp. 134–141). These 35-mm hololiths are quite similar in appearance to ancient carved Mayan ear flares.

Once a material has been conclusively identified, it is still prudent to try other tests to either support the conclusion or uncover something that might be amiss. Sure enough, short-wave ultraviolet radiation revealed—

by the pale blue fluorescence of the cement (figure 8)—that one of the jadeite pieces had been repaired with a nonjadeite material (it had no 437 line). Close examination of figure 7 shows how well this replacement component blends in. *Nicholas DeRe*

#### Cat’s-Eye OPAL from Brazil

The West Coast lab recently examined the 2.76-ct greenish yellow oval cabochon shown in figure 9. The owner reported that this material occurs in thin seams in northern Brazil.

The stone appeared to have refractive indices of 1.45 and 1.47. It fluoresced a dull yellow-green to long-wave ultraviolet radiation. The handheld spectroscope revealed a general absorption up to 530 nm and weak bands at 620 nm and 670 nm. Microscopic examination revealed a continuous series of very fine parallel fibers, some

of which appeared to be stained dark brown. Specific gravity was hydrostatically determined to be  $2.01 \pm 0.10$ . With the above gemological testing completed, it was still not possible to identify the material conclusively because of the anomalous R.I. readings. Therefore, we performed an X-ray powder diffraction analysis on the stone. The diffraction pattern showed the presence of cristobalite with an amorphous material in the background. This type of pattern is commonly obtained from opal. It is interesting to note that a stone with similar properties and an identical diffraction pattern was de-

Figure 9. Strangely enough, two refractive indices were seen in this 2.76-ct cat’s-eye opal.



cribed in the Spring 1983 Lab Notes section.

Gus Calderon and KH

## PEARLS

### Hollow Pearls

Pearls are submitted to the GIA Gem Trade Laboratory on a daily basis. The question usually asked by our clients is whether they are natural or cultured, which we determine by X-radiography. Typically, the X-ray of a solid natural pearl will show numerous concentric circles, or layers, of nacre. A cultured pearl with a shell-bead nucleus will show only the nacre added around the nucleus. However, X-rays sometimes reveal other details.

The East Coast laboratory recently received two pearl jewelry items—a baroque pearl pendant (measuring approximately 21 × 19 × 14 mm; figure 10) and a shark motif pin (about 77 mm long; figure 11)—in which X-radiography showed the pearls to be hollow as well as natural.

The X-radiograph of the pendant (figure 12) also revealed a composite

Figure 10. X-radiography proved that the natural baroque pearl in this pendant is hollow.



Figure 11. A hollow blister pearl was used to form the body of this 77-mm-long shark-motif pin.

filling material in the “hollow” of this natural baroque pearl. Such fillers are usually added to give weight, or to serve as anchorage for the metal post of a jewelry piece.

The X-radiograph of the “shark” (figure 13) revealed that it was actually a hollow natural blister pearl. Blister pearls are convex growths that appear on the inside surface of the mollusk shell. Usually the convex area is composed of nacre, and the base is the

Figure 12. This X-radiograph shows not only that the baroque pearl in figure 10 is hollow, but also that it has been filled with some sort of composite material to anchor the post.

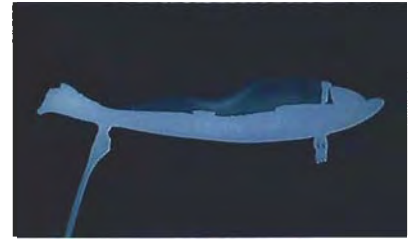


Figure 13. Although this X-radiograph shows the pearl in figure 12 to be a hollow natural blister, it could not be determined whether a shell base was attached.

mother-of-pearl shell. However, due to the metal backing, we could not determine from the X-radiograph if there was anything on the base of this blister pearl. *Nicholas DelRe*

### Hollow Pearl in an “Antique” Pendant

Staff members in the West Coast lab were intrigued by an unusual jewelry item that arrived for identification in a custom-fitted display case. As shown in figure 14, a large (approximately 24 × 18 × 15 mm) baroque pearl had been skillfully set in the grand style of the old Renaissance master goldsmiths to form the body of an owl. This *objet d'art* had its own supporting stand and, since it was also outfitted with a yellow metal bail, could even be worn as a pendant.

Despite the massive yellow metal mounting, we were able to X-ray and thus identify the baroque pearl as natural. The X-radiograph also showed that this pearl, like the ones in the previous entry, was hollow.

Since we could not find any hallmarks or other identifying characteristics that might provide evidence of provenance, either on the figure or in the display case, the origin of the piece remains a mystery. We would appreciate any comments from our readers that would help unravel its history.

*KH*

### Update on Treated Black Mabe Pearls

After reading our Lab Notes entries on the various enhancements in mabes



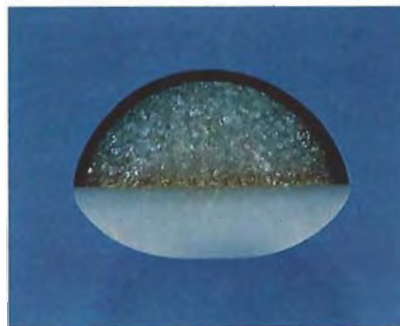
Figure 14. An X-radiograph also revealed that the natural baroque pearl used as the body of this "golden owl" objet d'art was hollow.

(assembled cultured blister pearls), several dealers confirmed that there was indeed a proliferation of such treatments. One dealer even sent a black mabe pearl that he had sawed in half to our West Coast lab. Figure 15 shows one half of the 13-mm round mabe pearl. Because the nacre top fluoresced a dull reddish orange to long-wave ultraviolet radiation, similar to the fluorescence of the treated black mabes reported in the Summer 1992 Lab Notes section (pp. 126–127), he suspected that it also had been treated.

We did not see any irregularities in the evenly colored, dark purplish brown nacre top either with the unaided eye or with magnification. The fluorescence to long-wave ultraviolet radiation was indeed dull reddish orange, unlike the reddish brown to red color usually seen in natural-color black pearls. However, there was no evidence of dye when a cotton swab soaked with the standard dilute (2%) nitric acid solution was applied to the nacre top. As can be seen in figure 15, this mabe pearl has three distinct components: a white mother-of-pearl base, a dark purplish brown nacre top (averaging

approximately 0.5 mm in thickness), and a dome-shaped core of an unusual material. In reflected light, the core showed a granular appearance; closer examination with the microscope revealed that it consisted of translucent white fragments embedded in a whitish mass. Also, a very sharp black demarcation line appeared at the border between the core material and the nacre top. We determined that the white fragments consisted of a car-

Figure 15. A client sawed this 13-mm dyed black mabe assembled cultured pearl in half to show its construction.



bonate, since they reacted strongly to a dilute (10%) hydrochloric acid solution. Exposed to the hot needle of the thermal reaction tester, the white mass started to liquefy and gave off the characteristic odor of an epoxy resin.

Chemical analysis of the nacre top by means of EDXRF showed, in addition to calcium, trace amounts of silver and small amounts of bromine. This is consistent with the chemical components determined for the treated mabe pearls discussed in the Summer 1992 Lab Notes. KH

### Dyed SAPPHIRE as a RUBY Imitation

Recently, the East Coast laboratory received for identification a multiple strand of 6- to 7-mm purplish red beads, which were represented to be natural rubies (figure 16). The client pointed out several similar-appearing necklaces in recent auction gallery catalogues, which were described as natural rubies.

The beads were a believable ruby color, but this color seemed unusually uniform for natural ruby and no dichroism was detected. They all appeared to have similar extensive internal fractures, which strongly suggested quench crackling. Routine tests confirmed that they were corundum, and a simple acetone swab test established that they had been dyed. When exposed to long-wave ultraviolet radiation, the beads showed a strong orange fluorescence distributed along the pervasive cracks. It seemed that these beads could be similar to the dyed natural corundum ruby imitations reported in ICA Laboratory Alert No. 50 and by Schmetzer et al. (*Gems & Gemology*, Summer 1992, pp. 112–115).

If the beads were actually dyed pale ruby, weak chromium lines should be observable in the handheld spectroscope. None could be detected, but a relatively strong iron line at 450 nm was seen, indicating that they might be sapphires.

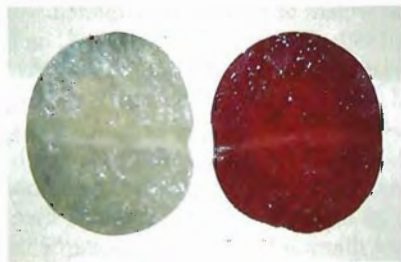
In the interest of further research, the client removed one bead from the necklace and permitted us to divide it



Figure 16. This multiple strand of 6- to 7-mm-diameter red beads was represented as natural ruby.

in half. Observation of the split bead showed that the red color was confined to the cracks penetrating the entire stone. The absorption spectrum of one half recorded with a U.V.-visible spectrophotometer confirmed the lack of chromium absorption, showing only a broad band centered at 560 nm and

Figure 17. The half bead on the left shows the true color of the starting material for one of the beads illustrated in figure 16; the half on the right shows the dyed color.



iron lines at approximately 450 nm and 380 nm. This spectrum and the color distribution are the same as those observed by Schmetzer et al.

Pale pink sapphire dyed to imitate ruby has been recorded before in the literature (e.g., *Gems & Gemology*, Spring 1971, p. 285), but the recent article by Schmetzer et al. implied that the material being dyed was some other color entirely. In an effort to determine the true underlying color of these beads, one of the halves was soaked in warm acetone for several hours. This treatment removed the dye from a shallow surface area, but dye remained in the deeper portions of the cracks, still hiding the true body color. Since acetone evaporates too rapidly for prolonged soaking, and because an organic dye was suspected, the half-bead was then soaked in warm nitric acid overnight. By morning, all red color had been removed, revealing a pale green sapphire (figure 17).

GRC and Ilene Reinitz

### Large Cat's-Eye ZIRCON

A client submitted to the East Coast laboratory a cat's-eye zircon that he claimed was the world's largest. The grayish green round cabochon weighed 125.47 ct and measured 26.05–26.75 mm in diameter by 15.00 mm deep. The "eye" of the stone was sharp, straight, and unbroken.

Because brown and green zircons are often radioactive, we decided to check this one with a Geiger counter (it arrived before the West Coast radiation-testing facility was in operation). The stone proved to be slightly radioactive, about one to two times background level.

Using a Beck handheld spectroscope, we observed extremely strong zircon absorption lines. The strength of these lines may be due to the longer light path through this larger stone.

DH

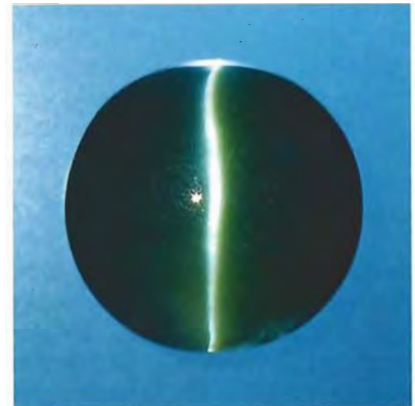


Figure 18. This cat's-eye zircon weighs 125.47 ct.

#### PHOTO CREDITS

The photos used in figures 1–4, 7, 8, 10–13, and 16–18 are by Nicholas DelRe. Figures 5 and 6 were supplied by Vincent Cracco. Maha Smith-DeMaggio provided figures 9 and 15. Figure 14 is by Shane McClure.



# GEM NEWS

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

## DIAMONDS

**New treatment plant at Alexander Bay.** The new Rietfontein South diamond-treatment plant began operation at Alexander Bay on the west coast of South Africa in early 1992. The plant, located some 30 km south of Alexander Bay, was designed to process as much as 300 tons of ore per hour. The plant includes primary and secondary crushing, screening, and scrubbing circuits, as well as an 80-ton-per-hour dense-media-separation operation. The plant runs on seawater pumped to an on-site reservoir. (*Mining Journal*, April 17, 1992, p. 279)

**Results of Canadian bulk sampling.** A 160-ton bulk ore sample, taken from the Point Lake kimberlite pipe in the Lac de Gras area of the Northwest Territories, Canada, has yielded 101 ct of diamonds, according to claim-holder BHP Minerals. Approximately 25% of the diamonds were gem quality, and a few of these were in the 1–2 ct range.

This past spring, the company completed an aerial geophysical survey. The results confirm the locations of several possible kimberlite pipes. These will be evaluated for the purpose of a possible bulk sampling program in the near future. (*Mining Journal*, July 3, 1992, p. 4)

**British Crown Jewels to move in 1994.** The Historic Royal Palace Agency, which manages the Crown Jewels for the British Department of Environment, has approved plans to relocate the jewels from their present location—15 m (50 ft.) below ground in the Tower of London—to a larger room on the ground floor by 1994. This move is designed to make these state treasures more accessible to the public. Among the exceptional gems that will be affected are the Cullinan I and the Koh-i-Noor diamonds. (*Diamond Intelligence Briefs*, February 20, 1992, p. 860)

**India plans increased mining.** Although in 1991 India imported an estimated 60 million carats of rough and fashioned 75% by weight of the world's output of gem and near-gem diamonds, it remains a minor player in terms of diamond mining. Only about 18,000 carats per year are recovered from a single mine, Majhgawan, located at Panna in Madhya Pradesh State.

That, however, could change if India's National Mineral Development Corporation realizes its goal of increasing rough diamond production to 100,000 carats annually over

the next two to three years by modernizing exploration and mining techniques. To this end, NMDC is already prospecting for new deposits in Panna and at Vajrakarur, in Andhra Pradesh State, and is finalizing a collaboration agreement with an as-yet-undisclosed organization in Australia. (*Mining Journal*, June 19, 1992, p. 444; June 26, 1992, p. 462)

**Expansion at Jwaneng.** Debswana Diamond Co. has announced plans to proceed with a fourth phase of expansion at the Jwaneng mine, located in central Botswana. According to the August 14, 1992, *Mining Journal*, when the expansion is completed in late 1994, the volume of ore treated will increase 33% over current capacity, to 7.68 million tons per year. Total diamond production, which in 1991 came to 9.4 million carats, is projected to increase 21%.

This is the mine that De Beers's Harry Oppenheimer called the greatest discovery since Kimberley (1870). If these figures are accurate, 1991 production yielded 163 carats per 100 tons of ore, which is phenomenal for Africa. Reportedly, about 70% of the output is of cuttable quality.

**Diamonds from Myanmar.** Although very well known for its exceptional rubies, sapphires, peridot, and jadeite, Myanmar (formerly Burma) also produces a small amount of diamonds. These are mined primarily from alluvial deposits in the Mohawk area just north of Momeik (north of Mogok) and in the Theindaw district near Myeik (in the south of the country). At the 28th Myanmar Gems, Jade and Pearl Emporium held in February 1991, 28 lots of polished diamonds with a total weight of 77.51 ct were offered.

In the spring of 1992, one of the editors (RCK) and Robert E. Kane had the opportunity to see some of these diamonds (figure 1) and the facility at which they are fashioned in the Myanma Gems Enterprise (MGE) headquarters in Yangon (figure 2). The cut diamonds—all round brilliants—reportedly averaged 0.3–1.0 ct, with the largest cut stone approximately 10 ct. MGE officials indicated that, to date, relatively few diamonds had been recovered in Myanmar. A report in the 1992 Mining Annual Review published by *Mining Journal*, showed production of only 95 carats per year for the past three fiscal years. The same report, however, indicated that Stockdale Prospecting Ltd. was involved in negotiations to prospect in the Theindaw

district because of the high quality of the diamonds produced there.

**Venetia mine officially opens.** On August 14, 1992, De Beers officially opened the Venetia mine in northern Transvaal. This large open-cast mine encompasses two adjoining kimberlite pipes. It is expected to reach full production by December of this year, processing 4.6 million tons of ore annually to yield over 5 million carats of diamond rough. Venetia is the first major diamond mine to be developed in South Africa in over 25 years. It is also the first in the country to operate continuously, seven days a week. (*Mining Journal*, August 21, 1992, p. 130)

**Diamond-cutting plant in Vietnam.** The Hai Duong Diamond Factory has been established by a Belgian company, Geminvest, at a site in Vietnam halfway between Hanoi and the port city of Haiphong. The facility, which opened early in 1992, employs approximately 30 workers, including instructors from Thailand. Sawn diamonds are provided from Antwerp, and the cut stones are returned there for marketing. (*Europa Star*, August 24, 1992, p. 922)

#### COLORED STONES

**Amber with insect "inclusion."** Unlike most gem materials, amber is of organic origin. Its wealth of organic inclusions have told us much about the earth's distant past. Particularly interesting is the vast array of insect inclusions that have been discovered over the years (see, e.g.,



Figure 1. Myanmar's gem wealth also includes diamonds, which are recovered from alluvial deposits near Momeik and in the Theindaw District. Illustrated here are 20 crystals, ranging from 3.50 to 10.13 ct, and a 2.65-ct faceted diamond from Myanmar. Photo by Robert E. Kane.



Figure 2. Diamonds from Myanmar deposits are faceted in Yangon at a cutting facility within the headquarters of the MGE. Here, two cutters work simultaneously on the same scaife. Photo by Robert C. Kammerling.



Figure 3. This 11.62-ct cabochon of Baltic amber (25.34 × 18.52 × 8.17 mm) has had an insect "inclusion" carved into its base. Photo by Maha Smith-DeMaggio.

Figure 4. Southwestern Montana is reportedly the source of this chalcedony; the smallest cabochon is 4.37 ct. Photo by Robert Weldon.



the entry on a "hairy insect" in the Winter 1991 Gem News section).

At a summer 1992 jewelry trade fair in Vicenza, Italy, two of the editors came across a different type of insect "inclusion" in a piece of Baltic amber. The specimen, an 11.62-ct oval cabochon, had the image of an insect—about 11 mm long—carved into its flat base (figure 3). When viewed from above, the carving resembled a three-dimensional inclusion.

**More amber from Russia.** In the Spring 1992 Gem News column, we reported the greater availability of Baltic amber at this year's February Tucson show. Since then, we learned through *Jewellery News Asia* (May 1992, p. 62) that Palminic International Co. has been formed in Hong Kong to purchase Baltic amber from a joint-venture firm in Moscow (also called Palminic) and market it to distributors and manufacturers in a number of countries worldwide, including Australia, Japan, the United Kingdom, and the United States.

According to the agreement, Palminic will purchase 100 to 200 tons of rough amber a year for 10 years, as well as amber jewelry manufactured in Kaliningrad of the Russian Federation. The rough amber is cut and (approximately 90% of it) heat treated to produce a golden brown color in Shenzhen, in the People's Republic of China. It is then polished in Hong Kong. In the second half of 1991, Palminic received three shipments of rough totaling 200 tons. Sales of loose amber have averaged 560 kg a month since January 1992.

**Blue chalcedony from Montana.** Paul Peterson of Deer Lodge, Montana, recently provided GIA with samples of an attractive chalcedony for examination. The material, marketed as "Glory Blue" chalcedony, is reportedly recovered from a new source in southwest Montana (figure 4). Four cabochons, which represented the range of color from yellowish gray through grayish blue to violet, were selected for testing. The gemological properties were found to be consistent with those reported in the literature for chalcedony. All of the samples luminesced a strong, chalky bluish white to long-wave U.V. radiation, followed by a brief white phosphorescence; they gave a weaker blue luminescence—and white phosphorescence—to short-wave U.V. The spectra produced by U.V.-visible absorption spectroscopy and energy-dispersive X-ray fluorescence (EDXRF) spectroscopy were consistent with those observed in blue-to-gray chalcedonies from other localities.

**An unusual zoned specimen.** Occasionally, the editors are shown unusual specimens that consist of two or more distinct, intergrown minerals. The Winter 1991 Gem News column, for example, contained a report on a tumble-polished intergrowth of sunstone feldspar and iolite from India.

More recently, we were shown an unusual zoned specimen that Pierre Stéphane Salerno of Edmonton, Alberta,

Canada, reported to be from the Betroka area of southern Madagascar (figure 5). With magnification, three distinct concentric layers were evident in this 6.97-ct specimen (14.02 × 8.13 × 5.94 mm). The hexagonal core was colorless and highly included. It was surrounded by a thin dark green layer which in turn was rimmed by a dark blue layer.

X-ray powder diffraction analysis of all three layers revealed that the central core was composed of a corundum crystal (which is consistent with its morphology), the green layer was spinel, and the outer layer was sapphirine. This is the first time we have seen this combination of gem materials in a single specimen.

*Figure 5. This 6.97-ct specimen consists of a central crystal core of colorless corundum encased in a layer of green spinel, which in turn has an outer cover of blue sapphirine. Photo by Maha Smith-DeMaggio.*



**Diopside from Tanzania.** The recent discovery of green zoisite from the Merelani Hills mining area of Tanzania gained widespread coverage in the gem trade this past year (see the article by Barot and Boehm in *Gems & Gemology*, Spring 1992, pp. 4–15). It was thus interesting to learn that at least one kilogram of another green gem material had recently been found at the same locality, which is best known for its production of the purplish blue zoisite, tanzanite.

The largest specimen, a 62.66-ct dark yellowish green piece of rough (figure 6), was subsequently made available by Dr. Horst Krupp and Pala International (Fallbrook, California) to the GIA Gem Trade Laboratory for testing. Refractive-index readings of 1.670 and 1.689 were determined on an exposed cleavage plane. Examination with a desk-model prism spectroscope revealed a spectrum typical for chrome diopside. The specific gravity, as determined by hydrostatic weighing, was 3.29. Magnification revealed



*Figure 6. This 62.66-ct diopside specimen (25.9 × 25.5 × 15.0 mm) was recovered from the Merelani Hills gem deposits in Tanzania. Photo by Maha Smith-DeMaggio.*

several partially healed fractures, composed of secondary syngenetic two-phase fluid inclusions, throughout the specimen. X-ray diffraction analysis confirmed the identity of this specimen as diopside.

**Ironstone matrix as a carving material.** Australian ironstone is generally thought of as matrix material in which opal is found. At the February Tucson show, however, Rod Griffin of Opal Magic, Sydney, Australia, offered interesting items made from what many consider waste material. Using ironstone with minor opal veining, this material from the Cleopatra mine had been fashioned into such items as small animal carvings and “cases” for desk clocks.

**Mansfieldite gemstone egg.** On a 1991 buying trip to Germany, Si and Ann Frazier of El Cerrito, California, acquired a collection of five polished light grayish green “eggs” fashioned from the mineral mansfieldite. According to the Fraziers, the rough material—a rare hydrous aluminum arsenate—was recently collected near Djebel Debar, northeast of Hammam Meskhoutine, Constantine, Algeria, by a young German mineralogist on a trip to the type locality for dussertite, another rare arsenic mineral.

The polished mansfieldite eggs superficially resemble the ornamental gem material variscite, a member of the same mineral group; however, identification was confirmed by X-ray diffraction analysis in Germany. The 58.6 × 44.2 mm sample shown in figure 7 was subsequently obtained for GIA’s permanent collection. According to the Fraziers, mansfieldite is not listed as a gem material in any gem-related books of which they are aware. A literature search



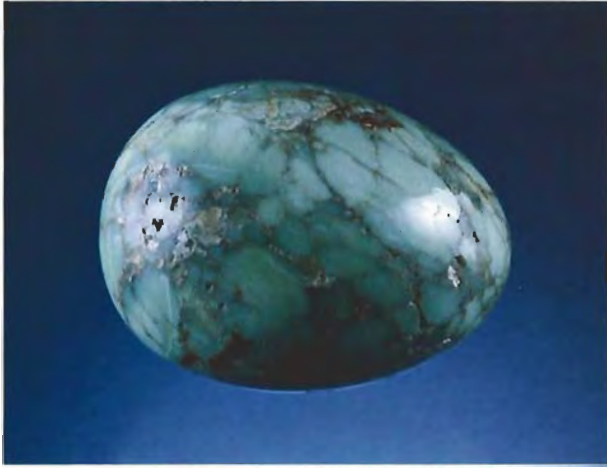


Figure 7. This 896-ct "egg" has been fashioned from the rare arsenate mineral, mansfieldite. Photo by Maha Smith-DeMaggio.

by the Gem News editors also failed to uncover any references to the use of this mineral as a gem material.

**Pearls from Baja California.** As reported in the Spring 1991 Gem Trade Lab Notes, it appears that the Gulf of California is again a significant source of natural pearls. Recently, the editors were shown some shells measuring approximately 13 cm × 14 cm that had been fished off the coast of Baja in the Gulf of California. The shells were identified as those of the pearl-producing oyster *Pinctada mazatlanica*. One shell still had a 3/4 blister pearl attached. The slightly off-round, light gray pearl measured approximately 11.5 mm in diameter.

Figure 8. These natural pearls (2–9 mm in diameter) were recovered recently from a Spanish Colonial shipwreck off the coast of Florida. Photo by Maha Smith-DeMaggio.



Figure 9. This large (42 mm in longest dimension) unusual cultured South Seas pearl is partially filled with a liquid. Photo by David Baker.

**Natural pearls from the New World.** A treasure trove recently recovered from a Spanish colonial ship that had been wrecked off the Florida coast contained a cache of thousands of pearls believed to be from the Margarita Islands of Venezuela. A small sampling of pearls from this find were subsequently examined by GIA Gem Trade Laboratory staff members. The 33 pearls, some drilled, ranged from 2 to 9 mm in diameter (figure 8).

All samples showed obvious signs of deterioration; most still exhibited some orient and luster, but some were brittle and completely chalky in appearance. Some of the pearls had black areas, but this dark coloration was confined to a thin surface layer that could probably be peeled away easily to reveal the underlying white nacre. Similar surface "coatings" have been seen by staff members on white pearls that have been charred in fires. It was, however, remarkable how relatively well preserved these pearls were after centuries in the corrosive saltwater without the protection of an oyster.

**Large South Seas pearl illustrated.** An entry in the Fall 1991 Gem News column described an unusual, large (42 mm long) South Seas cultured pearl. The pearl, described as gray, egg shaped, and with a high luster, was also partially filled with a liquid (water?), which moved when it was shaken. The report had been submitted by William A. Weidinger of Columbus, Ohio, who saw the specimen while visiting Naga Noi Island, off the coast of Phuket, Thailand.

Following publication of the Gem News item, Mr. Weidinger was contacted by David Baker of nearby Dublin, Ohio. Mr. Baker had also visited the Naga Noi pearl farm and photographed a pearl that was undoubtedly the same one Mr. Weidinger had described. He kindly provided the photo (figure 9) to share with our readers.



Figure 10. Research is being carried out to develop pearl culturing using the oyster *Pinctada radiata*, a 65.5 × 63.5 mm example of which is shown here. Photo by Maha Smith-DeMaggio.

**Pearl culturing in Venezuela.** Although Japan is probably the best-known producer of saltwater cultured pearls, there are many other localities where this organic gem is produced with the help of human intervention. These include Australia, China, and Tahiti, as well as a number of other islands in the South Pacific.

Recently, the editors learned of early efforts to develop a pearl-culturing industry in Venezuela. According to Gary Kraidman of Margaronics, Inc., natural pearls were first reported to have been found in abundance around several islands off the Venezuelan coast in 1498. Pearls have continued to be recovered from this area over the centuries, although their host, the oyster *Pinctada radiata* (figure 10), has been valued primarily as a source of food. Mr. Kraidman believes, however, that the relative thickness of the nacreous layer and its orient hold promise for the production of fine cultured saltwater pearls that should compare favorably with those from Far Eastern sources. Several potential culturing areas have been identified, and the feasibility is being studied jointly by Margaronics and a Venezuelan research foundation.

**Faceted ruby from Longido, Tanzania.** In the Fall 1991 Gem News section, we ran an update on production at the Longido ruby deposit in northern Tanzania, best known for its ruby-in-green-zoisite carving material. As mentioned in that entry, little facet-grade ruby is recovered from this locality; a recent estimate indicated that 20 tons of ruby typically yield enough transparent material to produce only five or six carats of faceted stones, whereas cabochon-quality material is more common. It was, therefore, with interest

that we examined the 0.20-ct modified round brilliant shown in figure 11. Despite its small size, the stone exhibited an intense red body color. Gemological testing revealed properties typical of ruby. When exposed to long-wave U.V. radiation, the stone fluoresced a moderate to strong red; it was inert to short-wave U.V.

**Sapphires from Madagascar.** During an extended visit to the island of Madagascar, Pierre Stéphane Salerno explored the mining area southwest of Betroka, in the Province of Tuléar, where an unusual type of multi-colored sapphire is recovered. These parti-colored sapphires, known also as polychrome sapphires because of their distinct color banding, are mined from pits in this southern part of the island, at a locality called Iankaroka.

According to Mr. Salerno, the sapphires are mined along contact zones between granites and migmatites. The principal component of the host rock in which the sapphires are found is iolite, with green tourmaline and biotite also present.

The sapphire crystals are elongated to tabular hexagonal prisms and bipyramids (figure 12) that are strongly color zoned perpendicular to the c-axis in thin layers of blue, green, brownish orange, pink, and red. When a crystal is viewed down the length of the c-axis, these color layers appear to blend into a relatively uniform pinkish purple. When the stone is viewed perpendicular to the c-axis, however, the dominant color seems to be brownish

Figure 11. This 0.20-ct ruby comes from the Longido mining area, in northern Tanzania. Photo by Maha Smith-DeMaggio.





Figure 12. Madagascar is the source of these rough and faceted parti-colored sapphires. The emerald cut weighs 1.11 ct; the center crystal, 1.27 ct. Courtesy of Pierre Stéphane Salerno; photo by Robert Weldon.

orange, although the color zoning usually is still visible (again, see figure 12).

The editors examined the two faceted stones shown in figure 12 and found that the gemological properties are typical of corundum. Many of the crystals and the two cut

Figure 13. This green sphalerite was recovered from a quarry in Thomasville, Pennsylvania, earlier this year. The crystals are approximately 1.5 cm long, and the cut stone (faceted by Art Grant, of Coast to Coast Rare Gemstones) weighs 3.5 ct. Courtesy of Bryon Brookmyer; photo © Wendell E. Wilson.



stones contained opaque gray-to-black octahedral inclusions that appeared to be magnetite; specimens with large inclusions of this type were actually lifted with a small magnet. Primary two-phase liquid/gas (CO<sub>2</sub>) inclusions (which prove that these samples have not been heat treated) were also observed in thin, planar cavities oriented perpendicular to the c-axis.

**Pennsylvania sphalerite.** Dr. Wendell E. Wilson, editor of the *Mineralogical Record*, reported that two mineral collectors, Bryon Brookmyer and Steve Myers, discovered a pocket of sphalerite crystals in March 1992 at the Thomasville Stone and Lime Company Quarry No. 1 in Thomasville, Pennsylvania. Over 100 specimens were recovered, primarily single crystals less than 2 cm long, but also some 3- to 4-cm-long crystal clusters. As can be seen in figure 13, the sphalerite is very similar in color to peridot.

**Tourmaline with distinctive inclusions.** The Fall 1990 issue of *Gems & Gemology* featured an article on tourmalines from São José da Batalha, Paraíba, Brazil. Among the distinctive features reported for some crystals from this locality were numerous pinkish yellow specks, with a metallic luster, that were provisionally identified as a sulfide mineral.

Recently, David Humphrey of Geodesign, Pacific Palisades, California, showed the editors an attractive green modified triangle-cut 4.26-ct tourmaline that reportedly originated from Paraíba. Traversing almost the entire length of the stone was a band of yellow metallic-appearing inclusions (figure 14). This is the first example of a faceted tourmaline with such inclusions that the editors have seen. The fact that the inclusions are extremely thin and oriented parallel to the prism faces of the host crystal suggests that they are a product of epigenetic exsolution. Microchemical testing with nitric acid, done on a crystal with exposed inclusions, indicated the presence of copper.

## ENHANCEMENTS

**Diffusion-treated sapphire cabochons sold as natural.** Diffusion-treated sapphires continue to be one of the most controversial of all color-enhanced gems. An ongoing debate rages in the trade—and trade press—about appropriate nomenclature to describe this material, while dealers and retailers alike continue to express concern about their ability to detect the treatment so they do not unwittingly misrepresent a stone.

Recently, gemologist William A. Weidinger observed a number of “runners” in Chanthaburi, Thailand, offering large parcels of blue sapphire cabochons that had been salted with diffusion-treated stones. Mr. Weidinger was later told by Bangkok gem dealers that such treated cabochons (in sizes down to 3 mm in diameter) are commonly offered in Chanthaburi as natural-color stones. Mr. Weidinger confirmed that, as described in the Summer 1990 *Gems &*

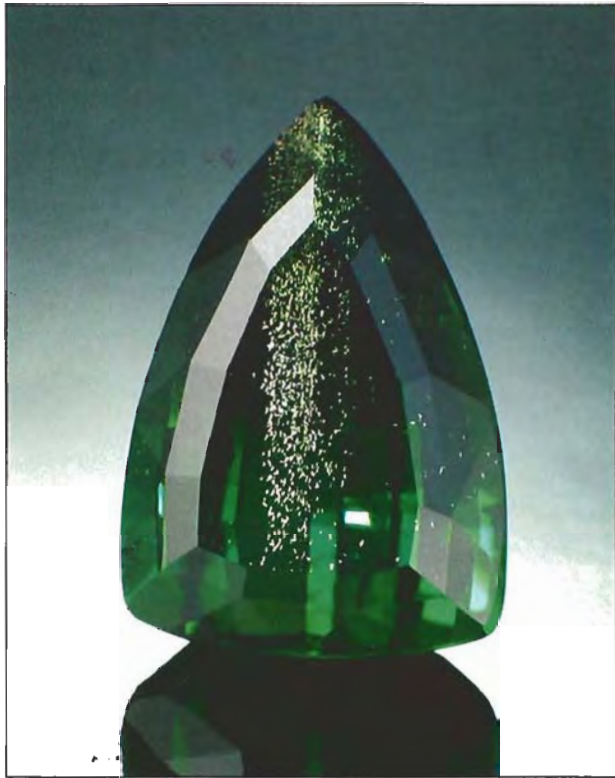


Figure 14. Striking yellow metallic-appearing inclusions run almost the entire length of this 4.26-ct tourmaline that is reportedly from Paraíba, Brazil. Courtesy of Russell E. Behnke, Meriden, Connecticut; photo by Robert Weldon.

Gemology article by Kane et al. on diffusion-treated sapphires, these diffusion-treated cabochons can be identified by the characteristic dark blue outlining of the girdle when they are examined while immersed in methylene iodide. Sometimes, however, the treatment is not detected until repolishing, when the turning of the stone against the cutting wheel often produces a "snail shell"-like spiral pattern of partial color removal.

**Kit with colored fracture filler.** It is well known that emeralds with surface-reaching fractures and other voids are routinely treated with oils, synthetic resins, and other substances to lower the relief of these features and thus make them less noticeable. Most of these treatments use essentially colorless fillers. Occasionally, however, we encounter lower-quality emeralds that have been treated with colored fillers, so-called green oils.

At the Tucson show this year, we saw a complete "kit" for color treating emeralds. It included a dark green, viscous fluid labeled "Green Miracle"; a circular, open-top container with three legs; a strainer divided into four com-

partments; and a desk lamp with a small, 100-watt incandescent spotlight-type bulb (figure 15).

According to the instructions, the stones to be treated should first be sorted (e.g., by size or shape) and then put in the separate strainer compartments. The strainer is then placed in the container, and the "Green Miracle" liquid added until it covers the stones. The lamp head is placed at the top of the container, the lamp turned on, and the light left on for 72 hours. The stones are then removed, cleaned with a towel, and buffed "until shiny."

Although substances for dyeing and/or fracture filling stones can be obtained from chemical- or lapidary-supply stores, this is the first time the editors have seen a complete kit, along with instructions, offered for the specific purpose of dyeing emeralds.

**Update on dyed green quartz.** Because of its great abundance, colorless quartz has long been dyed to imitate other gem materials. In fact, the dyeing of quartz to imitate emerald is perhaps one of the oldest treatments in recorded history. As early as the first century A.D., Pliny wrote "I have in my library certain books . . . wherein there are descriptions as to how to give the color of *smaragdus* [emerald, in part] to *crystallus* [single-crystal quartz] . . ." (see K. Nassau, "The Early History of Gemstone Treatments," *Gems & Gemology*, Spring, 1984, pp. 22-33). Today, this material continues to be seen in the gem trade and is offered by a number of distributors. Golay Buchel USA representative Kuniko Kishiki kindly donated several examples for GIA research and educational use.

Figure 15. This "kit" allegedly provides everything needed to fracture fill emeralds with a green "dye." Photo by Maha Smith-DeMaggio.

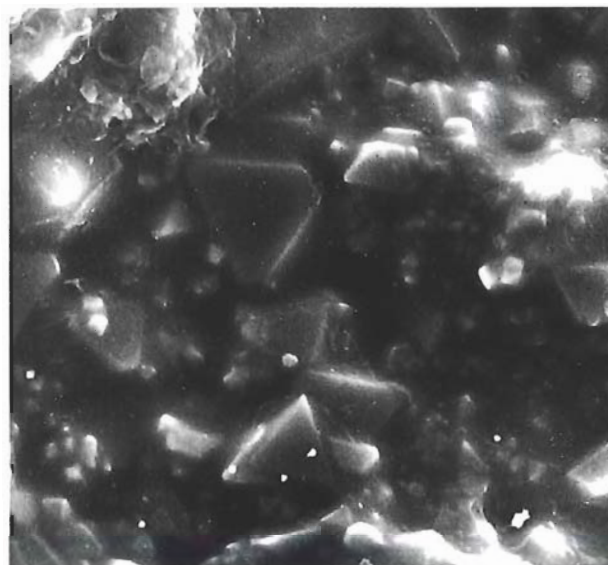


Faceup, this dyed quartz is a very convincing emerald simulant. Not only is the saturated green color credible, but the numerous dye-filled fractures impart a "velvety" look that has come to be associated with some oiled emeralds (figure 16). However, this material can be readily identified even without magnification: When the stones are held table-down about 3–5 cm above a white background (an envelope or business card will do) and viewed through the pavilion, the numerous green dye-filled fractures are readily visible.

Routine gemological testing on six specimens revealed properties typical of single-crystal quartz. When examined with a DISCAN digital-readout diffraction-grating spectroscope, all six stones showed the dark absorption band from approximately 660 to 690 nm that typically appears when an organic green dye is present in a gem material.

However, infrared absorption spectroscopy showed a series of sharp absorptions at approximately 2870, 2930, and 2965  $\text{cm}^{-1}$  that are identical in position, shape, and relative proportion to those found in the epoxy resin Opticon, the filling material commonly used to enhance the clarity of emeralds. It appears, therefore, that a dye has been mixed with Opticon or an Opticon-like resin before being introduced into the fractures of the faceted quartz. In fact, the use of a green-dyed epoxy resin in quench-cracked quartz may predate the use of Opticon to fill fractures in emerald.

*Figure 16. Faceup, this quench-cracked and green-dyed quartz (1.30 ct) makes an effective emerald imitation. I.R. spectroscopy determined that the dye was carried by an Opticon-like epoxy resin. Photo by Maha Smith-DeMaggio.*



*Figure 17. This scanning electron photomicrograph shows triangular octahedral faces of spinel that have crystallized on the inner walls of surface-reaching cavities of a natural ruby, resulting from an apparently new form of treatment. Courtesy of Juan S. Cozar; magnified 5,000 $\times$ .*

**New ruby treatment?** In ICA (International Colored Gemstone Association) Laboratory Alert No. 56 (June 3, 1992), Juan S. Cozar, laboratory director for the Spanish Gemological Institute in Madrid, described what appears to be a new form of enhancement for natural ruby. He based his conclusions on the examination of a 20  $\times$  15 mm natural ruby crystal with an intense red color.

The crystal was coated with a transparent, "glassy" substance. Evidence of strong corrosion could be seen through the coating in the form of the dissolution of the crystal's surface as well as the penetration of the coating substance into surface-reaching fissures and parting planes. In addition, surface-reaching cavities were filled with a white, microcrystalline substance that appeared to be intermixed with a transparent, colorless, amorphous material.

The specific gravity of the crystal, as determined by hydrostatic weighing, was unusually low, approximately 3.75. Strong red luminescence to both long- and short-wave U.V. radiation was noted. An absorption spectrum typical for ruby was observed with a handheld-type spectroscope, and refractive index values were those expected of corundum.

A scanning electron microscope with an energy-dispersive X-ray fluorescence spectrometer showed that the walls of the coated cavities were decorated with tiny octahedra of spinel that apparently recrystallized from the coating material (figure 17). To our knowledge, this is the first time that such a coating has been identified on a ruby crys-

tal. Because the transparent coating/filling material described was essentially amorphous, the treatment may have some similarities to the glass filling of surface cavities in fashioned corundums [see, e.g., the article on this treatment by Kane et al., *Gems & Gemology*, Winter 1984, pp. 187–199].

## SYNTHETICS AND SIMULANTS

**New synthetic alexandrite.** The Spring 1991 Gem News column included a report on a Czochralski-pulled synthetic alexandrite, marketed by J. O. Crystals; a follow-up report on this material appeared in the Spring 1992 issue.

Recently, the editors learned of another synthetic alexandrite being marketed under the trademark name Allexite by The House of Diamonair, a subsidiary of Litton Airtron. According to a promotional brochure, this synthetic alexandrite is also produced by the Czochralski method, with seven to 10 days usually required to produce a single large crystal.

A 1.26-ct oval mixed cut was donated to GIA by Litton Airtron (figure 18). This specimen showed a strong color change from reddish purple in incandescent light to bluish green in day/fluorescent light, which is comparable to the color change seen in fine Brazilian alexandrites. The appearance of both colors was affected by the presence of a very strong red luminescence to visible light (also known as red transmission). Among the gemological properties determined were: R.I.'s of 1.740 to 1.749, with a birefringence of 0.009; strong red luminescence to long-wave U.V. radiation and moderate red reaction to short-wave U.V.; red appearance through the Chelsea color filter; and S.G. of 3.72. Magnification revealed distinct curved striae.

**Glass from Mount Saint Helens rock?** Following the May 1980 eruption of Mount Saint Helens in Washington State, a green glass appeared on the market that supposedly was made by fusing ash that had spewed from the volcano. A subsequent investigation, carried out by Dr. Kurt Nassau and detailed in the Summer 1986 *Gems & Gemology*, refuted the claim as to the composition of the green glass. Dr. Nassau showed that fusing ash from the volcano produced a black glass with a composition different from that of the green material.

Nevertheless, a green material continues to be marketed as "Mount Saint Helens glass," not only in the American Northwest but also at major gem shows like Tucson. At the February 1992 Tucson show, a firm marketing this material as "Emerald Obsidianite" provided customers with a business-card-size "flier" that stated that the material was produced by fusing "rock dust" (not ash) from the volcano. The flier even included a chemical breakdown of the material's composition. Interestingly, it also stated that the pulverized rock was fused under reducing conditions, with traces of chromium, iron, and copper added to produce the green color.



Figure 18. Czochralski-pulled synthetic alexandrite (here, 1.26 ct) is marketed under the trademark name Allexite. Photo by Maha Smith-DeMaggio.

**Unusual assembled glass imitation.** Recently, Benjamin Pecherer of Mimports, Lafayette, California, encountered a most unusual glass imitation of what at first appeared to be a large alexandrite that had been poorly oriented in cutting. The badly scratched stone had been brought to him for repolishing. According to Mr. Pecherer, the imitation was set in a good-quality gold mounting said to be "rather old." Once the 3.89-ct stone was removed from the mounting, however, the doublet structure became obvious. Unfamiliar with this type of imitation, Mr. Pecherer sent it to one of the editors for study.

Standard gemological testing established that the stone was composed of glass of two different colors. Magnification revealed that the two components had been fused together, with the interface delineated by numerous small spherical gas bubbles. The central portion of the pavilion was red glass, while the remainder of the stone, including the entire crown, was green.

Most red-green color combinations in fashioned simulants are reminiscent of alexandrite. However, this particular arrangement (figure 19, left) reminded the editors more of "watermelon" tourmaline, although this gem material is faceted only rarely (figure 19, right) because it is typically highly included.

**Another assembled imitation crystal opal.** In the Spring 1992 Gem News column, we reported on an apparently new imitation of crystal opal that consisted of an irregular fragment of synthetic opal encased in colorless glass. At a recent gem and mineral show, the editors came across yet another imitation of crystal opal, and purchased several samples for testing. This imitation consisted of a trans-



Figure 19. In diffused transmitted light, the red centers of both the 3.89-ct glass imitation (left) and the 1.09-ct watermelon tourmaline (right) are easily visible. Photo © GIA and Tino Hammid.

parent colorless top that was fashioned to resemble a faceted gem with a flat base; the base was "foil" backed with a diffraction laminate of various patterns that produced a moderately effective imitation of an opal's play-of-color when the assemblage was viewed faceup (figure 20).

Gemological properties determined for the transparent top of one specimen were consistent with those of plastic. Magnification revealed a "lip" around the base, rounded facet junctions, and an "orange peel" effect—all indicating that it was produced by molding rather than faceting. The most interesting feature was noted when the assemblage was examined with a desk-model spectroscope and the internal reflection method of illumination. This revealed a series of dark lines across the spectrum, some of which were at a slight angle from the expected vertical and shifted their position and angle with the orientation of the sample. These features are probably due to an optical effect related to the pattern on the laminate, rather than to the "absorption spectrum" of either component. A similar effect, even more pronounced, was noted in the plastic imitation opals described in the Summer 1991 Gem News section.

**Natural-appearing synthetic rubies on the Thai-Myanmar border.** From an educational standpoint, some of the most interesting materials gemologists encounter are the clever imitations that surface in gem-producing areas, such as composite imitation emeralds from Colombia and Brazil, "native" cut flame-fusion synthetic sapphires in Sri Lanka, and "rough" flame-fusion synthetic rubies in Vietnam.

It should come as no surprise, therefore, that one of the editors was confronted recently with a variety of synthetics in Mae Sot, a city in western Thailand very close to the Myanmar (Burma) border that is a known locality for

cross-border gem smuggling. Both in the city's gem-market area, and on the border itself along the Moei River, the editor was presented with a great variety of flame-fusion synthetic corundums that were misrepresented as natural gems.

Among the most interesting items encountered were yellow metal rings of the type used as stone holders, that is, more for display of the mounted stones than for jewelry. What caught the editor's eye were several such rings, each set with three transparent red "gems" said to be Burmese rubies. One was subsequently purchased for examination (figure 21) after the vendor admitted that the gems were not natural.

The three synthetic stones in the ring outwardly had a very natural appearance and good color, but they were poorly cut and polished. All three exhibited both eye-visible inclusions and surface cavities. Magnification revealed gas bubbles, which confirmed that the stones were synthetic. Each stone also had numerous large fractures, which may well have been induced through thermal shock ("quench crackling"). Interestingly, fractures in two of the stones appeared to have been filled with a substance of undetermined composition. In thicker areas, this filling appeared opaque and had a granular texture; in other areas, it was transparent. This may represent dried residue from "ruby oiling," a treatment sometimes used on rough in Thailand.

Figure 20. This imitation of crystal opal, approximately 12 mm in diameter, consists of a colorless plastic "gem" that has been backed with a patterned diffraction laminate. Photo by Maha Smith-DeMaggio.





Figure 21. This ring, purchased on the Thai-Myanmar border, contains three synthetic rubies that have a deceptively natural appearance. Photo by Maha Smith-DeMaggio.

**A new twist to imitations of Vietnamese ruby.** Numerous reports have appeared concerning flame-fusion synthetic rubies that have been misrepresented as natural material from Vietnam. The latest twist to this ongoing saga of deception was provided by Dr. Grahame Brown through ICA Laboratory Alert No. 60 dated September 2, 1992.

The 6.36-ct specimen described by Dr. Brown was purchased in Thailand as Vietnamese rough. Lacking definite crystal faces, it had a decidedly waterworn appearance. Perhaps most interesting, examination with the unaided eye revealed small areas of dark blue on the surface that superficially appeared consistent with the blue color zones in rubies from Vietnam described by Kane et al. in their Fall 1991 *Gems & Gemology* article on Vietnamese rubies. Closer examination with magnification, however, revealed that all such areas were confined to surface irregularities. Further testing indicated that the blue areas were composed of a hard blue wax-like substance that could be easily scraped away.

The specimen was subsequently sawed in half, with one section fashioned into a 1.55-ct stone. Magnification revealed diffused curved color banding, which is typical of a heat-treated Verneuil synthetic.

**Assembled imitation bicolored tourmaline.** The Winter 1991 Gem News section included an entry on imitations of Paraíba tourmaline. Among these were faceted stones consisting of a tourmaline crown and a glass pavilion.

ICA Laboratory Alert No. 57, dated June 30, 1992, and

issued by Drs. Hermann Bank and Ulrich Henn of the German Foundation for Gemstone Research, reported on another type of assembled tourmaline simulant. Represented as a natural crystal from Madagascar, it actually consisted of a tourmaline with concentric zones cemented to a lighter-colored piece of glass. The specimen, described in the report as weighing 61.41 ct, gave R.I. readings of 1.629 and 1.648 for the tourmaline portion and 1.520 for the glass. Magnification revealed a distinct boundary plane between the two sections, as well as gas bubbles in both the glass component and the cement contact zone (figure 22). Dr. Henn subsequently revealed that he had seen approximately 100 such specimens.

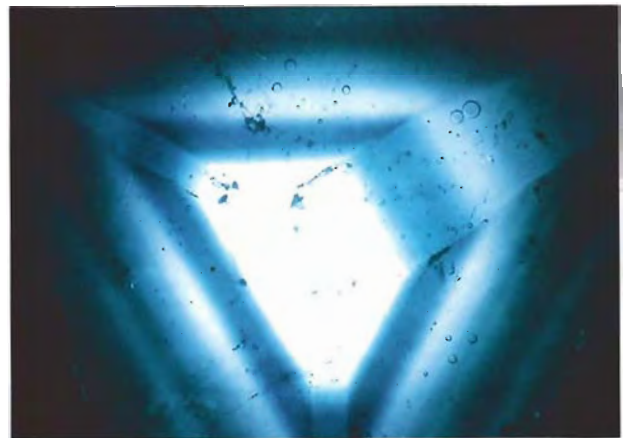


Figure 22. This cross-section of a tourmaline-glass assembled crystal section (approximately 6 cm in diameter, 61.41 ct) reveals gas bubbles in the contact zone. Photomicrograph courtesy of Dr. Ulrich Henn; magnified 5 $\times$ .

#### IN MEMORIAM

Mr. Vahan Djevahirdjian passed away on July 1, 1992. Mr. Djevahirdjian, of Monthey, Switzerland, was president of the board of directors of Hrand Djevahirdjian S.A., a major manufacturer of flame-fusion synthetics (corundums and spinels) and cubic zirconia, the latter marketed under the trade name "Djevalite." A near-legendary figure in the field of crystal synthesis, Mr. Djevahirdjian was a good friend of GIA, always generous in providing samples of his firm's production as well as information about synthetic gem materials. He is survived by his daughter, Katia.



## CORUNDUM

By Richard W. Hughes, 314 pp., illus., publ. by Butterworth-Heinemann, London, 1990. US\$39.95\*

This is the seventh, and thus far the largest, book in the Butterworth's Gem Book series. Considering recent developments in corundum enhancement and synthesis, this book can also be considered a timely reference.

Following a short section that summarizes corundum's mineralogical and gemological properties, a brief introduction leads into the 11 chapters that comprise the main text. Each chapter has its own bibliography, and there is a subject index to the entire book.

Chapter 1 addresses the history of ruby and sapphire as gems, with references back to 315 B.C. Chemistry and crystallography are discussed in chapter 2, which includes sections on twinning and on crystal morphology as it relates to various localities.

Chapter 3 addresses physical and optical properties. Chapter 4 covers color and luminescence, with sections on absorption spectra and on pleochroism and its importance to the lapidary.

Inclusions in natural rubies and sapphires are the focus of chapter 5. Mr. Hughes discusses the inclusion suites most commonly associated with the gem corundums found at each of the major ruby and sapphire sources.

Chapter 6 devotes 28 pages to the various corundum enhancements. It also addresses color stability, treatment disclosure, specific heat-treatment methods, and detection.

Synthetics and assembled stones are examined in chapter 7. In his discussion of identification techniques, Mr. Hughes focuses on visual characteristics as seen through a microscope.

Chapter 8 illustrates and discusses faceting for best color and brilliance. It also addresses the proper orientation of the rough to produce asterism in a cabochon.

Following a review of notable rubies and sapphires, chapter 9 examines the key variables in determining quality in these stones and placing them in a classification. The chapter concludes with an outline of world-



wide consumer markets that notes each country's general preference for color, proportions, and clarity.

Chapter 10 addresses the gem-corundum deposits, listing the localities and the mode of occurrence at each. The geology of four of the best-known deposits is then summarized.

The last and longest chapter, on world sources of corundum, is also one of the most interesting. Mr. Hughes takes the reader from the Mogok Stone Tract in Burma (Myanmar) to the sapphire-producing areas of Montana.

When he learned I was reviewing *Corundum*, Richard Hughes sent me a 25-page appendix titled "Corrections and Additions." It is too bad that these were not caught soon enough to be properly incorporated into the book. In addition, although there are many black-and-white illustrations, there are only two pages of color photos and photomicrographs.

In spite of these shortcomings, Mr. Hughes is to be congratulated for providing the gemological community with this excellent book.

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

## PROPERTIES AND APPLICATIONS OF DIAMOND

By John Wilks and Eileen Wilks, 525 pp., illus., publ. by Butterworth-Heinemann, Oxford, England, 1991. US\$175.00\*

Diamond has many unique physical and mechanical properties of both scientific and technological interest, quite

independent of its exceptional gemological characteristics. Consequently, much of the literature on diamonds is found in the domain of physicists, physical chemists, materials scientists, and engineers. This book, written by a world-famous team of physicists, succeeds in bringing together all of the properties and applications of diamond that have scientific and industrial significance.

The book begins with a short introductory chapter on the current status of diamond research that is primarily concerned with diamond synthesis and thin films. The main text is divided into three parts.

Part 1, on structure, will be of the greatest interest to gemologists. It covers such topics as chemical impurities and physical inclusions; optical absorption and causes of color; luminescence; morphology, and geometric defects in the lattice (e.g., twinning, thermal conductivity).

The mechanical properties of diamond are the focus of part 2, which discusses strength, fracture, and plastic deformation; polishing (including polishing rates and directional effects); friction; and laboratory-grown polycrystalline diamond (PCD).

Part 3, on applications and wear, is the largest in the book. Primarily of interest to materials scientists and engineers, it covers a range of topics, including wear and surface characteristics, and the use of diamonds in tools.

This is an excellent, well-illustrated reference book. However, it is written at a level that assumes some familiarity with basic scientific and technological concepts and units, as well as sophisticated instrumentation. Although gemologists should be aware of the availability of this book, it is not an essential part of a basic gemological library.

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

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# GEMOLOGICAL ABSTRACTS

DONA M. DIRLAM, EDITOR

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## COLORED STONES AND ORGANIC MATERIALS

**The chemistry of vesuvianite.** L. A. Groat, F. C. Hawthorne, and T. S. Ercit, *Canadian Mineralogist*, Vol. 30, 1992, pp. 19–48.

Seventy-six vesuvianite specimens from 54 different localities were analyzed, and the results of those analyses are reported herein. While most of the article is of little interest to gemologists, the observations on the chromatic effects of constituent metals is worthy of note, as facetable vesuvianite is known from at least five different localities. That

containing the most titanium (Ti) was from the Jeffrey mine, Quebec, Canada. Those having the least Ti from this locality are green, while the richer (more than 0.10 wt.% of TiO<sub>2</sub>) samples are brown. Manganese (Mn) is an established chromophore. Fe-poor samples with small amounts of Mn are pink or lilac. Jeffrey-mine crystals consist of green (Fe-rich) prisms capped with lilac (Mn-rich) pyramidal faces. Chromium (Cr) is described as a strong chromophore, typically imparting a vivid green color. A dark green sample from Xanthi, Greece, contains the most Cr of those studied, some 0.34–0.63 wt.% Cr<sub>2</sub>O<sub>3</sub>. As the article did not focus on color, no other connections are made between chemistry and crystal color.

*John Sampson White*

**Crystalline solution series and order-disorder within the natrolite mineral group.** M. Ross, M. J. K. Flohr, and D. R. Ross, *American Mineralogist*, Vol. 77, No. 7/8, 1992, pp. 685–703.

Some members of the natrolite group (all zeolites) are known to occur in facet-quality crystals. The authors did not discuss the “gemminess” of their samples, as that was not their objective, but they do provide a very useful identification of crystals from major localities.

Natrolite, scolecite, and mesolite are names long familiar to mineral collectors; however, tetranatrolite and paranatrolite, introduced in 1981, are relative unknowns. As far as this abstractor is aware, the others (thomsonite, gonnardite,

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*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.*

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edingtonite, and tetraedingtonite) are never found in gem quality, although thomsonite is often cut *en cabochon* and made into jewelry. Unfortunately, great confusion often exists over proper species designations for many of these occurrences, so this article is very helpful.

Perhaps the only gemologically important locality is Bound Brook, New Jersey, where hundreds of large and often clear crystals of natrolite were once found, crystals that produced flawless gems up to about 20 ct. Another important locality is Mont St.-Hilaire, Quebec, where one may find natrolite and tetranatrolite in the same specimen, with paranatrolite elsewhere in the quarry. Scolecite and mesolite from India also have some faceting potential.

John Sampson White

**Emeralds from Madagascar.** D. Schwarz and U. Henn, *Journal of Gemmology*, Vol. 23, No. 3, 1992, pp. 140–149.

Emeralds from primary mica-schist deposits of the Morafeno region in southeast Madagascar are described. The physical properties of these emeralds are similar to those from Zambia. Chemical analyses and absorption spectra are also reported. The former are compared to chemical components of emeralds from other localities with respect to relationships among substitutional elements. U.V.–visible/near-infrared spectra revealed features primarily associated with octahedral  $\text{Fe}^{2+}$  and  $\text{Cr}^{3+}$ , as previously reported for emeralds. Infrared features typical of  $\text{H}_2\text{O}$  in beryl channel sites were also observed. Internal features include brown mica crystals, unoriented greenish brown tremolite/actinolite rods and needles, and oriented colorless transparent prismatic crystals generally associated with fluid inclusions. This last type is almost identical to inclusions found in many Brazilian emeralds. Other inclusions observed are rounded, colorless, transparent crystals; opaque grains; opaque pseudo-hexagonal plates; colorless to pale brown crystals with strong relief; healed fractures with fluid inclusions; and multi-phase inclusions. The crystals are often color zoned, with an almost colorless center and a green rim. Several tables and graphs accompany the article, but no photographs of the emeralds themselves are provided.

CMS

**Idar's opal village.** S. Frazier and A. Frazier, *Lapidary Journal*, Vol. 46, No. 3, June 1992, pp. 34–39.

As part of an entire issue devoted to opals, this article offers the reader interesting information on the Australian material and its historical relationship to opal cutting in the Idar-Oberstein region of Germany. It chronicles Idar-Oberstein's role from the arrival of the first pieces of rough in 1893–94, through the boom years leading up to World War I, and ends with a brief vignette on current cutting in the region. Also mentioned are prominent people responsible for the development of the opal industry. A separate box includes discussion of opal pseudomorph "pineapples" and fossils.

KBS

**Petrified.** J. C. Zeitner, *Lapidary Journal*, Vol. 46, No. 6, September 1992, pp. 36–39.

This informative article discusses numerous uses for petrified materials. For jewelry purposes, they have been fashioned into beads, rings, pendants, bola ties, earrings, brooches, bracelets, cuff links, intarsias, and cabochons.

The author discusses four types of petrified materials: limb wood, "precious" opalized wood, common opalized wood, and jet. Limb wood is often completely replaced by chalcedony in clear, white, or pastel colors; it can include dendrites, plumes, or a "turtleback" pattern, and it is occasionally used in jewelry. "Precious" opalized wood, considered the "true gem" of petrified wood, is especially suited for pendants, brooches, and earrings. This particular type—which shows vivid colors against a black groundmass—is found in Rainbow Ridge and Denio, Nevada. Common opalized wood is found in Nevada, Washington, Oregon, Utah, and California.

Although jet does not fit the true geologic definition of petrification, the author has included it in this discussion. A soft but tough gem material, jet takes a high polish and has a long history in jewelry. It is often used by Native American lapidaries. Also discussed briefly are nonjewelry applications of petrified wood—miniatures, replicas, tabletops, and flooring. Two color photographs accompany the article.

RT

**Quartz as "diamond."** S. Frazier and A. Frazier, *Lapidary Journal*, Vol. 45, No. 1, April 1991, pp. 109–136; Vol. 46, No. 1, April 1992, pp. 153–168.

This two-part preview of an upcoming book, *Encyclopedia of Quartz*, explores the origin and misnomers of the word *diamond*. Ancient Greek and Hebrew writings about gems and minerals contain the first references to diamond. The derivation and development of the Greek word *adamas* is traced from its earliest recorded occurrence, where it was used to describe many minerals—including quartz, colorless corundum, topaz, hematite, magnetite, and iron. In fact, it is doubtful that the word actually applied to the mineral that we call diamond. In Medieval Latin and French, the Greek epithet transformed into *diamantes*; it then passed into the various forms presently used in modern Western European languages.

The establishment of chemistry as a science in the latter part of the 18th century provided a new basis for mineral classification. French chemist Antoine Laurent Lavoisier (1743–1794) was the first to determine that *diamond* was made of carbon, which ultimately provided diamond with a precise definition, thus eliminating other substances, especially quartz, previously included under the same heading.

As the monetary value of diamond rose, the practice of using the term to describe clear, colorless quartz crystals became popular. This misuse was commonly accompanied by a locality designation. These articles provide a com-

prehensive list of quartz "diamonds," from Alaska "diamond" to Zabeltitzter "diamanten," including individual descriptions of mineralogy, lore, history, name derivation, and the materials themselves. The authors appeal to readers for additional information about quartz names, references, accurate descriptions of specimens, suggestions, and corrections.

AGP

**Surface features on natural rubies and sapphires derived from volcanic provinces.** R. R. Coenraads, *Journal of Gemmology*, Vol. 23, No. 3, 1992, pp. 151–160.

Sapphires of volcanic origin lack the crystal habits typical of other types of corundum because the original crystal surfaces were dissolved by the alkali basaltic magmas that carried the material to the surface. However, information about their formation can be gleaned from residual surface features. For this study, a large sample of corundum from placer deposits in eastern Australia and Thailand were examined by scanning electron microscopy at magnifications from hundreds to thousands of times original size.

The observed features fall into three broad categories: negative crystal impressions, surface resorption or etch features, and surface damage associated with alluvial transport. The first of these includes deep, sharp-edged, geometric holes about 0.5 to 1.0 mm in diameter that exhibit tetragonal symmetry. These developed during growth as part of a coarsely crystallized aggregate that included anorthoclase, zircon, and spinel. Surface etch features include flat-topped triangular hillocks about 15–20 micrometers across; bands of shallow hexagonal depressions (approximately 5–10 micrometers in diameter); inclined stacks of elongated, triangular "bricks"; triangular depressions; random, blade-like textures; and chatter marks. Many of these can be analyzed to determine the relationship of a particular surface to the original c-axis of the crystal. Transport damage includes narrow, deep fractures that probably represent healed or partially healed stress fractures, some with fingerprint-like patterns. Conchoidal fracturing was also observed.

Conclusions about the history of these corundums that were drawn from their surface features include: (1) the crystals grew as part of a coarsely crystallized aggregate along with anorthoclase, zircon, and spinel; (2) the corundum reacted with the magmas that carried it to the surface; and (3) minimum alluvial transport took place.

CMS

## DIAMONDS

**Grade-tonnage and other models for diamond kimberlite pipes.** J. D. Bliss, *Nonrenewable Resources*, Vol. 1, No. 3, 1992, pp. 214–230.

Since 1869, when the first primary occurrence of diamonds in kimberlite was discovered in South Africa, data have been accumulating on various aspects of this rare rock type

and the even rarer diamonds it may contain. There are now sufficient data on economically viable diamond-bearing kimberlites, from several continents, so that statistically meaningful conclusions can be drawn with regard to several important gemological, geological, and mining parameters. In this article, which is based on statistical models (working hypotheses), the author has determined the median values (i.e., the point at which one-half the values in a distribution are less and one-half greater) for the following parameters of economic diamond-bearing kimberlite pipes (neither kimberlite dikes and sills nor lamproites are considered): (1) the median tonnage is 26,000,000 metric tons (mt); (2) the median diamond grade is 0.25 ct/mt; (3) the median of the average diamond size is 0.07 ct (7 points); (4) the median percentage of diamonds that are industrial grade (including "near-gem" qualities) is 67%; and (5) the median outcrop area of diamond pipes is 12 hectares (29.6 acres). One very sobering conclusion is that even when a diamondiferous kimberlite pipe is found, the likelihood that it can be worked economically for diamonds is extremely low (the probability is approximately 0.005; i.e., one in 200), unless the newly discovered pipe is a member of a cluster (as in the Kimberley area, South Africa) that contains an economic kimberlite, in which case the probability is increased 56 times.

There are many other fascinating facts and statistically based conclusions in this article that will be of interest to the diamond community; they are essential knowledge for those involved in any aspect of diamond exploration.

A. A. Levinson

**Manufacturers hurting in rough-starved market.** *New York Diamonds*, No. 16, 1992, pp. 12, 14.

For many months, De Beers has been selling smaller sights and buying all the "outside" open-market rough to tighten the market during this slow economy. With little or no rough, diamond cutters are having trouble remaining in business. Those who can get rough are slowing operations.

At the same time, rough from the outside market is now coming directly to De Beers's buying offices at nearly triple the usual rate. On the one hand, some of the large manufacturers who usually buy such rough have reduced their purchases because of the slow market. On the other hand, illegal digging in Angola and increased smuggling from Zaire have created an even larger supply of rough—which De Beers is also attempting to control.

"This is our role. We stockpile rough when times are difficult to maintain market stability. Some of our clients may feel they could sell more goods than we are providing, but we have to consider the big picture, not just the needs of one or two," said Michael Grantham of the Central Selling Organisation (CSO).

Some dealers predict that tight supply will equate with price increases. "Price increases usually restore industry confidence because it increases the value of diamond inven-

tories," Grantham said, "but right now, there is not sufficient demand to justify an increase." This is not new policy. The role of De Beers in controlling the market is well documented. This article examines the rough diamond market in greater detail, and explains De Beers's efforts to keep supplies at cautious levels until the world economy improves. GAR

**"The most unkindest cut of all"—recutting the Koh-i-Nur.**  
N. B. Israel, *Journal of Gemmology*, Vol. 23, No. 3, 1992, p. 176.

This one-page note is in response to a recent Letter to the Editor written by Alec Farn. The author briefly outlines the history of the recutting of the Koh-i-Nur (also spelled *Koh-i-Noor*), and addresses the issue of its recut-versus-original weight. Confusion over its reduction in weight as a result of the recutting has arisen due to conversion factors between old English carats and metric carats, combined with the perpetuation of erroneous reports of the stone's past weights. This note throws some light on the issue, but ends with an appeal to readers for more input. CMS

**Russia and CSO: Change but no change.** *Jewellery News Asia*, No. 95, July 1992, pp. 154, 156, 158, 168.

In July 1990, the Soviet administration for diamonds and precious metals, Glavalmazoloto, signed a US\$5 billion sales contract with the CSO. With the formation of the new Russian Federation, however, Glavalmazoloto ceased to exist, and a new organization, Rossalmazoloto, took its place. In addition, payments for shipments were now to be directed to the Bank of the Russian Federation instead of the Central Bank of the Soviet Union. Through all of the changes, the two parties have attempted to conduct business as usual. According to CSO director Gary Ralfe, Rossalmazoloto is managed by the same people who managed Glavalmazoloto, and the agreement remains unaffected by the dissolution of the Soviet Union.

Although recent developments in Russia suggest that this analysis is no longer current, the article does provide details on the July 1990 diamond sales agreement between Russia and the CSO, and includes a map that shows locations of Russian recovery plants and cutting factories. JEM

**SI<sub>2</sub>: Slightly included or slightly outdated?** R. Shor, *Jewelers' Circular-Keystone*, Vol. 163, No. 8, August 1992, pp. 88-89.

The expansion of the SI clarity grade is a controversial, but important, issue facing the diamond industry today. The author tries to clarify the difficult situation facing the industry by quoting people at the Gemological Institute of America (GIA) and in the trade.

The trade proposes that GIA expand their SI clarity grade scale because "the quantities of lower quality stones

appearing—especially those in larger sizes—has made it apparent the SI category is broader than the better clarity grades, the boundaries blurrier (especially on the lower side) and the lab graders less experienced in lesser qualities." Some of the dealers who favor the SI<sub>3</sub> (or low SI<sub>2</sub>) argue that there is often a 30% or greater price difference between "high SI<sub>2</sub> and low SI<sub>2</sub>" stones when all else is equal—too much to be encompassed within the same grade. However, Bill Boyajian, president of GIA, points out that "adding an SI<sub>3</sub> grade would only give the same problem a new name." KBS

**Venetia's reserve/Shades of green—view from De Beers.**  
*Environmental supplement to Mining Journal*, Vol. 319, No. 8188, August 28, 1992, p. 10.

These two short articles discuss how the diamond-mining industry is responding to the global environmental movement. One example is the newly opened Venetia mine, the first major diamond mine to be developed in South Africa in 25 years.

As early as 1983, De Beers had ecological baseline studies performed on the property. To date, De Beers has spent some R17 million on impact assessment and amendment projects for the surrounding area. When De Beers initially approved capital for the mine, it also approved R11 million for the purchase of approximately 30,000 hectares of adjacent subeconomic overgrazed farmland to establish the Venetia Limpopo Nature Reserve and reintroduce formerly indigenous species, such as wild dogs and elephants.

In addition, the following measures are a direct result of the environmental impact studies conducted early in the development process:

- Constant monitoring of the water supply will ensure little if any deterioration in water quality. Ultimately, up to 40% of the water used in the mining process will be recycled.
- Waste dump sites have been constructed in such a way that they will not erode quickly, which will permit faster revegetation.
- Buildings at the mine site are constructed along the natural contours of the area and are painted in colors that blend in with the surrounding landscape.
- Electrical pylons in the area are specifically designed to prevent the electrocution of birds.
- Baobab trees in the immediate area have been uprooted and replanted.

According to De Beers, all new projects will be subject to similar environmental investigations. For the most part, diamond mining is relatively kind to the surrounding environment, and only water is used in what is essentially a crushing and washing process. The company feels that most environmental damage in diamond mining is created by small-scale miners performing illicit diamond mining in such countries as Sierra Leone, Guinea, and now Angola. However, even these scars are soon covered over by vegetation. JEC

## GEM LOCALITIES

**Vietnamese ruby: A discriminatory problem for gemmologists.** G. Brown, *Australian Gemmologist*, Vol. 18, No. 2, 1992, pp. 43–46.

The Luc Yen and Quy Chau ruby mines of Vietnam created quite a stir when first discovered in 1987 and 1990, respectively. Resembling Burmese ruby in both appearance and in internal characteristics, rubies from these Vietnamese sources became an appropriate commercial substitute for the rare Burmese stones. Origin authentication became increasingly difficult as stones from the new sources entered the market. Compounding the provenance question, some parcels of natural rubies were found to be "salted" with heat-treated Verneuil synthetic rubies.

A table of gemological properties of Vietnamese rubies is listed, but use of a high-quality gemological microscope is recommended by the author for successful identification of origin and separation of natural from synthetic.

The heat treatment of Verneuil synthetic ruby reduces the resolution of curved striae in the synthetic stone, although it does not eliminate gas bubbles already present. The persistent gemologist, by immersing the stone in liquid (toluene, bromoform, methylene iodide, etc.) under shadowed illumination, should be able to find some evidence of the elusive curved striae. The reader is advised to beware of misleading pseudo-polysynthetic twinning and dark fractures in the synthetics, and to watch for somewhat elongated internal cavities in the Vietnamese rubies that may simulate the "stretched" bubbles of the Verneuil synthetic.

The question of provenance between Vietnamese and Burmese rubies is also difficult. Since the color and inclusions of the two tend to overlap, observation of a few key minerals that are sometimes present in Vietnamese ruby provides the only way to positively identify origin. Still to be established is the possibility that electron microprobe and/or X-ray fluorescence analysis might prove conclusive.

JEC

**Wolodarsk-Wolynskii. Geologischer Aufbau und Mineralogie der Pegmatite in Wolynien, Ukraine (Volodarsk-Volynsky. Geological structure and mineralogy of the pegmatites of Volynya, Ukraine).** I. M. Koshil, I. S. Vasilishin, V. I. Pavlishin, and V. I. Panchenko, *Lapis*, Vol. 16, No. 10, 1991, pp. 24–40, 82.

In recent times, beryl and topaz from Volodarsk, Ukraine, have become available in larger quantities than ever before. However, little has been written about this locality, and most of it is in Russian. In this article, Koshil et al. describe the geology of Volynya and the minerals found there.

Gem minerals are found in granites and pegmatites associated with the Korosten pluton. On the basis of structure and mineral content, several types of pegmatites can be distinguished. The "chamber pegmatite" ("Kammer-pegmatit") generally contains the widest range of minerals

(over 90 species are listed in the article). This type is also the main source of gem specimens (mostly beryl and topaz, but with some smoky quartz, amethyst, citrine, and phenakite).

Beryl occurs in opaque-to-transparent columnar crystals up to about 30 cm (12 in.) long. The crystals are predominantly green to yellowish green, but golden yellow and blue stones are also found. Most crystals show etched faces, and stones corroded to completely irregular forms are not rare. Interestingly, the highly corrosive conditions for beryl seem to be favorable for the growth of topaz. Therefore, these minerals rarely occur together in the pegmatites. Topaz occurs in etched crystals, too, but for the most part the Volodarsk crystals are well formed and resemble topaz from Ilmen and Adun-Chilon. Crystals can reach considerable sizes (the largest stone on record weighed 117 kg). The topaz occurs in various pale to intense hues (colorless, blue, pink, red, yellow), some of which change with heat treatment or irradiation.

The article, written in German, contains a geologic map, several cross-section sketches of typical pegmatites, and many beautiful color photographs of gem and mineral specimens.

Rolf Tatje

## INSTRUMENTS AND TECHNIQUES

**Application of geochemistry to exploration for gem deposits, Sri Lanka.** C. B. Dissanayake and M. S. Rupasinghe, *Journal of Gemmology*, Vol. 23, No. 3, 1992, pp. 165–175.

Exploration for sedimentary gem deposits in Sri Lanka utilizes geochemical analysis of stream sediments and heavy-mineral surveys. The principles of this process are outlined here, including fairly detailed discussions of the various elements involved, such as fluorine and rare-earth metals. The jeweler-gemmologist will find the graph of density (specific gravity) values particularly useful, as it includes a number of less common materials as well as many of the usual gems. The fairly extensive bibliography will be a welcome resource for those who are interested in obtaining more information on this topic—one rarely addressed in the gemological literature.

CMS

**H<sub>2</sub>O and all that!** R. K. Mitchell, *Journal of Gemmology*, Vol. 23, No. 3, 1992, pp. 161–164.

Most of this article consists of basic information about the various properties of water, including how its temperature affects its role in gemological testing as well as the formation of various gem minerals. Of great interest to most gemmologists, however, will be the procedure outlined for obtaining a relatively accurate determination of the specific gravity of a mounted gemstone. Rather than try to paraphrase—and risk confusing—the process here, I recommend that gemmologists who ever have the need to test mounted goods take the time to read this brief note, includ-

ing the example provided. A table of specific-gravity values for various types and karats of gold is included. CMS

**Spéctrométrie et fluorescence X, des aides pour la détermination de types de gisement de saphirs (Spectrometry and X-ray fluorescence as aids in the determination of types of sapphire deposits).** J.-P. Poirot, *Revue de Gemmologie A.F.G.*, No. 110, 1992, pp. 7–9.

Poirot proposes criteria for the determination of locality of origin of blue sapphires based on U.V.–visible, near-infrared, and X-ray fluorescence spectroscopy. He states that a strong, broad band at 850 nm in the near infrared indicates volcanic origin, while absence of this band implies metamorphic origin. Another division, based on whether a given stone absorbs at 350 nm or continues to transmit down to 310 nm, further narrows possible localities of origin. Sapphires of metamorphic origin (i.e., without a strong band at 850 nm) include those from Myanmar and Sri Lanka (transmitting to 310 nm) and those from Kashmir (absorbing at 350 nm). Sapphires of volcanic origin are found in Thailand and Cambodia (both transmitting to 310 nm), as well as in several other localities—Australia, East Africa, France, Madagascar, and Vietnam (absorbing at 350 nm). Heat treatment is associated with a lessening of iron-related peaks.

Spectra for samples from all of the localities named are presented to support this theory. Unfortunately, they are poorly reproduced and some spectra for metamorphic sapphires do not include the energy range needed to illustrate the absence of a peak at 850 nm. More clearly presented data from a larger number of stones of known locality are needed to support this interesting theory.

Meredith E. Mercer

## JEWELRY MANUFACTURING ARTS

**Antiques: Japanese cloisonné, ultimate refinements in the art of enameling.** A. Berman, *Architectural Digest*, May 1992, pp. 178–179, 181, 182, 204.

Cloisonné, an ancient decorative art form once used exclusively by artists of the Japanese imperial court, experienced renewed interest in the late 19th and early 20th centuries. Credited with starting that resurgence is Kaji Tsunekichi (1802–1883), who single-handedly reinvented the craft basically by trial and error. Precious little knowledge about cloisonné (the process of applying enamel separated by thin wires to metal) had survived the ages. Tsunekichi perfected the process by painstakingly studying surviving examples of it, sometimes breaking a piece to better understand its inner workings.

Artists throughout Japan opened workshops and even factories, and the reincarnation spread, attracting international attention. Not content with merely copying the old ways of cloisonné, some improved on it. For example, extra

layers of enamel were added to certain areas, thus producing a bas-relief effect. Sculpting various thicknesses of wire and enamel, known as *moriage cloisonné*, stimulated further interpretation of the art with the use of transparent enamel. *Plique-à-jour*, a backless enameling that imitates stained glass, used the cloisonné wire as a supporting frame to suspend the enamel. Namikawa Sôsuke (1847–1910) went one step further: Using the creative technique of wire-less cloisonné, in which the wires are pulled out before firing, he produced soft naturalistic scenes of flowers, birds, and landscapes. Today, multicolored enameling is recognized as a Japanese art form that thrived in the Meiji period (1868–1912), and decorative pieces from that era demand top dollar. AGP

**Cadmium revisited.** M. Plotnick, *American Jewelry Manufacturer*, Vol. 40, No. 3, March 1992, pp. 89–98.

The use of cadmium in jewelry arts has come under fire from the U.S. Occupational Safety and Health Administration (OSHA). Cadmium, which is used in such techniques as the soldering and casting of white metal alloys, has been linked with several health problems, such as restrictive lung disease, lung cancer, and kidney filtration problems. Consequently, OSHA is formulating new regulations for cadmium that are the most restrictive ever. They would like cadmium fumes reduced from current levels of 100 micrograms per cubic meter of air, and cadmium dust from current levels of 200 micrograms per cubic meter of air, down to “either 1 or 5 micrograms per cubic meter of air . . . with no differentiation between fumes and dust.” OSHA also proposes that short-term exposure not exceed “either 5 or 25 micrograms per cubic meter of air in a 15 minute period.”

One company, Armbrust Chain Co., in Providence, Rhode Island, coats its chains with talcum powder to help prevent them from sticking together in the furnace. However, the cadmium-bearing solder then contaminates the talcum powder. When the talcum powder is removed from the jewelry, it must be safely discarded, a problem that still has not been resolved satisfactorily.

At this time, there is no way to properly dispose of this metal outside of a landfill. “According to the Environmental Protection Agency regulations, if more than one part per million of cadmium is found by standard toxicity metal testing procedures, it will not be acceptable for disposal in a sanitary landfill. Instead, it must be disposed of as a hazardous waste in a secured landfill, where it costs more than \$200 to dispose of a 55-gallon drum containing talcum powder.”

The author recommends precautions to take when soldering with cadmium-bearing materials, such as good ventilation, clean metals, and sufficient flux. It is also important to heat metals broadly and uniformly so that the possibility of producing dangerous fumes is lessened. The author further discusses the pros and cons of alternative metals, such as cadmium-free alloys and indium, that can be used in place of cadmium. KBS

**Crystal-clear genius.** D. Scarisbrick, *Country Life*, January 2, 1992, pp. 48–50.

This brief but informative article describes a recent exhibit of jewelry by René Lalique at the Musée des Arts Decoratifs in Paris. Scarisbrick manages to condense Lalique's background, stylistic influences, use of unusual materials in jewelry, and descriptions of specific pieces into three pages. The exhibition displayed jewels and artwork from many sources, both public and private, including the Gulbenkian collection and the collection of the museum itself, to show Lalique's evolution from traditional jeweler to undisputed leader of the Art Nouveau jewelry movement.

Although much of what is covered will be familiar to those knowledgeable about Lalique, there are a few "new" pieces from private collections, such as a mermaid tiara of opal and patinated bronze, and a dog collar of rock crystal with gold cats and larch trees. Seven color photos augment the text. EBM

#### **The Islamic influence in European and American jewelry.**

J. Zapata, *Antiques*, Vol. 162, No. 3, 1992, pp. 360–368.

Because cultural differences and distance kept the countries of the East and the West separate, forms and motifs of ornamental design developed independently for centuries. Not until the late 19th century did the two cultures begin to interact. The 1851 Great Exhibition in London played an important role in influencing both jewelry design and craftsmanship. European artists, manufacturers, and the public were exposed to Islamic collections, primarily those from India. The characteristic patterns of flowing lines, vibrant fused colors, and combinations of different materials within a single Islamic piece soon made their way into the works of Western designers.

The Western application of the Eastern-inspired floral motif strongly contributed to jewelry design in the late 1800s. Carlo Giuliano (1831–1895) and his son, Arthur (1864–1914), drew heavily on Indian styles of colored gemstones and enamel, but they reversed the emphasis for their London clientele. In traditional European jewelry, gemstones dominate the piece, whereas the Eastern manner is to use gemstones and pearls as enhancements.

In Paris, Jacques Cartier (1884–1942) brought Islamic ornamental designs fully into the 20th century. Derived from the linear style of Islamic art and architecture, Cartier's designs flourished in the Art Deco period. A frequent traveler to India, Cartier established an intimate association with Indian royalty and gemstone brokers. Marked by complexity of ornament, his pieces—which often used Indian emeralds and other colored gems—were accented with elaborate enamel and gold work. As the Europeans gained recognition at international exhibitions, American manufacturers were quick to pick up on the trend and produce their own collections. AGP

## **JEWELRY RETAILING**

**Colour combinations strongest trend.** C. Kremkow, *Jewellery News Asia*, No. 94, June 1992, pp. 62, 64.

The jewelry industry has been enjoying an increased demand for designs that incorporate more color, thanks to the emphasis on color in women's clothing. Colored stones are not just being used individually, but in complementary and contrasting combinations to add interest and style. In addition to the variety that color combinations offer, consumers have also discovered up-to-date designs incorporating the classic cabochon as well as the new bullet, tongue-shape, and strong geometric (square and triangular) cuts. Designers are also using more uncut crystals, finding that natural surfaces contrast well with polished metals. Five color photographs illustrate the article. JEM

**FTC guides: Ready for action.** *Jewelers' Circular-Keystone*, Vol. 163, No. 8, August 1992, pp. 150–152.

Proposals for changing the current "Federal Trade Commission Guides for the Jewelry Industry" finally have been made, and the industry is now being asked to comment on 34 key questions. The questions are laid out in this brief yet complete article, with an address to which participants can respond. The future guides, as currently proposed, would cover appraisers, graders, consultants, and sellers of jewelry products. They would, for the first time, cover pens, pencils, and optical frames that contain gold. The Jewelers' Vigilance Committee believes in the usefulness of the guidelines and recommends that they be "read carefully by everyone in the industry." This article provides a good start on learning about the proposed changes, which include issues such as misleading modifiers of the term *synthetic*, disclosure of fracture fillings, and source of certificates. KBS

**Van Gogh meets Van Cleef.** A. Gold, *American Jewelry Manufacturer*, Vol. 40, No. 7, July 1992, pp. 43–48.

This informative article offers innovative ideas for marketing jewelry to museum gift stores—which provide a growing market for original, adaptive, and reproduction jewelry.

The author attributes the growth of the museum gift store to greater pressure on museums to find optional sources of revenue, particularly in recessionary times. Sources indicate that jewelry sales may account for up to 25% of a museum shop's annual income, depending on store size and the scope of its collection. Handsome catalogs and satellite stores help promote the store's merchandise even further.

Museum-store sources include in-house workshops, local artists, manufacturers, and gift, jewelry, and craft shows. Some museums do everything in-house, whereas others develop their own designs and work with small manufacturers to produce exclusive pieces. However the



jewelry line is assembled, it should relate in some way to the museum's collection. Reproductions should be as accurate as possible, and adaptations should retain a sense of the original piece.

Generally, museum shops set fairly high production standards, and attention to detail is crucial. Ideally, the jewelry should correlate in period with featured exhibitions.

Most jewelry sales from museum stores fall into the moderate retail price range. Sterling and vermeil do particularly well, since people tend to view these materials as "genuine," but careful buying and merchandising can also provide good opportunities for karat-gold pieces with or without gemstones. JEC

## PRECIOUS METALS

**Gambling on gold.** L. Malkin, *Town & Country*, Vol. 146, No. 5148, September 1992, pp. 56, 62, 64.

The troubled economies of various countries have placed pressure on their currencies and lowered the value of their gold holdings. As inflation has discouraged investing, economic growth has evaporated and the gold market has slid to record lows. For three years, gold has held steady at US\$350 an ounce. Malkin argues that gold is not likely to ever again reach its all-time high of \$843 an ounce. Gold production has become an unprofitable business, what with rising costs of mining, depleted sources, and disinterest in further exploration. Another significant factor is the uncertain political and economic future of the Russian and South African governments, who together hold 44% of the world's gold supply. Investors advise that only 5% of a personal portfolio be invested in real gold purchases or gold stocks. The strongest recommendation is for gold funds, which yield interest mainly through holdings in stocks of recognized gold-mining companies. AGP

## MISCELLANEOUS

**House on a hill.** C. McCarthy, *Lapidary Journal*, Vol. 46, No. 85, August 1992, pp. 26-31.

The Hillwood Museum, located in Washington, DC, is one of the largest holders of Russian art outside the former Soviet Union. Once the home of Marjorie Merriweather Post, heiress to the Post cereal fortune, it contains many objects that were purchased in the late 1930s when her husband, Joe Davies, was the U.S. ambassador to the Soviet Union. The author focuses on the gem and mineral collection.

Discussed in depth is Fabergé, his artistic philosophy and style, and the types of material in which he worked. The museum's Fabergé holdings include decorative gold and stone boxes, imperial Easter eggs, animal carvings, bell pushes, and seals. Displayed next to Fabergé's works are more opulent versions from his contemporaries.

The museum also contains chandeliers and cande-

labra with rock-crystal drops; objects made from malachite mined in the Ural Mountains; two 18th-century chests of carved walrus ivory; and Orthodox Christian icons and ecclesiastical objects decorated with enamels, bloodstone, chalcedony, nephrite, carnelian, and diamonds; among many other items.

Those interested in touring Hillwood must make reservations in advance; a small fee is required. Seven color photographs illustrate the article. RT

## Gemstone photography: Capturing the beauty.

R. Weldon, *Jewelers' Circular-Keystone*, Vol. 163, No. 9, September 1992, pp. 54-57.

If you want to learn the basics of gemstone photography, read this article! Cameras, f-stops, lenses, bellows, different film types, and lighting are discussed in this first in a two-part series on gemstone photography. Color illustrations show how different conditions yield different results, and a helpful chart guides the neophyte gem photographer through the interplay of films and lighting. Mr. Weldon concludes by pointing out that gemstone photography is not an exact science, and requires experimentation for best results. KBS

## The mineral collection of John Ruskin in the Ruskin

Gallery, Sheffield. J. Barnes, *U.K. Journal of Mines & Minerals*, No. 11, 1992, pp. 26-29.

Although John Ruskin (1819-1900) is not immediately remembered for his interest in mineralogy and geology, his name is strongly associated with the naturalist artistic movement of the late decades of the 19th century. In fact, Ruskin had an acute interest in mineralogy from his early childhood onward, which led him to return repeatedly to the mineral collection of the British Museum and study it intensely.

An ardent mineral collector in his adult years, Ruskin acquired rock and mineral specimens in the course of his travels, or purchased them from dealers. Eventually, he amassed a personal collection of over 3,000 specimens.

While teaching as Slade Professor of Fine Arts at Oxford University, Ruskin became concerned with the lack of educational opportunities among working people and ultimately founded the Guild of St. George. In 1875, under the patronage of the guild, he established an educational museum in Sheffield, the St. George's Museum, in which he placed much of his mineral collection. Ruskin also donated collections of minerals to various institutions, and gave specimens of diamond and ruby to the British Museum.

The present collection at the Ruskin Gallery in Sheffield contains approximately 2,000 mineral specimens, many of excellent quality. The pieces on display occupy two showcases. The collection features quartz-variety minerals, as well as Hungarian opals, Siberian blue topaz, Kongsberg silver, emerald crystals in matrix, and an interesting suite of fluorite. JEC