

Gems & Gemology

VOLUME XXII

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Gems & Gemology

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ABOUT THE COVER: Currently one of the most productive, if little known, emerald mines in Colombia is the Coscuez mine. The 14.52-ct emerald illustrated here shows the highly saturated bluish green color that is characteristic of emeralds from this locality, which lies only 10 km from the famous Muzo mine. Ron Ringsrud's article in this issue takes a comprehensive look at Coscuez, its history, geology, mining activities, and the emeralds found there. Photo © 1986 Harold & Erica Van Pelt—Photographers, Los Angeles, CA.

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THE COSCUEZ MINE: A MAJOR SOURCE OF COLOMBIAN EMERALDS

By Ron Ringsrud

The Muzo emerald district, in Boyacá, Colombia, contains several mines. Although the Muzo mine is undoubtedly the best known, the Coscuez mine is rapidly gaining significance as a major source of fine emeralds. Yet few in the trade outside of Colombia are aware of the importance of Coscuez or know about the emeralds mined there. The Coscuez mine is literally hundreds of years old, and its history is closely tied to that of Muzo. Located only about 10 km apart, the two areas also share many geologic features and both are currently exploited using open-cut mining methods. The Coscuez emeralds are similar to Muzo stones in their physical properties, but they occur in a somewhat broader range of hue and saturation. Prospects for even greater production at Coscuez in the future are good.

ABOUT THE AUTHOR

Mr. Ringsrud is a major partner in Constellation Gems, Inc., an import firm specializing in Colombian emeralds, which is headquartered in Los Angeles, California.

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Whenever fine emeralds are discussed in the gem trade, the term *Muzo* is invariably used to describe the best. Yet Colombia's Muzo district actually encompasses several mines, of which two are currently major producers: Muzo and Coscuez. Many stones properly referred to as "Muzo emeralds" actually come from Coscuez (figure 1), which lies only 10 km from the Muzo mine (figure 2). Although smaller than Muzo, the Coscuez mine has for more than 300 years produced some of the best emeralds from the Muzo region, at times in quantities that have even surpassed the Muzo mine.

Five years ago, *Gems & Gemology* published an article outlining the history, geology, and production of Colombia's two major emerald-mining regions: Muzo and Chivor (Keller, 1981). Soon after that article appeared, however, production from the Chivor region began to fall, while that from the Coscuez mine accelerated rapidly. During this same period, the Muzo mine continued to supply good quantities of emeralds. Today, most of the emeralds mined in Colombia come from the Muzo district, and the Coscuez mine has grown to become the second largest producer of emeralds in Colombia.

Yet in spite of its prominence, little has been written specifically on Coscuez or the Coscuez emeralds in the jewelry and gemology literature, and few in the trade outside of Colombia are aware of its importance as a major source of fine emeralds. In March 1984, the author traveled to Coscuez in the company of local dealers; two years later, in May 1986, he revisited the mine as a guest of Colombian Mines Co., a major stockholder of ESMERACOL, the present leaseholder of the Coscuez mine. Based on information gathered during these visits as well as from other sources, this article reviews the fascinating history of mining at Coscuez, describes the geology of the area and the nature of mining operations, and examines the gemology of the Coscuez emeralds.



Figure 1. The emeralds (weighing 1.76 and 5.19 ct, respectively) in these two rings represent some of the brighter, cleaner material found at the Coscuez mine, a major source of emeralds in the Muzo district of Boyacá, Colombia. Jewelry courtesy of Constellation Gems, Inc.; photo © Harold & Erica Van Pelt.

HISTORY

Much interesting history about the Spanish discovery and conquest of the emerald regions of Colombia was published in 1948 by the Bank of the Republic after it took over the administration of emerald mining from the government. The author was G. Otero Muñoz, head of the Colombian Institute of History. Unlike many other publications, *Esmeraldas de Colombia* provided considerable information specifically on Coscuez. Much of what follows is from this source.

In their conquest of South America, beginning in the 16th century, the Spaniards encountered Colombian emeralds among the local Indians as far north as Mexico and as far south as Peru and northern Chile (Sinkankas, 1981). Judging from the emeralds found in these ancient Indian sites, archaeologists believe that pre-Colombian tribes began to systematically mine and trade emeralds as early as 1000 A.D. (Sinkankas, 1981). In the region near present-day Bogotá, Spaniards led by Gonzalo Jimenez de Quesada easily conquered the Chibcha and Fusagasugae Indians. From the Chibchas, the Spaniards learned of an emerald mine at a place called Somondonco, which they located in 1537 and later renamed Chivor (Wokittel, 1960). The Chibchas also told them of another rich emerald area to the northwest. But to penetrate this region, the Spaniards would first have to subdue a far more formidable tribe: the Muzos. The Muzos were known as the most warlike, ferocious, and valiant Indians in the region, and further were reported to be cannibals. They were famous not only for their poison arrows, but also for their hidden

jungle traps, camouflaged pits, and numerous fortifications.

The Muzos inherited from their ancestors the ancient legends surrounding the Fura-Tena, a colossal pair of granite peaks (the tallest is 625 m above the Minero River), approximately 40 km from the Coscuez mine. As one approaches from the east, the Fura-Tena looms up majestically as a sentinel to all who enter the emerald region. One Muzo legend states that Fura is the prince and Tena is the princess, both born to the god of the mountains. The god gave them wealth in the form of rich veins of emeralds, one of which was sacred and not to be touched. A devil named Zarv convinced the princess to take the forbidden stones. As she and the prince attempted to remove the cursed emeralds, the god turned them into the two granite peaks, and their tears of remorse became the Minero River.

In 1538, Spanish Captain Luis Lanchoero launched the first campaign against the Muzo Indians (Piedrahita, 1881). Although Lanchoero was forced to retreat after much fighting, accounts of the campaign show that while butchering local wild turkeys for food, he and his soldiers found small emerald crystals in the caws. This was more than enough incentive to convince the colonial governors to continue attempts to conquer that region. More campaigns were launched against the Muzos in 1545, 1550, and 1551, but these too were ultimately unsuccessful.

In 1558, however, Lanchoero reentered Muzo territory with a force consisting of Spanish soldiers and members of local tribes that were also at war



Figure 2. The Muzo and Chivor emerald-mining districts in Boyacá, Colombia. Note the proximity of the Coscuez and Muzo mines to each other.

with the Muzos. Up until this confrontation, the steel swords, armor, and firearms that had been adequate to conquer local Indian tribes throughout much of the continent had not been enough to subdue the Muzos. Their defeat was ultimately brought about by Lanchero's timely use of a new weapon: ferocious European hunting dogs. When the dogs were turned loose in mid-battle, they created havoc and confusion in the ranks of the Indians (figure 3). In two costly and decisive battles, Lanchero and his forces finally succeeded in

bringing the land of the Muzos under Spanish control.

Following their success, in 1559 Lanchero's men created a settlement close to where the Indians' emerald mines were supposed to be and called it Santísima Trinidad de los Muzos. Captain Lanchero and his men soon located the mines and began to work them in the name of the Spanish Crown. Coscuez, named after an Indian princess, had been worked by the Indians for centuries prior to the conquest and was undoubtedly one of the

first located by the Spaniards. Ironically, a chest wound that Lanchero had received more than two decades earlier in his first battle with the Muzos had never healed, and in 1562 it turned gangrenous and killed him. Yet the value of the legacy he left was evident in the eventual establishment of a royal counting house, a royal treasury, and numerous cathedrals in the town of Muzo. The cost to the Muzo Indians, however, was dear: Enslavement to work the mines and exposure to new diseases introduced by the Spaniards killed thousands. Eventually the loss of slave labor led to a steady decline in emerald production, and the seat of local government was moved from Muzo to Tunja.

Spanish records indicate that in July of 1646 there appeared in the city of Muzo a Captain Francisco de Ovalle, carrying a royal seal that named him Lord of Mines and overseer of all that he discovered in the Coscuez heights "as long as the rocks there show the green of the emerald." This situation caused some official confusion at first, because the mine was already known and being worked by others. In those days, however, the governorship changed hands frequently, and in 1647 the new governor accepted the captain's claim. This is one of the first instances on record where the Coscuez mine was considered separately. Up until this time, in the history recorded by the Spaniards as well as in the government concessions and leases, the Coscuez mine was included with Muzo.

During the colonial period, the miners extracted the emeralds simply by following the good veins with tunnels. At Coscuez, a magnificent 18-oz. (550-ct) crystal was extracted by this method, and was reportedly sent to a museum in Madrid. In the mid-1600s, a large cave-in at the Coscuez mine buried almost 300 Spaniards and Indians. Work in the area was abandoned soon after. Two centuries later, in 1850, mining operations uncovered the same tunnel complete with the bones of the victims and their bamboo and metal tools (C. Torres, pers. comm., 1986). The vein became known to the miners as the Dead Man's Underpass, and today goes by the name El Español (The Spaniard).

In 1824, the newly independent government of Colombia leased the mining area around Muzo to Colombian mineralogist José Ignacio Paris, who controlled the mining operations for the next 22 years. During this period, acting on the advice of English mining engineer George Cheyne, Paris

changed the operation at Muzo from tunneling to open-cut mining, using a form of benching, that is, cutting the slopes horizontally in a step-like fashion and washing away the resulting debris with water. Because water was not as readily available, Coscuez was worked less extensively at this time, and mainly by tunneling. Paris is remembered today primarily for his part in the discovery at Muzo of the mineral parisite, a rare fluorocarbonate of cerium that was named in his honor. After Paris, a number of foreign and Colombian lessees continued to work the deposits with varying degrees of success. Little has been recorded about activity at Coscuez during the latter half of the 19th century except that it was repeatedly worked, abandoned, and reopened (Pogue, 1916; Oppenheim, 1948).

RECENT HISTORY AND PRODUCTION

The Muzo mine was responsible for most of the emeralds produced in the district from 1925 until it was closed again in 1938. In 1946, the Colombian government turned responsibility for the mining and marketing of all emeralds over to the Bank of the Republic. The bank was unable to maintain tight control, however, so illegal mining and black marketing of emeralds flourished. Finally, in 1969, the government formed ECOMINAS (Empresa Colombiana de Minas—Colombian Ministry of Mines) to control the mines. In 1977, private companies were sought to work the mines on a five-year lease arrangement ("Coscuez, an Emerald Mine Reborn," 1979). The Coscuez lease was awarded to ESMERACOL, a company whose present major stockholders are Colombian Mines Co. (a Bogotá-based cutter, broker, and exporter), Victor Quintero (who also runs the Chivor mine), Jaime Murcia, and the family of the late Juan Francisco (Pacho) Vargas.

Through ECOMINAS, the Colombian government records the number of carats of emeralds legally exported each year. Until 1968, totals for many of the individual mines were reported; since then, inexplicably, records show only totals exported from all mines. In addition, illegal mining and unreported exporting diminish greatly the reliability of the official statistics. It is not surprising, then, that the author was unable to obtain any accurate, detailed production figures, either from the government offices or from the mine officials. However, trends can be seen in the ECOMINAS



Figure 3. Adorned with emeralds, the Muzo Indians fought the Spanish invaders fiercely. Ultimately, European hunting dogs were a deciding factor in Captain Luis Lanchero's defeat of the Muzos in 1558. From Otero Muñoz (1948). Reproduced by permission of the Colombian Institute of History.

records that substantiate the recent decline in production from the Chivor mine, continued strong production from the Muzo mine, and significantly greater production from the Coscuez mine. For example, totals in the ECOMINAS production registry show that the Chivor mine averaged 10,000–40,000 ct of gem-quality emeralds per year during the 1920s and 1930s, and 10,000–20,000 ct annually until 1963, when production dropped and stayed low. Dealers in Bogotá who are familiar with the market reported to this author that in the 1960s and 1970s Chivor production was erratic—with some good and some bad years—but that it has stayed low since 1980.

ECOMINAS records show that Muzo also averaged 10,000–40,000 ct of gem-quality emeralds

per year during the 1930s and 1950s, but that production increased after 1963. Dealers in Bogotá estimate that Muzo is currently producing several hundred thousand carats of emeralds annually. Production at the Coscuez mine, unreported until 1960, exceeded 25,000 ct in 1963, even surpassing Muzo for that year. Mr. Samuel Gad, a major partner in Colombian Mines Co., estimates that more than 150,000 ct of emeralds per year are now being mined at Coscuez (pers. comm., 1986).

LOCATION AND ACCESS

The Andes Mountains begin in southern Chile and define the entire western edge of South America until they reach Colombia in the north, where the chain divides into three prongs covering the west-

ern portion of the country. The world's richest emerald-bearing region straddles the easternmost prong, known as the Cordillera Oriental. The Muzo district lies due north of Bogotá, the capital of Colombia, in the northern part of this emerald-bearing zone. The Muzo and Coscuez mines lie within 10 km of each other in the state of Boyacá (at 5°33'N, 74°11'W and 5°39'N, 74°11'W, respectively). Access to the mining region from Bogotá is accomplished by helicopter, traveling approximately 105 km (70 mi.) due north, or by field vehicle, traveling 260 km over what are primarily winding paved and unpaved roads that descend from the high flat plain on which the capital city is situated to the mountainous subtropical terrain of the lower altitudes.

The Muzo mine is about 800 m (2,625 ft.) above sea level and the Coscuez mine, 1120 m. In both places, the land is fertile and the vegetation thick. The weather at both mines is warm, although the heat at Muzo—which lies in a natural valley, sheltered from the wind—can be oppressive.

In spite of their close proximity, Muzo and Coscuez are not connected by any road. To get to Coscuez from Muzo by automobile, one has to go 90 km east and then, just before Chiquinquirá, take a second road northwest for approximately 90 km. A narrow footpath between the mines can be traversed in less than five hours. This path, as well as the roads that lead to the mining areas, is used only by the locals in that specific region. Territoriality is strong and has resulted in many local rivalries and skirmishes. Until conditions change, these areas should be visited only with extreme caution and in the company of local residents.

GEOLOGY

The Coscuez mine (figure 4) is one of several mines in the Muzo district, which also includes the Peña Blanca as well as the famous Muzo mine. The mines in the district are located within roughly 30 km of one another. Despite this close proximity, there is no evidence that the mines are linked in any way or that they are part of one continuous deposit. However, an understanding of the local geology has been hampered by the dense vegetation, rough topography, and limited detailed scientific study of the entire area. Further investigations under way may reveal a more direct relationship between the separate emerald deposits.

The geology of the Muzo district has been de-

scribed by several authors, including Pogue (1916), Schiebe (1933), Clements (1941), and Oppenheim (1948). This work is summarized in Sinkankas (1981) and Keller (1981). In general, the district is underlain by a great thickness of shales of early Cretaceous age. These shales are intensely folded. In addition, the area is transected by a number of northeast-trending faults that are accompanied by zones of brecciation.

Historical observations along with recent studies of these faults have shown that they are frequently concentrated at locations either of existing emerald mines or areas of emerald mineralization. Thus, plans are under way to use fault patterns as promising exploration targets in future prospecting for emeralds in the Muzo district and in surrounding areas in this part of Colombia. On a more local scale, experience has shown that areas of emerald mineralization are indicated by certain changes in the color or texture of the host rock or by areas of water seepage from the rocks which may indicate the presence of a fault.

In the Muzo district, the geologic formation in which the emeralds are found is known as the Villeta formation of Lower Cretaceous age (120–130 million years old). This formation and other sedimentary rocks in the area are rich in fossils, thus allowing for their age dating. The Villeta formation consists of a great thickness of black, carbonaceous shales and minor amounts of limestone. As with the other rocks in the district, the rocks of the Villeta formation have been intensely folded, faulted, and fractured. The Villeta formation was divided into two members by Lleras (1929). The underlying member consists of black carbonaceous shales and thinly bedded limestones. The overlying member is composed of black to yellowish gray shales. Locally, these two members are separated by two thin layers, which consist of calcite and minor quartz in a matrix of fine limestone cement; the difference between the two layers is principally textural.

As at Muzo, the rocks of the Villeta formation at Coscuez are cut by numerous calcite veins that partly or completely fill fractures in the sediments. The veins vary up to 35 cm in thickness and up to several meters or more in length. Having formed along fractures in the host rock, the veins are oriented in various directions within the rock but often cut across the original bedding plane of the sediments. The orientation of the veins can, however, often be directly correlated with the local

Figure 4. This view looking northeast at the Coscuez mine reveals both the rugged topography of the region and the relatively small area of exploitation of the mine. Photo by Jack Rotlewicz.



pattern of fracturing in the rock. In some instances the veins intersect. The fractures are generally filled by the calcite vein material, but occasionally there are open cavities within the calcite which may contain free-standing crystals.

For the most part, the emerald crystals are found with the calcite along these fractures in the shale and limestone. The shale and limestone are

often discolored, with a yellowish gray appearance, in the area of the mineralized calcite veins. The emerald crystals usually occur attached to the wall of the fracture and are surrounded by calcite, or they may be embedded within the calcite itself. Field observations indicate that the best-quality emeralds seem to be found in the narrower veins (5–10 cm thick). Barriga Villalba (1948) hypothe-



Figure 5. Below Coscuez, the Túnel la Tabla penetrates 600 m into the mountain as the miners follow the emerald-bearing calcite veins. Note the plastic tubes used to deliver air into the tunnel. Until recently, tunneling was the principal method of mining at Coscuez.

sized that this might be due to the mineralizing solutions and gasses entering the narrow fissures with higher pressure, providing for better crystallization, but this has not been further evaluated. The crystals are randomly distributed, but locally concentrated, within the calcite veins and can occur either singly or in groups. Associated with the emerald in the calcite veins are minerals such as pyrite, quartz, dolomite, parisite, and (rarely) fluorite, apatite, albite, and barite. "Trapiche" emeralds, as well as both dolomite and pyrite, are more common at Muzo than they are at Coscuez. Although the surface area of the Muzo mine is 10 to 15 times larger than Coscuez, the latter has a greater concentration of emerald-bearing veins.

The origin of the Coscuez, Muzo, and other emerald deposits in this region has long been the subject of geologic study but as yet has not been satisfactorily explained. Following their deposition, the sedimentary rocks of the Muzo district were subjected to a period of folding, faulting, and metamorphism. During these events, hydrothermal solutions appear to have been derived from within the sediments or from unidentified igneous sources. These solutions leached beryllium and other elements from the rocks occurring over a large area. Moving along zones of weakness in the rocks, such as fault zones, the solutions deposited emerald and other minerals along fractures in the metamorphosed sediments. Although there is

general agreement as to the basic features of this model of emerald formation, many questions await answers from further geologic study.

MINING

Historically, the rugged topography and steepness of the mountain on which the Coscuez mine is located have made access to Coscuez more difficult than Muzo (figure 4). In addition, the emerald-bearing sedimentary rock at Coscuez is somewhat harder than that found at Muzo. The harder host rock, along with the fact that Coscuez does not have abundant water available, has made open-cut mining difficult until relatively recently. Tunneling has been the chosen mining method throughout the history of Coscuez. One tunnel, begun privately over 19 years ago, penetrates 600 m upward and into a mountain close to the main mine area (figure 5). The tunnel follows emerald-bearing calcite veins and has produced enough in the past to keep a small group of locals occupied working it today. As heavy machinery became available in recent years, the more efficient open-cut mining became possible. Now the mine is worked with five bulldozers and some limited use of dynamite (figure 6). As the potentially emerald-bearing calcite veins are uncovered, they are checked by the miners with picks and then worked by hand if emeralds are found (figures 6 and 7).



Figure 6. Today, the mine owners at Coscuez use bulldozers to retrieve the emeralds more quickly and efficiently by the open-cut method. The bulldozers clear layers of black shale until the potentially emerald-bearing veins of white calcite are uncovered. On the right, a lone miner searches the white calcite for emeralds. Photo by Jack Rotlewicz.

Figure 7. These Coscuez miners use picks to search for emeralds in the white calcite veins uncovered by the bulldozers.



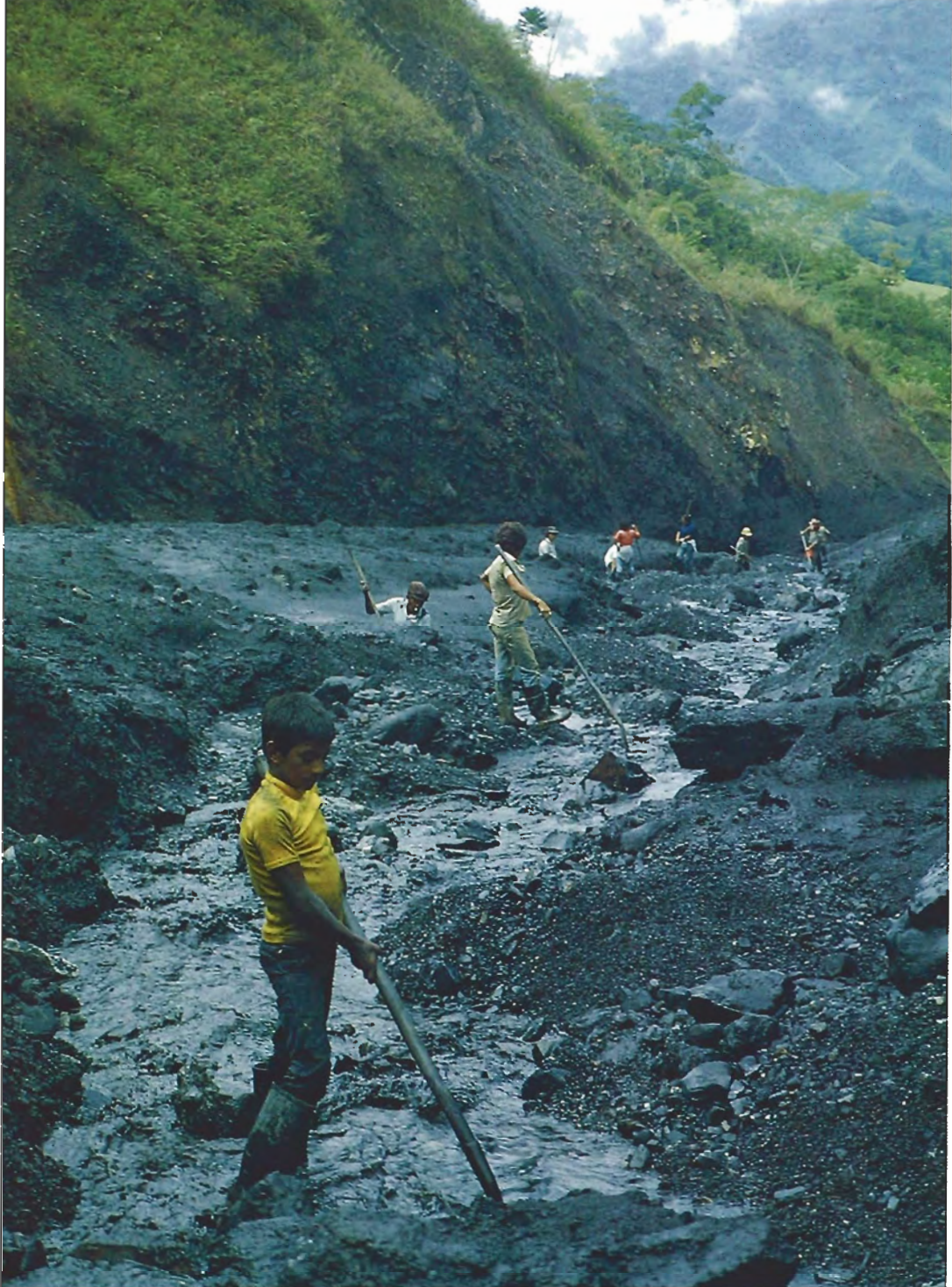


Figure 8. Independent *guaqueros* at Coscuez search for emeralds in the mine tailings that have been dumped into the small stream called La Culebrera. Whereas the Itoco River below Muzo has been known to support as many as 10,000 independent miners (see Keller, 1981), the author saw only 50 people working La Culebrera during his most recent visit.

The problem of the lack of abundant water at Coscuez has lately been mitigated by the construction of reservoirs fed by pumps at the upper levels of the mine. This water is released regularly into various channels to help flush and move large amounts of mine tailings. Below the main mining area, where the tailings settle, springs and small streams feed a winding stream called La Culebrera (the Serpent Pit), referring either to the winding nature of the stream or to the rough reputation of the local independents who dig for emeralds in it. La Culebrera widens after a few hundred meters

and at that point is called La Colombina, which runs north into the Quebrada La Caca, which then feeds the Minero River. Many of the mining wastes are pushed by bulldozers into La Culebrera. Because the terrain at Coscuez is so steep, the mine tailings are much easier to remove here than at Muzo.

All of the mines in Colombia share to differing degrees the problem of numerous local *guaqueros* ("diggers for treasure"), who live by selling whatever emeralds they can poach near or in the mines. In Muzo, *guaqueros* gather in the Itoco River. The

tailings from the mine are washed by the river and yield enough emeralds to support up to 10,000 people. The mine owners stay within the mine and the *guaqueros* generally stay at the river. In Coscuez, however, there is no river, only La Culebrera. Although local miners report that the stream can support more than 2,000 people, the author has seen only 50 or so (figure 8). It is more common in this area that the *guaqueros* enter the mine property at night and dig numerous tunnels in search of emeralds (figure 9). Territorial disputes among the *guaqueros* make security and control a problem in both Muzo and Coscuez, but with a stream that supports only a small number of people and a smaller surface area to exploit, the job of securing Coscuez is more difficult. It is interesting to note that the *guaqueros* of this region consist mainly of descendants of the Muzo and Colima Indians. The reputations that the *guaqueros* at the different mines have of aggressiveness and hostility tend to correlate directly with how deeply into the territory of the Muzo Indians the mine is found. Chivor and Gachalá, which are outside of what was once the territory of the Muzos, are relatively safe mines and can even be visited by tourists. The Muzo mine, to the north, in Muzo territory, is considered dangerous for visitors, and Coscuez slightly more so. North of Coscuez, the Peña Blanca mine is deepest in the heart of the Muzo Indians' old territory and correspondingly has by far the worst reputation of all the mines for danger and hostility among the locals.

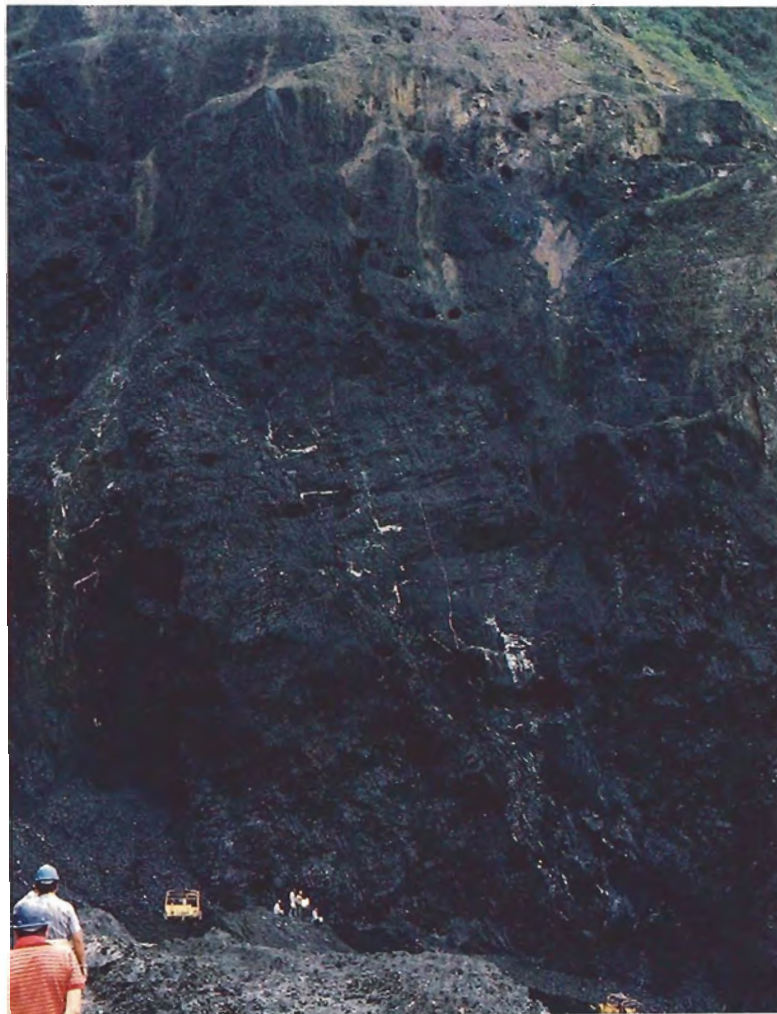
GEMOLOGY

Crystallization. Observations by local miners have suggested that the Coscuez emerald can occur in more complex crystal forms than the Muzo emerald. While both mines produce many simple prismatic crystal forms, at Coscuez are found a large number of emeralds that are aggregates of three to six or more crystals all with individual terminations (figure 10). The faces tend to be brilliant with little or no etching. The crystals found at Muzo are generally shorter and less likely to have terminations and aggregates than at Coscuez. This phenomenon may have been caused by a lack of open space in the vein during crystallization, which could have inhibited crystal growth. Oppenheim (1948) speaks of the Coscuez emeralds as being "famous for their exceptional green color and elongated crystals."

Color. In Colombia, the different mines are known to produce emeralds that differ slightly in color,

tone, and clarity. Muzo emeralds tend to be a well-saturated slightly yellowish green, while Chivor emeralds are generally less saturated and more bluish green. Dealers in Bogotá maintain that the best crystals (in terms of clarity and "life") come from Gachalá. About Coscuez, though, these same dealers have a saying: "From Coscuez comes a little of every (Colombian) mine." There is no one specific hue or degree of clarity associated with Coscuez emeralds; rather, a variety of hues occur, some of which are illustrated in figure 11. Sometimes Coscuez crystals are lively, clean, and lightly saturated in color like those from Gachalá, sometimes the material is very bluish like Chivor, and sometimes there is absolutely no difference from Muzo color and quality. However, one type of emerald commonly seen is typical only of Coscuez (but by no means the only material). Using the terminology of the GIA Colored Stone Grading System, this type of Coscuez emerald can be described as a strongly saturated, slightly bluish

*Figure 9. The face of this hill at Coscuez is literally covered with tunnels that the local *guaqueros* have dug in the dark of night searching for emeralds. Photo by Jack Rotlewicz.*



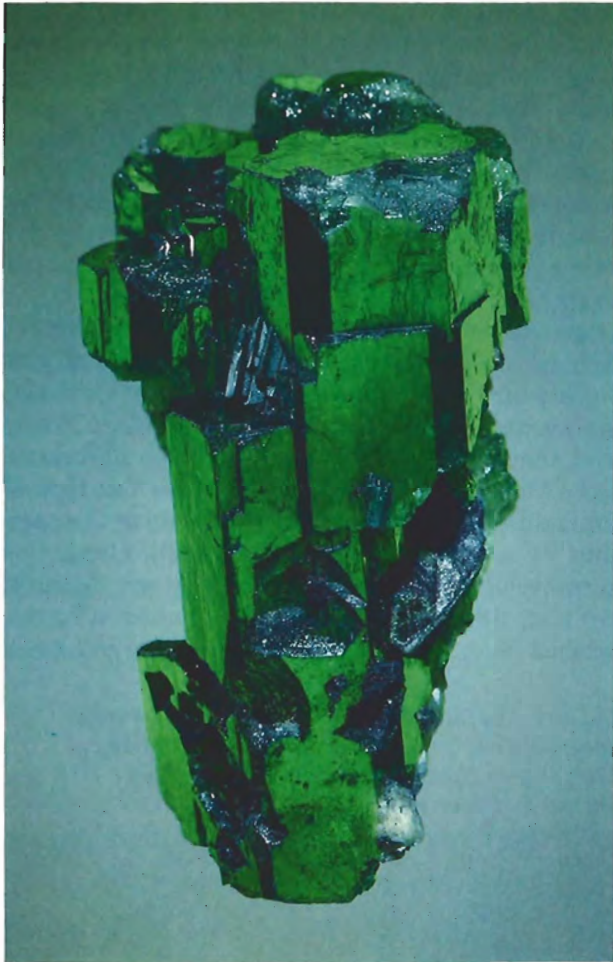


Figure 10. Note the multiple terminations on this 100+-ct emerald crystal from Coscuez. The highly saturated color evident here is also commonly seen in Coscuez emeralds. Specimen courtesy of AMGAD, Inc., New York; photo © Harold & Erica Van Pelt.

green stone with a medium dark to very dark tone. Often the tone is so dark that transparency and "life" are diminished. These stones are still very attractive, especially to those who appreciate strongly saturated color over brilliancy and transparency. Although the best color from Muzo is better than the best from Coscuez, many Coscuez emeralds are among the finest that Colombia has to offer. A top stone from Coscuez recently sold in New York for over US\$25,000 per carat.

It should also be noted that Muzo-mine rough is sometimes extremely color zoned, with a pale central core and darker, more saturated color on the crystal's outer edges or "rind." Coscuez rough, however, is generally uniform in color throughout the crystal.

Physical Properties. The properties of Coscuez emeralds do not vary significantly from those of Colombian emeralds in general: refractive index, 1.574–1.580; birefringence, 0.006–0.007; specific gravity, 2.68–2.71; inert or slightly pink, orange, or red when exposed to long-wave ultraviolet radiation, and inert to short wave; pink to red when viewed with the emerald filter.

Inclusions. A preliminary examination with the microscope of approximately 50 faceted and rough emeralds from Muzo and Coscuez revealed no significant differences in the number or type of inclusions. Emeralds from both sources have two- and three-phase inclusions and the typical internal features associated with Muzo-district material: "coaly" inclusions of carbonaceous matter, as well as calcite, albite, pyrite, quartz, and (rarely) barite, fluorite, and apatite. However, the main "jardin" feature of Coscuez and other Colombian emeralds is simply partially healed fractures. A seemingly endless variety of shapes and sizes of partially healed fractures and voids are found, which suggests interrupted and/or incomplete healing of fractures in the material. However, Muzo stones do seem to have more three-phase inclusions that are visible at lower magnifications (10× to 20×) than other emeralds from Colombia, while the partially healed fractures in Coscuez emeralds seem to be slightly more unidirectional than Muzo stones.

FUTURE POTENTIAL

Because of the difficult terrain and the dense overgrowth, systematic exploration of the Muzo and Chivor emerald districts has never taken place. In 1984, however, ECOMINAS geologists were able to define the boundaries of the potential emerald-bearing region into a polygon that reached from the Chivor-Guavio region to the Muzo-Coscuez region (again, see figure 2). Within those boundaries, analyses of the fault patterns mentioned earlier in this article have revealed several high-probability areas for emerald exploration; some are very close to Muzo and Coscuez, and others are in areas that have never before been explored (A. Florez, pers. comm., 1986).

A cooperative technical survey and study (1984-85) performed by United Nations scientists and Colombian geologists also showed promising results as well as some new geochemical guides for emerald exploration. For regional prospecting, the sodium content of stream sediments was recom-

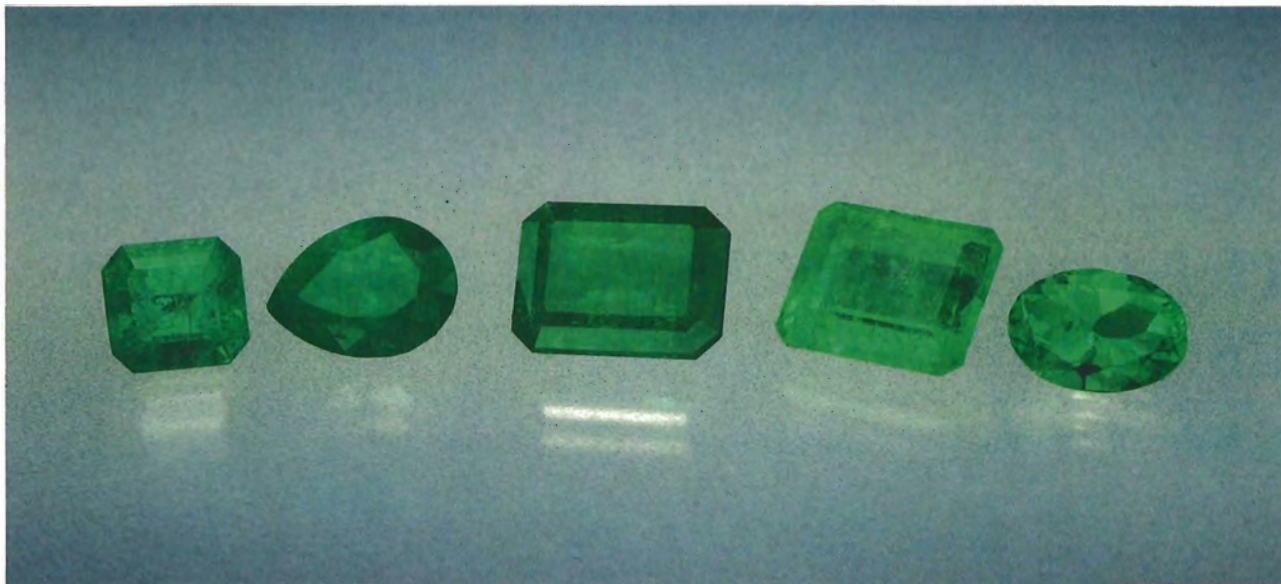


Figure 11. These faceted emeralds illustrate the range of hues, saturation, and "life" seen in Coscuez stones. The 1.69-ct oval stone is reminiscent of Gachalá material, while the 1.89-ct emerald cut at the opposite end and the 4.34-ct emerald cut next to the oval could easily have come from Muzo. The 2.51-ct pear shape and accompanying 4.51-ct emerald cut in the center are of a tone and saturation that comes only from Coscuez. Stones courtesy of Constellation Gems, Inc.; photo © Harold & Erica Van Pelt.

mended as a strong probable indicator of emerald-bearing deposits in nearby rock formations. Guided by the technical report, ECOMINAS geologists will begin prospecting in fall 1986 using the amount of sodium, lithium, and lead found in the soils of various areas as a guide.

Locally at Coscuez, the emerald-bearing sediments are in many places 50 m thick and thus far exploitation has depleted very little of the immediately workable deposits. Promising reserves are abundant, as is the optimism of ESMERACOL officials (J. Rotlewicz, pers. comm., 1986). By contrast, mining at Peña Blanca ceased recently because the emerald beds had been depleted in the main area and solid black shale bedrock encountered (A. Florez, pers. comm., 1986).

CONCLUSION

Because Coscuez lies in the Muzo district, the term *Muzo emerald* can apply to a Coscuez-mine stone. However, the Coscuez mine should be recognized for what it is: one of the world's most important emerald mines and worthy of consideration on its own.

Although there are many similarities in the historical development of the Muzo and Coscuez mines and in the emeralds found there, there are also differences in the geology of the two areas, the crystals produced, and the predominant color and clarity of the stones mined. Studies are currently being conducted by the Colombian government to

better understand the geology of this region and identify new deposits. All current indicators are, however, that the potential for continued strong production of emeralds at Coscuez is good.

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THE ELAHERA GEM FIELD IN CENTRAL SRI LANKA

By Mahinda Gunawardene and Mahinda S. Rupasinghe

Commercially important quantities of gem-quality sapphire, spinel, garnet, chrysoberyl, zircon, tourmaline, and many other gemstones are being recovered from deep gem pits and surface excavations in the Elahera gem field, a region in central Sri Lanka about 115 km northeast of the capital city of Colombo. Large-scale mining is being conducted in this highly metamorphosed sedimentary deposit by the State Gem Corporation in collaboration with the private sector. The chemistry and gemological characteristics of these gem materials are discussed; in many instances, characteristic inclusions were identified by microscopy, microprobe analysis, and X-ray powder diffraction analysis. It is estimated that the Elahera gem field currently provides approximately 35% of the gemstones exported from Sri Lanka. The continued steady production of good-quality gems is anticipated for the future.

ABOUT THE AUTHORS

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The island of Sri Lanka, often referred to as the "jewel box" of the Indian Ocean, has long been one of the major producers of fine-quality gemstones. Recent publications (e.g., Cooray, 1978; Munasinghe and Dissanayake, 1981; Zwaan, 1982) have yielded general information on gem occurrences in Sri Lanka but relatively little on specific gem fields. Although the major gem locality in Sri Lanka is still Ratnapura and its surroundings, Elahera, in central Sri Lanka, has become the second largest gem field.

Since the 1960s, Elahera has produced economic quantities of good to superior sapphire (figure 1), spinel, garnet, chrysoberyl, zircon, and tourmaline, as well as many other gem materials. Some of these stones are now in major museums or in the private collections of some of the world's wealthiest individuals. The poverty of those at the pits and the glitter of those who reap the benefits have been observed by the authors during the past few years and have led to the writing of this article on the history and geology of the Elahera region, as well as the gemology of the many fine materials found there.

HISTORY

Recent archaeological discoveries have revealed that Elahera was an active gem center for many centuries. During the regime of King Parakramabahu, who ruled during the 12th century A.D., even foreigners were allowed to mine in certain parts of the region. Recently, archaeologists excavated the remains of tools used to work the gem pits and even some engraved stones. However, civil wars and foreign invasions eventually forced the people to move to other areas of the country, leaving the troublesome kingdom. The Elahera gem mines were gradually abandoned, many covered over by rice paddies.

During the mid-1940s, a Sri Lankan engineer working on an irrigation project along the Amban Ganga (*ganga* means river) lost a ring along the side of the river

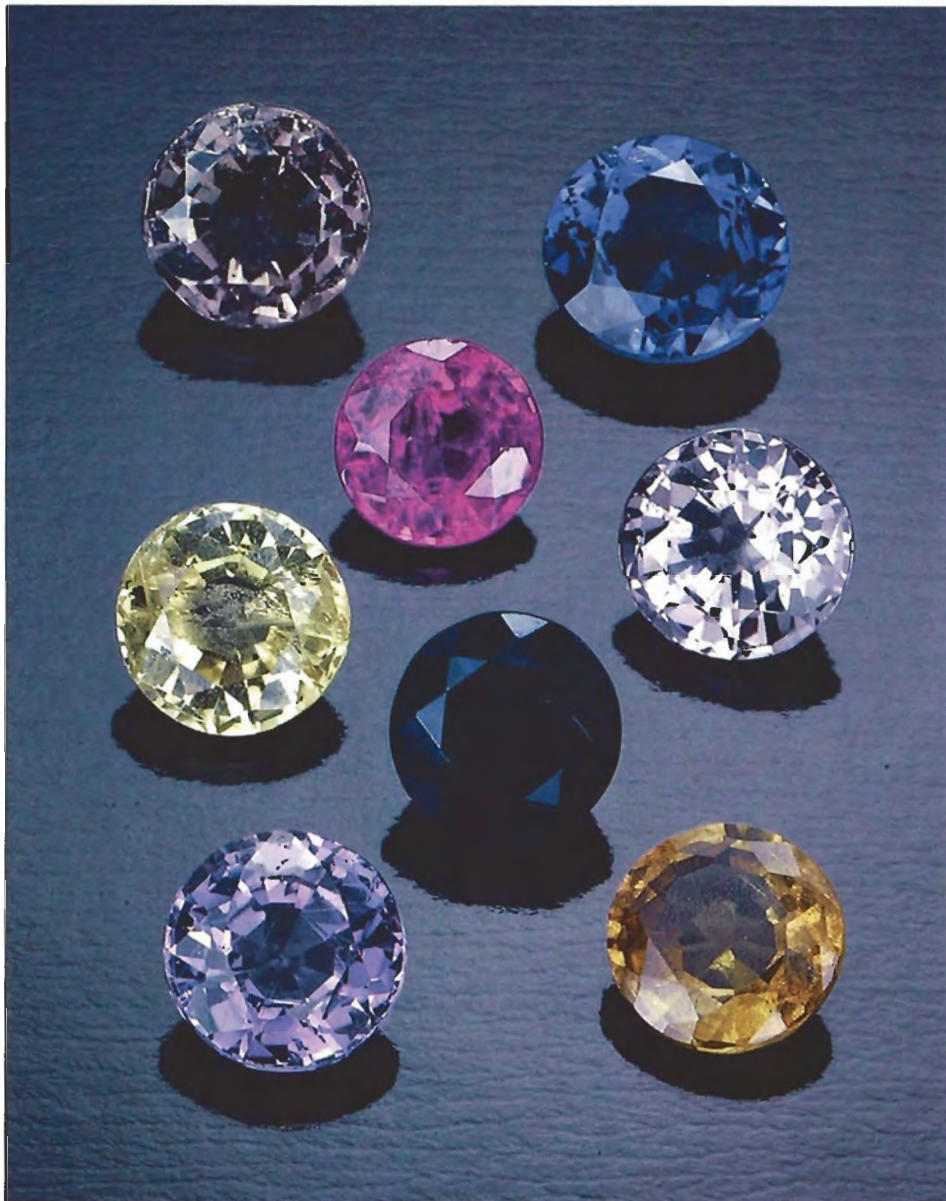


Figure 1. The gem corundums shown here illustrate some of the many colors found at the Elahera gem field, a major source of gem sapphires in the island nation of Sri Lanka. These stones average 1 ct. Photo © Tino Hammid.

while he was bathing. In the process of searching for the lost ring, he discovered a number of blue and red pebbles, which proved to be either corundum or garnets. He soon started mining but kept the discovery secret until early 1950. Around that time, construction workers on the Elahera-Pallegama road (see figure 2) found many pebbles of sapphire that had been exposed after a heavy rain. The news of their discovery gradually spread among the professional gem miners in Ratnapura, many of whom set up private, small-scale mining operations in the "new" district.

Gem-mining activity in Sri Lanka escalated after the government established the State Gem Corporation in 1971. The corporation took over

the functions of issuing gem-mining licenses and leasing government land for mining. In Elahera, the local farmers even used their own rice paddies for mining. In the late 1970s, the state body undertook large-scale gem mining in collaboration with the private sector. Current mining in the Elahera area proceeds along the Elahera-Pallegama main road, particularly between the 19- and 24-mile posts (figure 2), and is concentrated in the areas of Wallwala, Hattota-Amuna, Laggala, and Dahasgiriya. The State Gem Corporation has reported that just one of the joint state/private industry projects in this region—the Laggala-Pallegama project—earned US\$725,790 between June 30, 1981 and April 13, 1985.



Figure 2. The Elahera gem field in central Sri Lanka is noted for its vast production of many gemstone varieties. The main gem mining activity is between the 19- and 24-mile posts.

LOCATION AND ACCESS

The Elahera gem field covers approximately 150,000 m² in the Matale and Polonnaruwa districts of central Sri Lanka. The map of the Elahera region in figure 2 extends from approximately 80°45' to 80°55' east and from 7°35' to 7°50' north. The principal gem-mining area is centered at 80°50' longitude from north to south. Two tributaries of Sri Lanka's longest river, the Mahaweli Ganga, run through the main gem area. These are known as the Amban Ganga and the Kalu Ganga. The lower course of the river system almost parallels the main road between Elahera and Pallegama.

During the dry season, access to the gem mines is easily gained. During the rainy season (May to September and late October through February), however, the bridges are often under water.

The State Gem Corporation has encouraged local farmers to continue their rice cultivation without interruption. The area is attractive, with green landscape and blue sky, and the mines are

concentrated along the former main road (figure 3). The corporation, at its own expense, has built a new road (marked in figure 2) to connect Elahera and Pallegama. The project area is closed to the public, and anyone who wishes to visit the mines must obtain a permit at the corporation's head office in Colombo.

GEOLOGY

The island of Sri Lanka is underlain almost entirely by Precambrian metamorphic rocks which have been subdivided by Cooray (1978) into three groups: (1) Highland Group (pyroxene-granulite facies), (2) Vijayan Complex (amphibole-granulite facies), and (3) Southwestern Group (cordierite-granulite facies). The Elahera region lies entirely within the Highland Group terrain. The Highland Group consists of hypersthene granites (charnockites), quartzites, marble (crystalline limestone), garnetiferous gneisses, hornblende gneiss, granulites, and pegmatites (Dahanayake, 1980). Gem mining is carried out in the residual,



Figure 3. Large-scale gem mining is conducted along what was once the main bus route from Elahera to Pallegama, in the center of the Elahera gem field. Photo by Marion Gunawardene.

cluvial, and alluvial gravels overlying the Highland Group metamorphics. According to Dahanayake et al. (1980), the Elahera region is characterized by ridge and valley topography in a plunging synclinal structure. This structure forms the wide valley and floodplain of the Kalu Ganga. This floodplain is underlain by marble, while the bordering ridges consist of harder, more resistant garnetiferous gneisses, charnockites, and quartzites. Granites do outcrop as elongated intrusions along the length of the Kalu Ganga valley. Where the granites have intruded and come into contact with the marble, significant skarn deposits, consisting of diopside, tremolite, scapolite, spinel, and corundum, have developed.

The lithology and stratigraphy of the Elahera area have been described in detail by Silva (1976), by Dahanayake (1980), and by Dahanayake et al. (1980). Munasinghe and Dissanayake (1981), Asadi (1985), and Rupasinghe and Dissanayake (1986, in press) have also reported on the origin of gemstones in the island and are recommended for further reading.

The modes of occurrence of gem pits in Elahera can be divided into two main types: residual and alluvial. The residual gem pits contain large amounts of garnets, which are abundant in the gneisses. The gemstones found here are mostly eroded and only rarely retain their distinct original habits (figure 4).

Figure 4. A week's collection of rough blue and yellow sapphires found in Elahera are sorted here for faceting. Note the rounded appearance of the crystals, probably the result of water transport. Stones courtesy of MANYGEMS, West Germany.

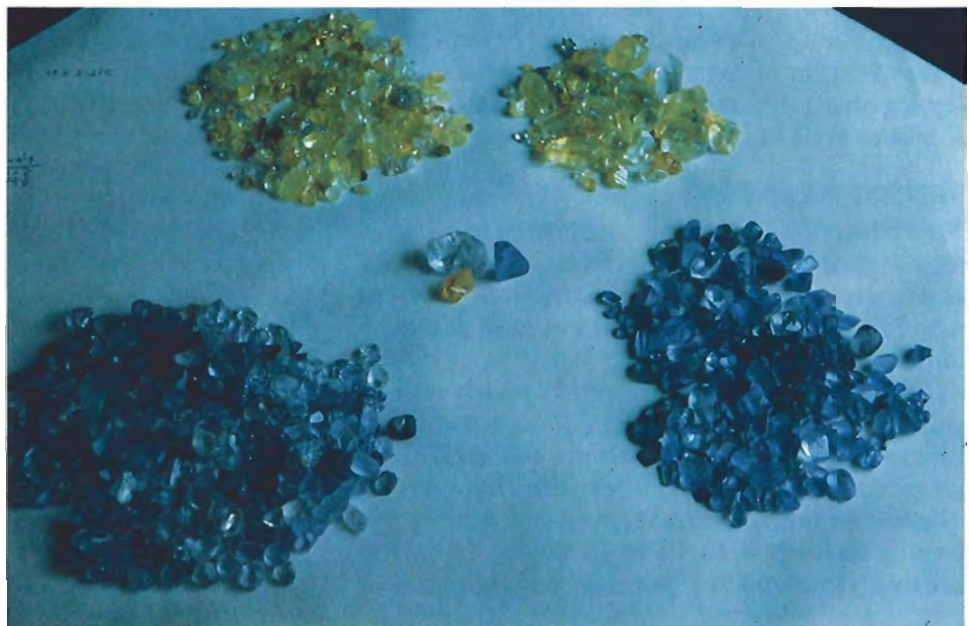




Figure 5. Two to three meters below ground level, the gem-bearing gravel is extracted by workers. Natives use picks and shovels to excavate the gem gravel, a common practice in pit mines in the Elahera field.

The alluvial gem deposits are characterized by clay and/or sand layers with abundant rock fragments. The gem minerals can be widely distributed. They exhibit evidence of having traveled over long distances and are often eroded. Most of the gem pits essentially indicate the alluvial nature of deposits in the area, which in turn also suggests that the various kinds of gemstones found in the deposits have different origins.

The Kalu Ganga has been a major vehicle for transportation of the gem materials into the valley, resulting in accumulations of deposits on hill slopes as well as along the banks of the river.

MINING METHODS

Traditionally, mining commences with astrological consultations and a short religious ritual offering foodstuff to "Bahirawaya," a spirit who is reported to be in charge of wealth hidden underneath the earth.

Because the soil in Elahera is relatively dry, gem mining is less complicated than in wet zones like Ratnapura. Two methods are primarily used: pit mining (figure 5) and surface mining (figure 6). The former is often carried out in rice paddies and usually extends 3 to 10 m in depth. The gem-bearing deposits are not far underground so

this method is economical. However, pit mining is disappearing now that the State Gem Corporation has undertaken large-scale surface mining. The recovery methods currently in use include such modern techniques as scraping the overburden with bulldozers, which lowers the costs involved and increases the yield of gem materials. With both pit and surface mining, the gem-bearing gravel is first washed in cane baskets, sorted, and then dried in sunlight before it is again carefully sorted by hand to recover any glittering pieces that were not identified during the washing. More than 650 miners currently work in the Elahera gem field. Unlike the early years of gem mining in this region, when many of the operations were independent, virtually all of the current miners are employed by the State Gem Corporation and licensed private enterprises.

THE GEMSTONES OF ELAHERA

Elahera produces a wide variety of gem materials, including: blue, pink, yellow, violet, and "padparadscha" sapphires; marvelous color ranges of spinel; rhodolite and hessonite garnets; chrysoberyls (including alexandrite and chatoyant varieties); many colors of zircon; lovely green and "cognac" tourmalines; brownish green kor-



Figure 6. These surface-mining areas measure 20 to 30 m². The earth is first excavated by bulldozers to a level just above the gem-bearing gravel. The workers then carefully loosen the gem gravel with picks and remove it in cane baskets. Photo by Marion Gunawardene.

nerupines; near-colorless to yellowish or greenish sinhalites; and many rare stones such as gem epidote, sillimanite (fibrolite), and taaffeite. Also found in the locality are rock crystal quartz, amethyst, and topaz, but for the most part these are more of mineralogical than gemological interest. Elahera is particularly noted as a source of large gem-quality corundums; crystals weighing as much as 200 ct have been recovered.

More than 500 gem-quality sapphires, spinels, garnets, chrysoberyls, tourmalines, korerupines, sinhalites, and rare gem taaffeites, epidotes, and sillimanites were examined during this study. The stones ranged in size from 0.30 to 45.00 ct. The gemological properties of each gem material will be discussed below. Electron microprobe and neutron activation analyses (NAA) were also conducted on samples obtained at various gem pits in the Elahera area. Details of these chemical analyses are available on request from the authors.

Corundum. Elahera produces particularly fine

blue (figure 1) and blue star (figure 7) sapphires. The majority are of good to excellent quality, with even coloration and transparency. The best blue sapphires are comparable to the well-known Kashmir blues. The average-grade stones are lighter in color but still brilliant and internally clean. The asteriated stones are usually grayish blue, but fine dark blue star sapphires are found on occasion (again, see figure 7).

Corundum with a milky-white body color, called "geuda" sapphire, is commonly heat treated to produce attractive blue stones (as discussed by Nassau, 1981; Gunaratne, 1981; Hänni, 1982; Gübelin, 1983; and Scarratt, 1983). Recently, a large quantity of "geuda" sapphires from the Elahera area surfaced on the local gem market. They appear to produce particularly nice blue stones with heat treatment.

The Elahera gem field also produces fine yellow, pink, and violet sapphires (figure 1). The yellow stones vary in color from intense "golden yellow" (known as "golden sapphires" in the local

gem trade) to light or pale yellow (see, for example, the uncut yellows in figure 4). Often they contain a tinge of brown or rosé; the latter tone is frequently misleadingly described as "padparadscha" (Crowningshield, 1983). Occasionally, good-quality "padparadschas" are found in Elahera (figure 8). Ruby is not common in Elahera, but the locality is noted for the particularly fine pink sapphires found there. Violet sapphires from Elahera are often heat treated to remove the reddish hue and obtain a blue color (Gunaratne, 1981; Gunawardene, 1984).

Color-change sapphires—blue in day or fluorescent light, purplish red in incandescent light—are occasionally encountered. The cause for the change of color has been detailed by Schmetzer et al. (1980). Corundum with color in only part of the crystal is also found in Elahera.

Chemical Analyses. Twenty different colors of corundum were selected from various gem pits in the Elahera gem fields and subjected to quantitative chemical (microprobe) analyses. They were found to have at least 99.43 wt.% Al_2O_3 . The blue sapphires reveal an iron oxide content of 0.06 to 0.13 wt.% (as FeO) along with 0.02 to 0.05 wt.% TiO_2 . Light red to pink gem corundum contains 0.01 to 0.09 wt.% of Cr_2O_3 , and the yellow sapphires show 0.03 to 0.14 wt.% FeO. These concentrations are comparable to those determined for corundum of

Figure 7. This 46.36-ct blue star sapphire found in Elahera indicates the availability of good gemstones in the area. Stone courtesy of H. Roos.

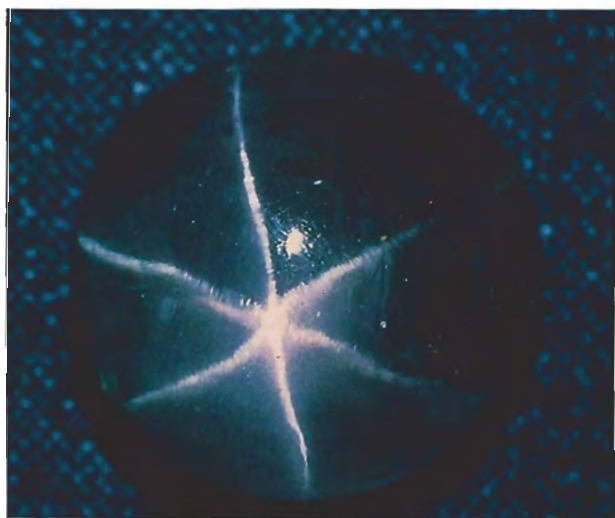


Figure 8. This rare gem "padparadscha" sapphire (2.95 ct) is representative of some of the fine stones of this unusual color found in Elahera. Stone courtesy of D. Humphrey; photo © Tino Hammid.

similar colors from other localities (Schmetzer and Bank, 1981; Schmetzer et al., 1983).

Optical Properties and Density. Refractive index, specific gravity, pleochroism, absorption spectrum, and ultraviolet fluorescence were determined for an assortment of colors of Elahera gem corundum, as detailed in table 1. The observed refractive indices and birefringences remain relatively constant, revealing no distinguishing variations either among the different colors or vis-à-vis corundum from other localities.

Inclusions. The gem microscope revealed many solid and liquid inclusions that were subsequently identified by X-ray powder diffraction and microprobe analyses. Abundant spinel crystals were common and proved to be the inclusion most characteristic of Elahera corundum (figure 9). Dark, platy, thin crystallites present were confirmed to be phlogopite, biotite, graphite, and ilmenite. Rutile, as hair-fine needles, was also observed in many of the corundums. One Elahera sapphire contained an oriented rod-like rutile inclusion (figure 10). As is common with other gems of Sri Lanka, the Elahera rubies and sapphires, particularly the yellow sapphires, revealed abundant

TABLE 1. Gemological properties of gem corundum, spinel, and garnet from the Elahera gem field.

Gem material ^a	Refractive index	Birefringence	Specific gravity	Pleochroism ^b	Absorption ^c (in nm)	Reaction to LW/SW U.V. radiation	Inclusions
Corundum							
Blue (95)	1.760–1.768	0.008	4.00	Greenish blue (M) Dark inky blue	450 (d) 460 (wk)	Light blue (SW)	Phlogopite, biotite, graphite, rutile, spinel, and zircon; healed "feathers," liquid "feathers," and negative crystals
Yellow (22)	1.760–1.768	0.008	4.01	Orange-yellow (W) Grayish yellow	694.2 (wk) 692.8 (wk)	Apricot reddish Apricot orange	Spinel, zircon, and rutile; healed and liquid "feathers," negative crystals
Ruby (2) and pink (12)	1.761–1.769	0.008	3.99	Reddish violet or pink (S)	694.2 (d) 692.8 (d) 668.0 (s) 659.0 (w) 476.5 (wk) 475.0 (wk) 468.5 (wk)	Distinct reddish Distinct pink	Rutile, apatite, zircon, ilmenite, and graphite; fingerprint-like liquid "feathers;" negative crystals
Star sapphire and ruby (16 total)	1.761–1.769	0.008	4.02	—	Same as blue sapphire or ruby	—	Rutile and other crystal inclusions mentioned above
"Padparadscha" (3)	1.760–1.768	0.008	4.00	Orange-yellow Yellowish orange	694.2 (d) 692.8 (d)	Strong apricot	Rutile and various liquid "feathers"
Spinel							
Red, brownish red, pink (35)	1.714–1.729 (mean 1.718)	None	3.58–3.60	None	680.0 (d) 675.0 (d) 650.0 (d) Broad absorption covering 585 to 500	Weak reddish or no glow in brownish red stones	Phlogopite mica typical; also spinel, apatite, and sphene
Blue, greenish blue, violet (82)	1.718–1.728 (mean 1.720)	None	3.58–3.62	None	455.0 (s) 470.0 (d)	None	Same as above
Green and bluish green (3)	1.716–1.753	None	3.60–4.05	None	Same as above	None	Same as above
Garnet							
Red (32)	1.749–1.778 (mean 1.765)	None	3.80–3.95	None	617.0 (w) 576.0 (d) 526.0 (d) 505.0 (d)	None	Rutile, apatite, and zircon; liquid "feathers"
Hessonite (20)	1.734–1.738	None	3.58–3.64	None	547.0 (d) 490.0 (d) 435.0 (d)	None	Apatite crystals surrounded by swirl-like structural features

^aNumber of stones examined is given in parentheses.^bS = strong, M = medium, W = weak^cd = distinct, s = strong, w = weak, wk = very weak

zircon crystals with their typical healed fissures and altered structure resulting from exposure to radiation [Rupasinghe, 1984]. Fingerprint-like liquid and/or healed "feathers" were common in most of the sapphires. Also detected were groups of negative crystals, often in the form of feathers (figure 11).

Spinel. Various colors of spinel are recovered in this region of central Sri Lanka. The ratio of spinel to corundum is only 3:4 (see also, Munasinghe and Dissanayake, 1981). The predominant colors are blue, bluish green, greenish blue, purple, plum red, brownish red, lilac, and violet (figure 12). The stones are often of good transparency. The star (6

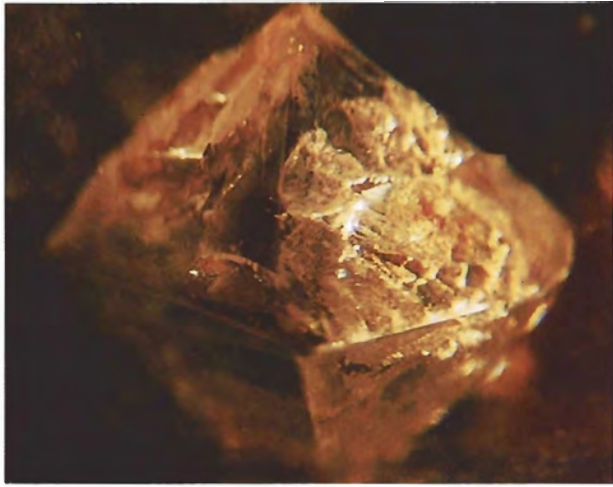


Figure 9. Characteristic of the locality, spinel crystals commonly occur in Elahera corundum. Magnified 80 \times , dark-field illumination.

rays) spinels are either dark brownish red, gray, or black in body color and are usually opaque (Bank, 1980). Change-of-color spinels are found occasionally.

Chemical Analyses. To obtain detailed information on the chemistry of Elahera spinel, we subjected 10 samples to both electron microprobe and neutron activation analysis (NAA). The major chemical components, Al_2O_3 and MgO , are in normal proportions. The blue, green, and purplish red spinels investigated during this study contain iron (0.88 to 3.54 wt.% FeO) and extend into the spinel-gahnite solid-solution series. This was further confirmed by the amount of Zn present (350–750 ppm). The purplish red sample also contains 480 ppm of Cr. Anderson et al. (1937) and Anderson (1964) have detailed the properties of zinc spinels.

Optical Properties and Density. The refractive indices and density values of Elahera gem spinels fall into three categories:

1. The red, brownish red, and pink spinels have a refractive index range from 1.714 to 1.729 with a mean value of 1.718. Specific gravity ranges from 3.58 to 3.60.
2. The blue, greenish blue, and violet spinels have a refractive index range from 1.718 to 1.728 with a mean value of 1.720. Specific gravity ranges from 3.58 to 3.62.
3. The green and bluish green (spinel-gahnite

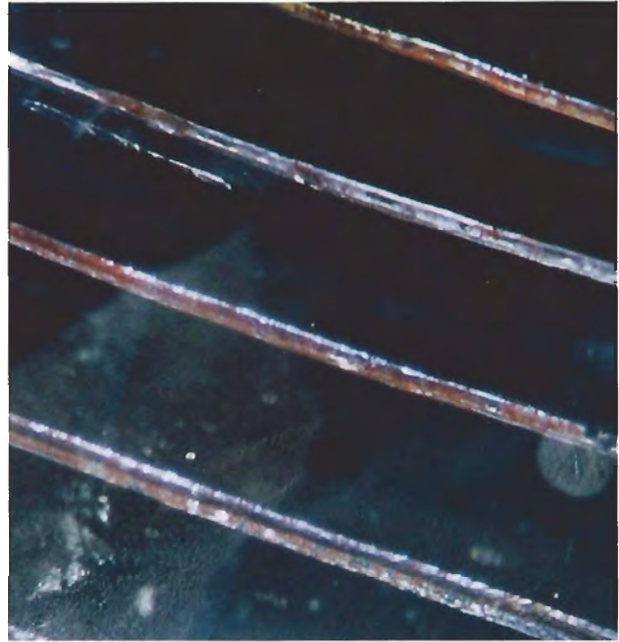


Figure 10. Rutile formations such as this one in a blue sapphire mined at Elahera are occasionally encountered. Magnified 60 \times , dark-field illumination.

series, or gahnite) spinels have a refractive index range from 1.716 to 1.753. Specific gravity ranges from 3.60 to 4.05.

Visible-light absorption spectroscopy of red spinels from Elahera revealed a strong absorption line at 685.5 nm; no other absorption lines were seen in these stones. Iron played an important role in producing absorption bands at 458, 478, and 508 nm in blue, blue-green, greenish blue, and some

Figure 11. Negative crystal inclusions arranged somewhat like a feather within a blue sapphire from Elahera. Magnified 40 \times , transmitted illumination with color filters.

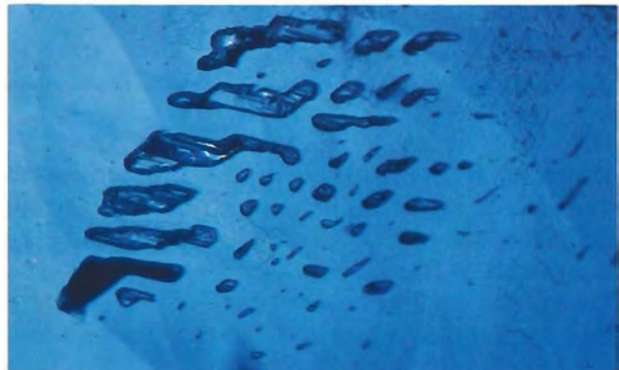
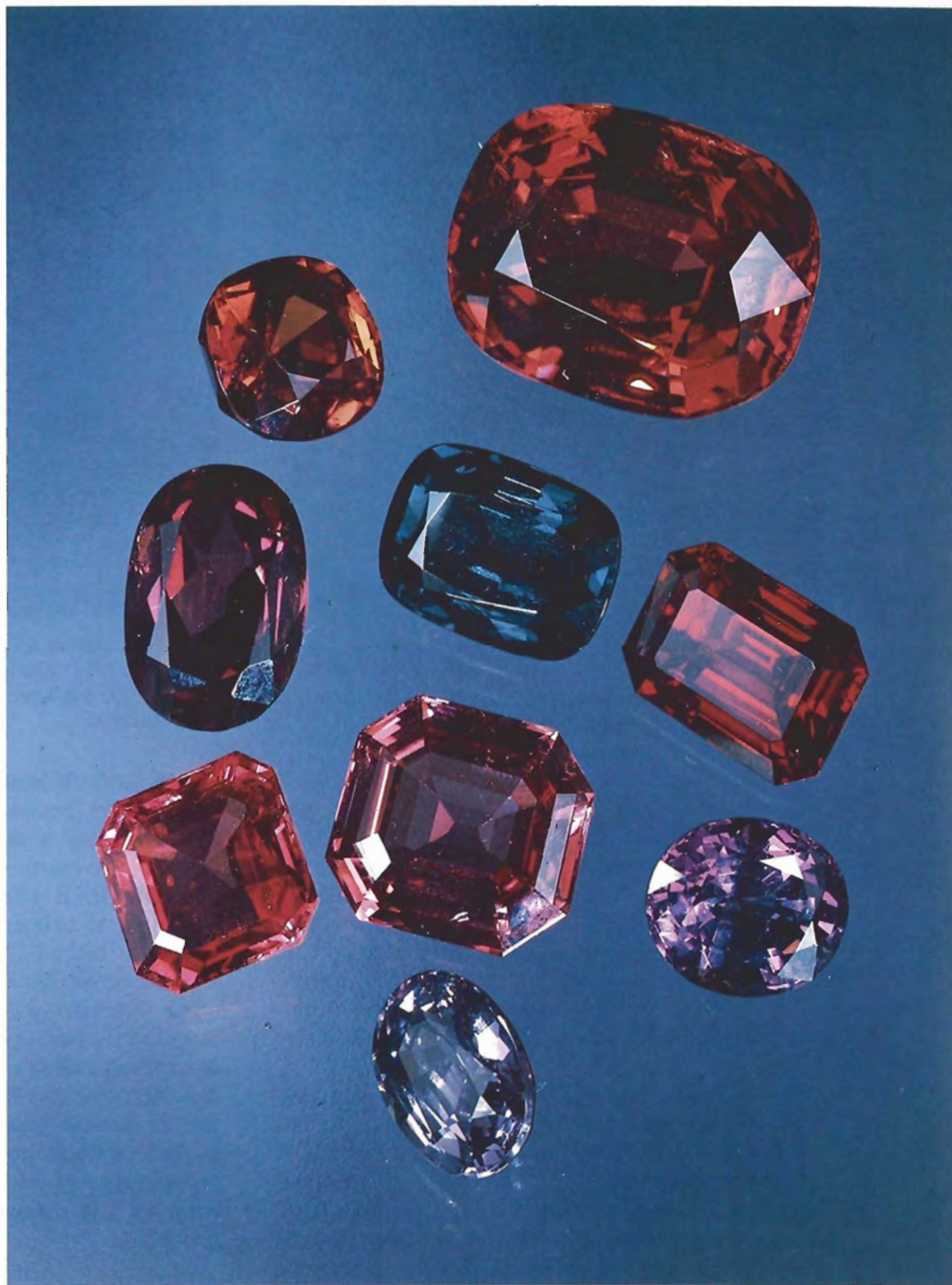


Figure 12. These gem spinels from Sri Lanka (6–55 ct) illustrate some of the many colors found at the Elahera gem field. Stones courtesy of the Hixon Collection at the Los Angeles County Natural History Museum; photo © Harold & Erica Van Pelt.



violet spinels. Much weaker absorption lines were also visible at 635, 585, 555, 443, and 433 nm.

Inclusions. Guest minerals detected in Elahera gem spinels include spinel (in feathery formations), apatite, and sphene. Phlogopite (figure 13) seems to be typical of spinels found in central Sri Lanka.

Garnets. Gemologically, the garnets found in Elahera can be classified as rhodolite and grossular

(variety hessonite). The rhodolites, which are more abundant than the hessonites, commonly are transparent and range in color from pink to purplish red. The hessonites usually range from orange-red to yellowish orange, although some samples resemble malaia garnet, a rich reddish orange. However, the majority of hessonites from this locality tend to appear cloudy.

Chemical Analyses. Three purplish red garnets were analyzed by the microprobe. The SiO₂ con-

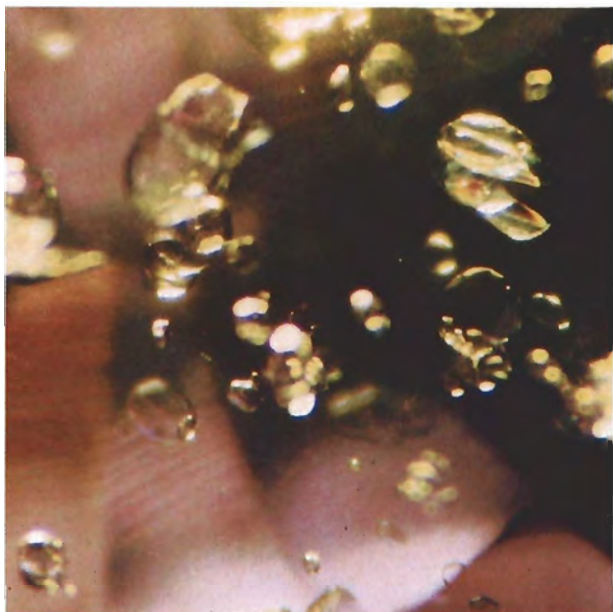


Figure 13. Phlogopite mica is a common inclusion in spinel found in central Sri Lanka. Magnified 35 \times , dark-field illumination.

tent varied slightly from 40.02 to 41.48 wt.%, and Al_2O_3 varied from 22.87 to 23.09 wt.%, whereas FeO and MgO contents were calculated as 18.14 to 15.82 wt.% and 13.93–15.01 wt.%, respectively. Less CaO (1.34–1.89 wt.%) and MnO (0.47–0.53 wt.%) were detected. On the basis of the data, these garnets can readily be classified as intermediate members of the pyrope-almandine solid-solution series (Manson and Stockton, 1981).

Optical Properties and Density. Refractive index and specific gravity were determined for 32 rhodolite and 20 hessonite garnets from Elahera. A refractive index range of 1.749–1.778, with a mean value of 1.765, was recorded for the rhodolites. These same stones varied in density from 3.80 to 3.95. The refractive indices of Elahera hessonite range from 1.734 to 1.738, with a density variation of 3.58 to 3.64.

The iron content in rhodolite garnets influences their absorption spectrum, which exhibits lines at 617, 576, 526, 505, 476, 438, 428, and 404 nm. The spectrum of the hessonite (also iron-related) shows peaks at 547, 490, and 435 nm.

Inclusions. Inclusions of rutile, apatite, and zircon seem to be common in the rhodolite garnets (figure 14). The apatite crystals were idiomorphic or euhedral. The internal appearance of the hessonite garnets is characterized by apatite crystals and swirl-like structural features.

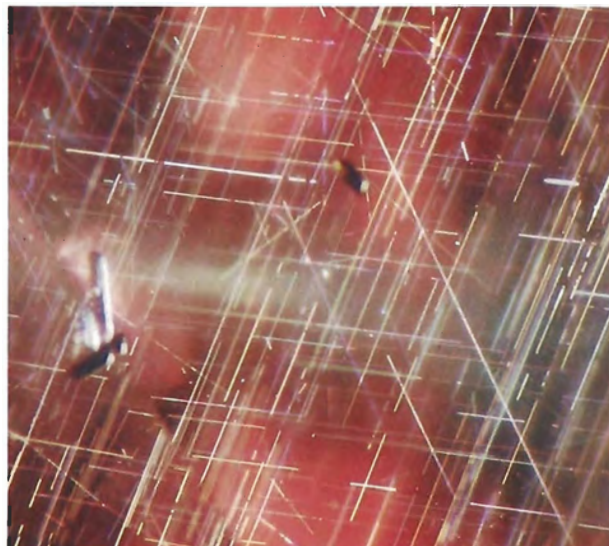


Figure 14. Idiomorphic apatite and three-dimensionally oriented rutile in a rhodolite garnet from Elahera. Magnified 30 \times , dark-field illumination.

Other Gem Materials. Twenty samples each of chrysoberyl, zircon, tourmaline, kornerupine, and sinhalite (see, for example, figure 15), as well as 10 samples of rare gem taaffeite, epidote, and sinhalite from Elahera were also studied. The gemological properties for these stones are reported in table 2. A number of the chrysoberyls, zircons, tourmalines, kornerupines, and sinhalites were also chemically analyzed by means of the microprobe and, in the case of zircon, by neutron activation analysis. Differences were noted in the chemistry of the Elahera stones as compared to that of similar material from other localities; the results of these analyses are available from the authors on request. Following are observations on some of the more important gems within this group.

Chrysoberyl. Brown, brownish green, and greenish yellow chrysoberyls (figure 15) are common in Elahera. Cat's-eye stones are also found here. The color-change variety, alexandrite, is seen, but only rarely.

When examined with the microscope, the Elahera chrysoberyls, including alexandrite and chatoyant stones, were found to be relatively clean and transparent. The most diagnostic features are growth zoning parallel to the crystallographic axes and liquid (monophase) inclusions. The growth zoning can be observed best under crossed polarized light (figure 16). The monophase inclusions occur as either feathery or single-cavity forma-

TABLE 2. Gemological properties of gem chrysoberyl, zircon, tourmaline, kornerupine, sinhalite, taaffeite, epidote, and sillimanite from the Elahera gem field.

Gem material ^a	Refractive index	Birefringence	Specific gravity	Absorption (in nm) ^b	Reaction to U.V. radiation		Inclusions
					Long wave	Short wave	
Chrysoberyl							
Alexandrite (1)	$\alpha = 1.745$ $\beta = 1.749$ $\gamma = 1.755$	0.010	3.70–3.72	680.5 (d) 678.5 (d) 665.0 (w) 655.0 (w) 649.0 (w) 640.0 to 560.0 (wd) 473.0 (wk) 468.0 (wk)	Weak reddish	Weak reddish	Growth zoning in various directions, liquid "feathers," and two-phase inclusions
Cat's-eye (5)	$\alpha = 1.741$ $\beta = 1.745$ $\gamma = 1.750$ $\delta = 1.757$	0.009–0.012	3.70–3.74	445.0 (s)	None	None	Fine parallel oriented hollow tubes
Other colors (10)	$\alpha = 1.742$ $\beta = 1.748$ $\gamma = 1.757$	0.008–0.015	3.71–3.73	504.0 (d) 495.0 (w) 485.0 (w) 445.0 (s)	None	None	Growth zoning in various directions, fingerprint-like liquid "feathers," and two-phase inclusions
Zircon							
Intermediate type (22)	$\epsilon = 1.838$ $\omega = 1.830$	0.006–0.008	4.04–4.06	653.5 (s) Many absorp. lines in the whole spectrum	Weak to distinct yellowish	Weak to distinct greenish yellow	Disc-like fissures, zircon crystals, various growth phenomena and partly healed "feathers"
Tourmaline (30)	$\epsilon = 1.618$ $\omega = 1.638$	0.018–0.020	3.04–3.07	A general absorption after 530.0	None	None	Zircon and apatite, negative crystals, and healed liquid "feathers"
Kornerupine (49)	$\alpha = 1.668$ $\beta = 1.679$ $\gamma = 1.680$	0.012	3.33–3.36	503.0 (s) 446.0 (w) 430.0 (wk)	None	None	Apatite, zircon with circulating cracks, two-phase inclusions, and liquid "feathers"
Sinhalite (5)	$\alpha = 1.669$ $\beta = 1.702$ $\gamma = 1.706$	0.036–0.037	3.48–3.49	525.0 (w) 493.0 (d) 475.0 (d) 463.0 (d) 452.0 (d) 435.0 (d)	None	None	Negative crystals and liquid "feather," two-phase inclusion
Taaffeite (5)	$\epsilon = 1.717$ $\omega = 1.723$	0.004–0.006	3.60–3.62		None	None	Well-formed apatite crystals; spinel, phlogopite mica, and zircon; "fingerprints" of negative crystals
Epidote (2)	$\alpha = 1.732$ $\beta = 1.746$ $\gamma = 1.767$	0.035	3.44	457.0 (wk) 455.0 (s)	None	None	"Feathers" and growth lines parallel to the horizontal crystal axes
Sillimanite (3)	$\alpha = 1.660$ $\beta = 1.662$ $\gamma = 1.682$	0.022	3.25	462.0 (d) 441.0 (d) 410.0 (wk)	None	None	Apatite and zircon with mica(?); "feathers" of negative crystals and liquid droplets; growth tubes parallel to one crystallographic axis in chatoyant stones

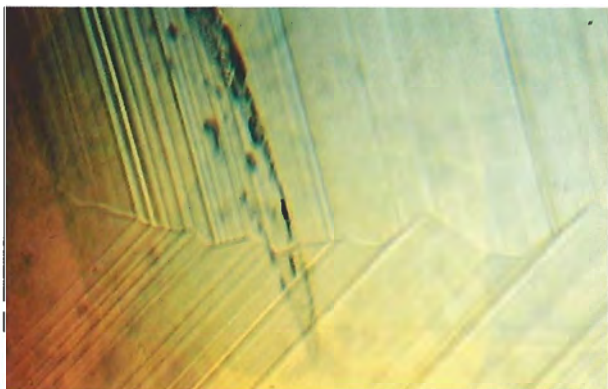
^aNumber of stones examined is given in parentheses.

^bd = distinct, s = strong, w = weak, wk = very weak



Figure 15. This faceted light green chrysoberyl (8.95 ct) and the accompanying 17.57-ct crystal are representative of some of the material found at the Elahera gem field. Photo © Tino Hammid.

Figure 16. Polysynthetic twinning lamellae in natural alexandrite from Elahera. Magnified 25 \times , crossed polarized light.



tions (figure 17). These inclusions are quite typical of Elahera alexandrite and can be used to distinguish it both from synthetics and from natural alexandrite found elsewhere.

Zircon. The various colors found at Elahera are either low or, most commonly, intermediate types. Brown, green, yellow, reddish brown, and yellowish brown zircons (figure 18) are mined here.

The chemistry and fluorescence behavior of zircon and its radioactive rare earth elements have been described in detail by Schwarz (1982) and Rupasinghe (1984). When viewed with the microscope, the Elahera zircons revealed many interesting internal features. Most abundant are the disc-like fissures that parallel one another. These discs are randomly oriented with respect to crystallographic directions. Also noted were euhedral zircon crystals and secondary growth zoning.

Tourmaline. Elahera is not well known for tourmaline, but greenish brown and dark green stones are occasionally found (again, see figure 18). The Elahera tourmalines exhibit a yellowish brown pleochroism that is attractive when the stones are faceted in the proper direction. They are often clean and of good transparency. When viewed with the microscope, tourmalines from Elahera exhibit a large number of zircons, negative crystals, prismatic apatite crystals with two-phase inclusions, and various liquid and healed "feathers."

Kornerupine. Gem-quality kornerupine is quite abundant in Elahera. The most common colors

Figure 17. Typical forms of liquid "feathers" and cavities in gem alexandrite from central Sri Lanka. Magnified 28 \times , transmitted illumination.

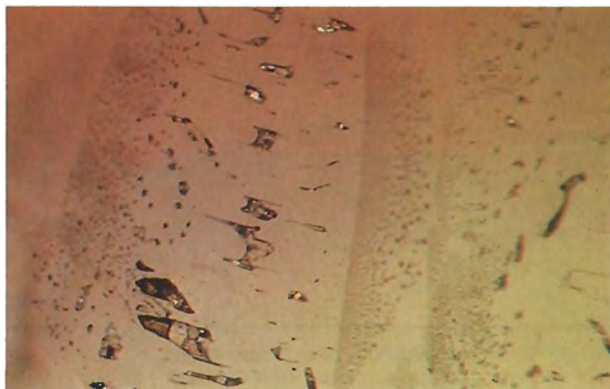


Figure 18. The color varieties shown here are typical of the following gems found at Elahera (clockwise, starting with the green stone at top): green zircon (4.43 ct), yellow zircon (2.78 ct), brownish green tourmaline (3.41 ct), reddish brown zircon (1.48 ct), green kornerupine (0.72 ct), dark green tourmaline (2.92 ct), and brownish yellow sinhalite (4.93 ct).
Photo © Tino Hammid.



range from brownish green to greenish brown (again, see figure 18). Well-formed apatite and zircon crystals surrounded by tension fissures are common inclusions in Elahera kornerupines. Oriented two-phase inclusions were also seen in some of the stones studied.

Sinhalite. Near-colorless to brownish yellow

sinhalite (figure 18) with good transparency is also often found in Elahera (Claringbull and Hey, 1952; Henn, 1985). When viewed with the microscope, the gem sinhalites from this region frequently appear clean. However, they occasionally exhibit a network of negative crystals and needle-like inclusions as described by Gunawardene and Gunawardene (1986).

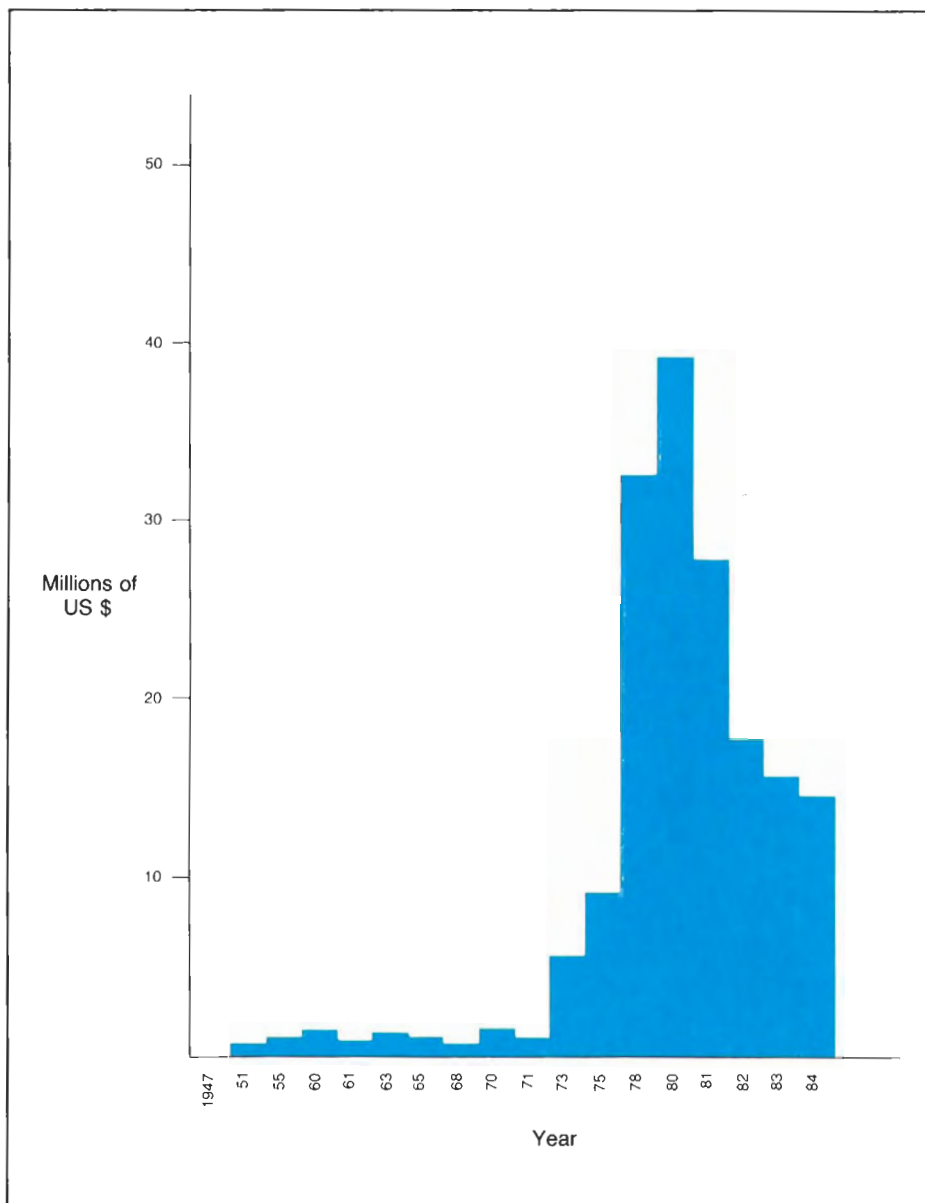


Figure 19. Export earnings by Sri Lanka for unset gemstones during the period 1947–1984, in U.S. dollars. Source: Sri Lanka Customs Department.

CURRENT PRODUCTION AND PROSPECTS FOR THE FUTURE

In Sri Lanka, the Elahera gem field is now second only to Ratnapura in the production of gemstones suitable for jewelry. While total exports of loose gems from Sri Lanka have dropped significantly from their 1980 peak of more than \$40 million annually, they appear to have stabilized at between \$15 million and \$20 million in recent years (figure 19). Although specific production figures are as elusive for this locality as they are for most others, the authors estimate that Elahera contributes 35% of these exports, or approximately 15,000 kg of sapphires and 8,500 kg of other stones

annually in recent years. The flow of gemstones from the Elahera district appears to be steady, so no significant fall-off in production is anticipated in the near future.

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NOTES · AND · NEW TECHNIQUES

SOME UNUSUAL SILLIMANITE CAT'S-EYES

By E. Gübelin, M. Weibel, and C. F. Woensdregt

Brown-black sillimanite cat's-eyes from Sri Lanka present an unusually sharp band, which would make them extraordinary gems were it not for the rather unattractive body color of the stones. A study of six of these stones found that they contain 0.5 wt. % iron oxide. The principal inclusion mineral is ilmenite, which occurs in elongated, submicroscopically thin lamellae. Complex thicker lamellae consist of hercynite spinel grown together with a member of the pyroxene group. These thicker inclusions were not found in all of the specimens investigated.

Sillimanite, also known as fibrolite, is a common metamorphic mineral. Cuttable material is extremely rare but is found in the Mogok Stone Tract of Burma and in the Sri Lankan gem gravels, as transparent rounded crystals with a blue, violet-blue, or grayish green hue (Webster, 1983). Recently, deep brown to blackish sillimanite cabochons with a sharp chatoyancy have appeared on the market and are claimed to be from Sri Lanka. In transmitted light, these cat's-eyes show a characteristic violet tinge.

The Geochemical Laboratory in cooperation with the Solid State Physics Laboratory (Swiss Federal Institute of Technology, Zürich, Switzerland) has undertaken an electron-microscopic study of the new sillimanite cat's-eyes and the oriented inclusions that cause their chatoyancy, with R. Wessicken as analyst. For this study, six sillimanite cat's-eyes, all purportedly from Sri Lanka, were acquired. They ranged in size up to 10 ct. The largest cabochon (figure 1) was cut parallel to the base and the lower half sacrificed to

thin-section study and the ion etching necessary for subsequent electron diffraction.

This article summarizes the results of the electron microscope study of the inclusions causing the chatoyancy, as well as the gemological characteristics of this unusual material.

EXPERIMENTAL METHODS

Chatoyancy, like asterism, is caused by the scattering of light on numerous fibrous inclusions aligned in one or more directions in the host crystal; proper cutting *en cabochon* is required to reveal the phenomenon. For good chatoyancy or asterism, the elongated inclusions must be thin compared to the wavelengths of light (Weibel, 1985). Such minute crystal individuals are not accessible to ordinary microscopy and X-ray analysis. Even though the inclusions may show up in a thin section viewed with a polarizing microscope, the images that appear are not real, but rather are produced by the scattering of light.

Two electron-microscopic techniques are particularly useful for the identification of ultrafine inclusions in gemstones:

1. A scanning electron microscope (SEM) fitted with an energy-dispersive X-ray microanalyzer

ABOUT THE AUTHORS

Dr. Gübelin, a prominent gemologist and author, is from Meggen, Switzerland; Dr. Weibel is professor of geochemistry at the Swiss Federal Institute of Technology, Zürich, Switzerland, and has just published a new book on gemstones; and Dr. Woensdregt is senior lecturer in crystallography at the Institute of Earth Sciences, State University of Utrecht, the Netherlands.

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Figure 1. One of the sillimanite cat's-eyes from Sri Lanka that was studied by the authors. The relatively flat cabochon measures 13 mm and weighs 5.24 ct (although the stone originally weighed 10 ct, the base was cut off for the analyses). Note the bifurcated light band produced by irregularities in the orientation of the fibrous inclusions.

enables the surface of a polished stone to be viewed and a chemical analysis to be made of areas as small as 1 μm .

2. A transmission electron microscope combined with an energy-dispersive X-ray microanalyzer serves as a high-resolution analyzer down to about 300 nm. The transmission electron microscope produces not only an image, but also a diffraction pattern, of the crystal lattice of an ultrafine inclusion. A thin slice of the gemstone must be etched by ion-beam thinning to reduce its thickness to less than 100 nm. Thus, a chip of the gemstone under consideration must be sacrificed for the analysis (Wenk, 1976).

For this study, both these techniques were applied. With the SEM alone (method 1), the oriented inclusions in the sillimanite cat's-eye could not be identified with certainty but required a more extensive investigation drawing on electron diffraction (method 2). The reason is that the matrix around a very small inclusion also tends to be excited by the electron beam, so the spectrogram obtained is a mixture of the compositions of the inclusion and the matrix. The analysis of diffrac-

tion patterns makes use of X-ray crystallography, which can distinguish the inclusion from the host. The details of the procedure followed and the intergrowth relations between the host and the inclusion will be published in a forthcoming paper intended for a crystallographic journal.

CHEMISTRY AND STRUCTURE

The largest sillimanite cat's-eye was analyzed for iron with the SEM. Between 0.5 and 0.6 wt.% Fe_2O_3 was found in the matrix. Since the chemical formula for sillimanite is Al_2SiO_5 , trivalent iron presumably substitutes for aluminum. Elongated lamellar inclusions are aligned strictly parallel to the c-axis of the sillimanite, which has a very perfect cleavage parallel to the c- and a-axes, that is the crystal plane (010). The cutter of a sillimanite cat's-eye usually chooses the cleavage plane of the stone to coincide with the base of the cabochon, but any orientation of the cabochon base parallel to the c-axis of the sillimanite would produce an optimum light band over the center of the stone.

GEMOLOGICAL PROPERTIES

The common optical properties of these sillimanite cat's-eyes concur very well with those of other sillimanites from Sri Lanka. The determinations were made by standard gemological procedures, and the following properties were found:

Refractive indices: $\alpha = 1.660$, $\beta = 1.662$, $\gamma = 1.680$

Birefringence: $+0.020$, $2V = 30^\circ$

Pleochroism: $\alpha =$ pale yellow, $\beta =$ clove-brown, $\gamma =$ gray-brown

Absorption: very faint shadows at 410, 441, and 462 nm

Density: 3.257 g/cm^3 (average of four hydrostatic measurements)

ORIENTED INCLUSIONS

If a thin section of a sillimanite cat's-eye is viewed through an ordinary light microscope, most of the oriented fibers show up as scattering images (figure 2), since they are thinner than the wavelengths of visible light (Weibel, 1985). In a more sophisticated study with the electron microscope, we found two varieties of fibrous inclusions, both of which measure up to a millimeter in length. First, there are relatively thick crystal lamellae (figure 3), which have a rectangular cross-section of 1 to 10 μm and consist of intergrowths of hercynite

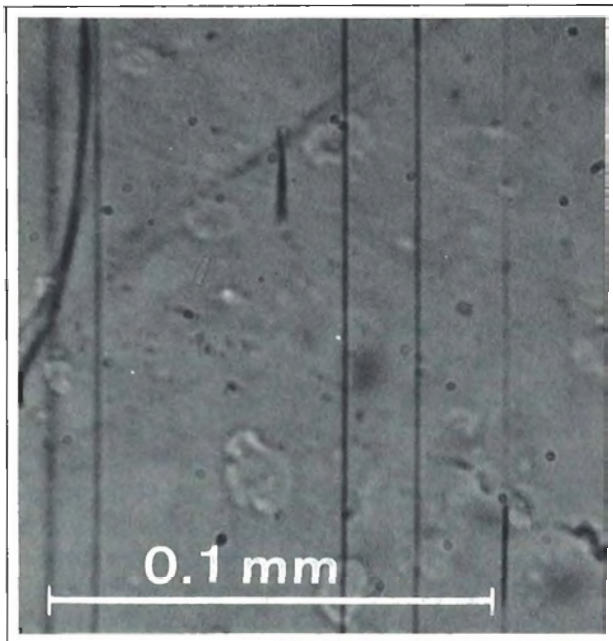


Figure 2. A photomicrograph of an optical thin section of a sillimanite cat's-eye that was cut parallel to the base of the cabochon, approximately parallel to the (010) plane of the crystal. The lamellae are intergrowths of a pyroxene and hercynite spinel. The much thinner ilmenite lamellae are not resolved.

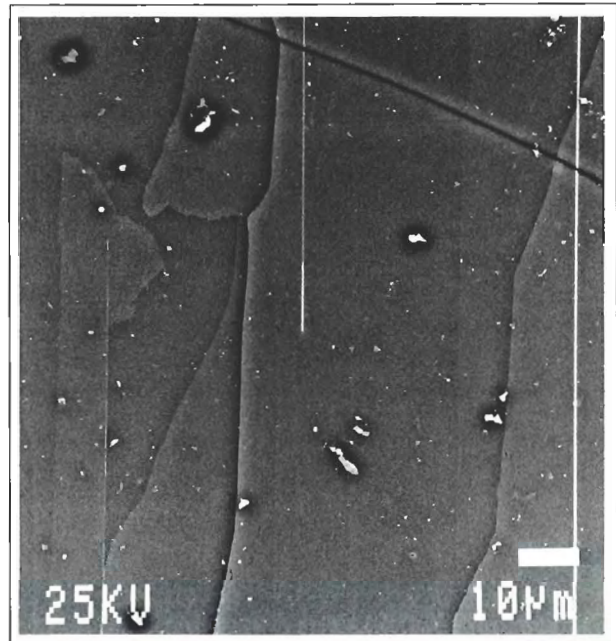


Figure 3. A scanning electron micrograph taken from a cleavage plane of a sillimanite cat's-eye. As in the photomicrograph shown in figure 2, the lamellae seen here are intergrowths of a pyroxene and hercynite spinel. The much thinner ilmenite lamellae are not resolved.

spinel and probably a pyroxene. The spinel was identified by energy-dispersive X-ray microanalysis and electron diffraction, whereas the nature of the pyroxene has not yet been established.

Since these thicker fibers do not occur in all of the sillimanite cat's-eyes included in our investigation, the chatoyancy must be caused by a second type of elongated structure. Electron diffraction showed that a more essential quantity of needles is composed of the mineral ilmenite. The ilmenite occurs as thinner lamellae, 0.05 to 0.5 μm across, with a rectangular cross-section that is probably imposed by the sillimanite structure. It is a most striking fact that in both systems of needles, the elongation contravenes the common crystal habit expected from the crystal structure of the included mineral.

Ilmenite as oriented inclusions is responsible not only for the chatoyancy and blackish appearance of the sillimanite cat's-eyes, but also for the chatoyancy of some rare aquamarine and chrysoberyl cat's-eyes (unpublished analyses of the authors). Most chrysoberyl cat's-eye, however, owes its chatoyancy to oriented rutile silk (unpublished analyses of the authors).

CONCLUSION

The characterization of a cat's-eye mineral requires the exact identification of the inclusions that cause the optical phenomenon. Moreover, the study of cat's-eyes reveals intriguing insights into the intergrowth of mineral phases, some of which appear to develop asymmetrically under strain. Thus, even a cubic crystal may display extreme elongation.

Apart from this, both chatoyancy and asterism (which can be described as double or triple chatoyancy) give a cabochon-cut stone an individual appeal highly appreciated by professional as well as amateur gemologists and gem collectors. An eminent scientific and aesthetic value is inherent in this strange group of rare gems.

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AN EXAMINATION OF FOUR IMPORTANT GEMS

By C. W. Fryer and John I. Koivula

The authors report on their gemological examinations of four important gemstones: the Star of Bombay sapphire, the Portuguese diamond, and two large diamonds known as the Marie Antoinette earrings, all of which are part of the collection at the Smithsonian Institution. Brief historical information on some of the pieces is also included.

In May of 1985, the Los Angeles County Museum of Natural History opened a new gallery devoted to Gemstones and Their Origins. This gallery, funded by Mr. Alex Deutsch and the Weingart Foundation, is a permanent part of the E. Hadley Stuart, Jr., Hall of Gems and Minerals. In conjunction with the opening of the new gallery, arrangements were made for a special exhibit of fine jewelry items provided by Harry Winston, Inc. of New York as well as some important stones from the collection of the U.S. National Museum of Natural History in Washington, D.C., a part of the Smithsonian Institution. While the special exhibit was in Los Angeles, the authors were offered the rare opportunity to perform gemological examinations on three famous pieces from the Smithsonian collection: the Star of Bombay sapphire, the Portuguese diamond, and the Marie Antoinette earrings. The results of these examinations are reported below.

THE STAR OF BOMBAY SAPPHIRE

A bequest to the Smithsonian by movie actress Mary Pickford, the Star of Bombay is a medium-intensity blue oval star sapphire (figure 1) that measures 36.30×28.82 mm and is 17.55 mm deep. Unfortunately, nothing is known of the history of this stone before Miss Pickford obtained it. Using the GIA weight estimation formula for cabochons, we estimated the weight to be approximately 184 ct, in very close agreement with the weight of 182 ct recorded at the Smithsonian. The dichroic colors are distinct to strong blue and slightly bluish green. The refractive index (spot method) is approximately 1.76–1.77. The specific gravity was not determined. Spectroscopic examination revealed a sharp line at 450.0 nm and a general



Figure 1. The 182-ct Star of Bombay sapphire. Courtesy of the Smithsonian Institution.

absorption in the green area of the spectrum. No evidence of any lines at 460.0 nm or 470.0 nm was observed. The stone is inert to ultraviolet irradiation.

Several interesting inclusions were observed with the microscope. In addition to the rutile needles responsible for the star, the most prominent inclusion found in the Star of Bombay is a primary negative crystal that contains two different solid phases (figure 2). One phase is a small grouping of opaque dark gray to black submetallic hexagonal

ABOUT THE AUTHORS

Mr. Fryer is chief gemologist, and Mr. Koivula is senior gemologist, in the Research Department of the Gemological Institute of America, Santa Monica, California.

Acknowledgments: The authors would like to thank Dr. Peter Keller for arranging the loan of these items with John Sampson White of the Smithsonian Institution. Our thanks also go to Dr. Anthony Kampf for inviting us to examine the stones and allowing us to use the facilities of the Los Angeles County Museum of Natural History.

Figures 1, 2, and 3 were photographed by the authors.

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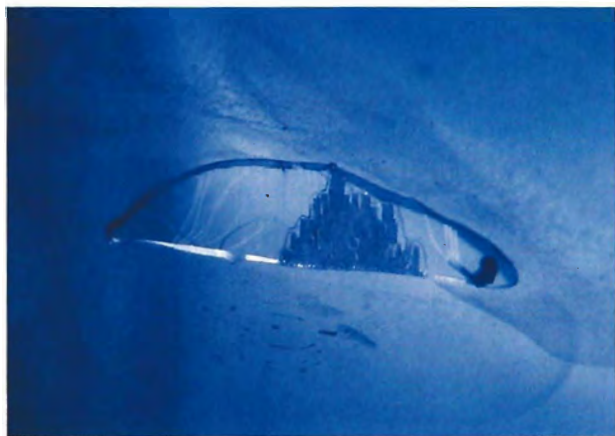
platelets which, from past experimentation with similar solid phases in Sri Lankan sapphires, the authors believe to be graphite. The second phase is an unidentified stalk-like spray of birefringent crystals extending inward from the cavity walls. Because primary negative crystals in Sri Lankan corundums commonly contain carbon dioxide, we thought that if the cabochon were slightly cooled we might be able to observe a phase change (gas \rightarrow liquid). After the stone was cooled by immersion in cold tap water, we did observe both liquid and gaseous carbon dioxide in the cavity. Slight warming with the microscope lamp caused the two phases of carbon dioxide to homogenize and the meniscus between the liquid and gas bubble to disappear. These test results indicate that the stone is from Sri Lanka.

This conclusion was further supported by the presence of a slightly rounded, nearly equidimensional, metallic opaque crystal that was visible without magnification. Although the inclusion could not be analyzed because of its position within the stone, experiments on Sri Lankan sapphires with very similar inclusions suggest that it is probably a protogenetic crystal of the iron sulfide pyrrhotite (figure 3).

THE PORTUGUESE DIAMOND

The Portuguese diamond (figure 4) was first mentioned in the literature by John Mawe (1813), who referred to it as the Regent of Portugal and listed it as the third largest known diamond, weighing 1 oz.

Figure 2. This negative crystal in the Star of Bombay sapphire has two distinct solid crystal phases. Transmitted and oblique fiber-optic illumination, magnified 15 \times .



troy (156 ct). He stated that the stone had been found in Brazil, which was then a colony of Portugal. Edwin Streeter (1882) also maintains that the Regent of Portugal came from Brazil and states that it was found by a slave near the Abaité River. However, he lists the weight as 215 ct, which is substantially larger than that given by Mawe. In any event, the stone was subsequently recut to its present size and shape. Somewhere along the line its name was shortened to the Portuguese. According to Krashes (1984), Harry Winston, Inc. purchased the stone in 1951, sold it, bought it back, and ultimately sold it to the Smithsonian in 1963.

The Portuguese is a lovely stone with a nearly octagonal outline, the corners being almost the same length as the sides and ends. The diamond measures 32.75 \times 29.65 mm and is 16.01 mm deep. It is set in a very simple four-prong mounting that ensures that the stone will rest in an upright position when exhibited. The mounted stone could not be weighed, but the GIA weight estimation formula indicated a weight of approximately 128 ct, less than 1 ct difference from the recorded weight of 127.01 ct (Krashes, 1984).

Although mounted stones cannot be graded accurately for color, the authors tentatively assigned a grade range of G to H, or I, on the GIA color scale, which is consistent with the observed presence of a 415.5-nm absorption line in the spectrum. (Colorless stones [D on the GIA scale] do not show the 415.5-nm line.) No other absorption lines were observed.

Figure 3. This solid crystal inclusion in the Star of Bombay sapphire is probably pyrrhotite, a familiar inclusion in Sri Lankan corundum. Oblique fiber-optic illumination, magnified 10 \times .

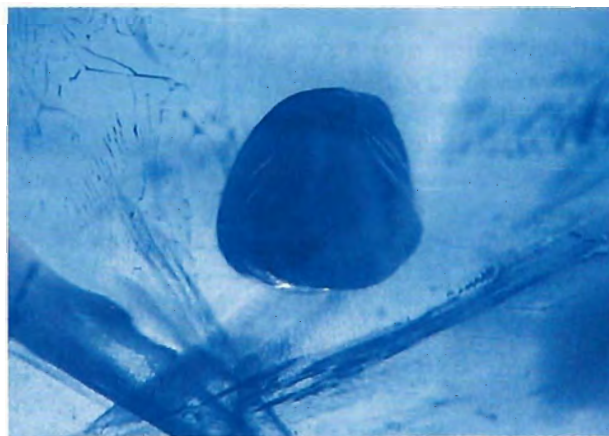




Figure 4. The 127.01-ct Portuguese diamond. Courtesy of the Smithsonian Institution; photo by S. Gipson, courtesy of the Los Angeles County Museum of Natural History.

Whatever color is present in the stone is most assuredly masked by the very strong blue fluorescence; in fact, the Portuguese was once thought to have been a blue diamond (Krashes, 1984). The stone fluoresces extremely strong blue on exposure to either short- or long-wave ultraviolet radiation. Even the relatively low proportion of ultraviolet light in an incandescent light source will cause the stone to fluoresce a soft blue color. In addition, there is a decided blue color to the strong ray of light that is transmitted through the stone when it is placed over the diaphragm of a spectroscopic unit with the light turned on for spectroscopic observation.

The only reference to the clarity of the Portuguese diamond that could be found in the literature was that by Gaal (1977), who said that the stone was flawless. However, our examination of the mounted stone revealed a small bruise on the junction between the first and second facets up from the girdle on one side of the crown, and two very minor scratches on the table, which would place it in the VVS category. These characteristics could have occurred subsequent to Gaal's report. However, there are also five extra facets at the corners of the pavilion facet junctions. The stone was also examined with the polariscope, but only a generalized strain pattern was observed, with no

indication of any localized stress such as is usually found around inclusions.

THE MARIE ANTOINETTE EARRINGS

Although the Marie Antoinette necklace is mentioned several times in the literature, little has been recorded about the earrings (figure 5). They were probably part of a suite of extremely large pear-shaped diamonds that were assembled by the court jeweler for Madam Jeanne du Barry, mistress to Louis XV of France. After his father's death, Louis XVI reportedly gave them to his queen, Marie Antoinette, who is said to have worn them constantly. The earrings were left in the Tuileries when the royal family attempted to escape from Paris in June, 1791.

The center stones in the earrings were the only ones examined by the authors in detail. Although the stones are rather large pear shapes, they are very shallow. One measures 23.21 × 19.36 mm and is 6.80 mm deep, and the other measures 24.40 × 17.00 mm and is 5.13 mm deep. Application of the GIA weight estimation formula provided weights of approximately 19 and 13 ct, respectively. It appears that the weight of 36 ct each indicated on the information card that accompanied the exhibit is in error and represents, instead, the total weight of the two stones.



Figure 5. The Marie Antoinette earrings. The large diamond drops weigh approximately 19 and 13 ct each, respectively. Courtesy of the Smithsonian Institution; photo © Harold & Erica Van Pelt.

The stones appear to be colorless, or nearly so, as would seem to be confirmed by the absence of a 415.5-nm line in their absorption spectra. However, it should be noted that the stones were tested at room temperature, and there is always the possibility of a weak 415.5 line becoming discernible if the stones were cryogenically cooled. One of the stones was inert to any ultraviolet radiation, while the other fluoresced a weak blue to both long- and short-wave rays.

Both stones had extremely thin girdles. As a result, over the years they have acquired a number of chips along the girdle edges. Some of these chips are relatively large and would probably place the stones in the VS category. Using a microscope at 10× magnification, we did not see any internal characteristics other than bearding at the girdle edge. However, the stones would have to be graded out of their mountings before any claims could be made that they might be potentially flawless if recut. Both stones showed considerable strain when examined in the polariscope, but no localized strain pattern.

CONCLUSION

Few stones equal the Star of Bombay sapphire, Portuguese diamond, and Marie Antoinette earrings in size, quality and, in the case of the latter, historical interest. We hope that our examinations will provide a more complete record on these stones for future researchers, and that the opportunity will become available to provide similar reports on other named pieces as we seek to learn more about these touchstones of gemology.

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GREEN GLASS MADE OF MOUNT SAINT HELENS ASH?

By Kurt Nassau

A specimen of green glass said to be made from ash from the May 1980 eruption of Mount Saint Helen in Washington State was examined and compared with a black glass made by melting a sample of the ash. The glasses are quite different in their properties, and analytical results show that the green glass contains at most 5% to 10% of mount Saint Helens ash, if any.

On May 18, 1980, Mount Saint Helens, in Washington State, erupted violently. The resulting ash cloud rose as high as 10 km (6 mi.) into the upper atmosphere, depositing some three cubic kilometers of material over several states. (About 600,000 tons of ash—basically fine particles of rock—fell on the town of Yakima, Washington, alone.) The author subsequently obtained samples of ash from Yakima, Spokane, and other localities, including a large sample collected in central Washington by C. B. Keenan.

The ash was determined to consist partly of glass and partly of crystalline material, including quartz, feldspar, and other minerals. The particles range from over 1 mm to less than 1 μm in size, and have a bulk density of approximately 1.5 g/cm³ (Nassau, 1981). Chemical analysis of a variety of ash samples revealed the following composition as typical of this material: 64 wt.% SiO₂, 17 wt.% Al₂O₃, 5 wt.% CaO, 4 wt.% FeO (total Fe), 4 wt.% Na₂O, 2 wt.% K₂O, 2 wt.% MgO, and 1 wt.% TiO₂ (Nassau, 1981). In view of the high silicon, aluminum, and calcium contents, a glass made from this ash would have very high melting and flow temperatures and viscosity (McLellan and Shand, 1984).

In 1983, a green glass appeared on the gem market, mostly in the western United States, with the claim that it had been made by melting Mount Saint Helens ash; purchasers thus could assume that ash is the major ingredient. This seemed to be a claim worth examining in view of the high melting point and viscosity expected of such a product. An examination was undertaken when a sample, shown in figure 1 (left), became available recently from R. J. Cormier. For general discussions of glass, see McLellan and Shand (1984); for discussions of

glass in gemology, see Webster (1983) and Nassau (1980).

TESTING

A sample of Mount Saint Helens ash was heated in a 3.75-cm (1.5-in.) alumina crucible in air in an electric furnace. Viscous flow began at about 1300°C, but because of the high viscosity the air bubbles did not disappear until the ash had been heated for several hours at 1500°C. The result is an essentially black glass (figure 1, right), which appears dark gray-green when examined in thin splinters. The color is presumably derived from ligand field and charge transfer processes (Nassau, 1983) involving the high Fe and Ti content, and can be expected to vary somewhat depending on whether the material is heated in an oxidizing or a reducing environment.

The refractive index of the green glass is 1.508, while the black glass showed considerable variation (1.500–1.526), because the high viscosity inhibited mixing of the various components. Specific gravity (measured by the hydrostatic technique) for the green sample was 2.448 and for the black, 2.485. The results for the two samples were sufficiently different to throw doubt on the claimed origin of the green glass, even though some variability in the composition of the ash could be expected.

Semiquantitative (relative) elemental analyses were performed by energy-dispersive X-ray fluorescence using tungsten and chromium radiation excitation. Some elements occur at similar concentrations in both glasses: silicon is 20%, and potassium 30%, higher in the green glass, while traces of chlorine, manganese, and zinc occur at about the same concentration in both glasses.

ABOUT THE AUTHOR

Dr. Nassau is a research scientist residing in Bernardsville, New Jersey.

Acknowledgments: The author thanks Roger J. Cormier for providing a specimen of the green glass, and Christopher B. Keenan for supplying a large sample of Mount Saint Helens ash. The photographs are by the author.

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Figure 1. Green glass (30 mm long) claimed to be made from Mount Saint Helens ash, and black glass that the author made from a sample of ash.

Some elements are present at significantly higher concentrations in the green glass: approximately twice as much calcium, chromium, and zirconium, and three times as much copper, were present. Other elements have significantly higher concentrations in the black glass: 25 times as much iron, 14 times as much titanium, and twice as much aluminum and strontium. These are all the elements that were detected; with the instrumentation used it is not possible to detect light elements such as boron, sodium, and magnesium.

Here again, a different origin is indicated for the two glasses. The high iron and titanium contents in Mount Saint Helens ash (about 4 and 1 wt.% as oxides, respectively) are adequate to account fully for the color in the black glass. Given the lower amounts of these two elements (1/25 iron and 1/14 titanium) in, and the lighter color of, the green glass, one can deduce that the material contains little if any Mount Saint Helens ash. Allowing for the variability in composition of the ash and for the semiquantitative nature of the analysis, a maximum of 5% to 10% ash in the green glass is indicated.

One final and quite conclusive test was performed by placing small pieces of each glass on platinum foil and heating them in a furnace in air, increasing the temperature by 100°C every 15 minutes. The green glass flowed at 800°C; the black glass did not flow until 1300°C (figure 2). This huge difference is undoubtedly caused by the higher silicon and aluminum concentrations in the black glass and the probable presence of significantly larger amounts of the undetermined oxides of boron and sodium in the green glass. The melt-

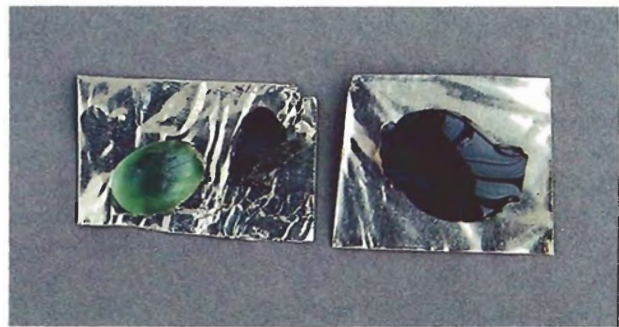


Figure 2. Left, the small, irregular pieces of green and black glass shown in figure 1 after heating to 800°C; right, the black glass heated to 1300°C.

ing point of the black glass is so high that it would be very difficult and costly to fabricate a uniform glass from it on a commercial scale.

CONCLUSION

Green glass claimed to be made from ash from the 1980 eruption of Mount Saint Helens has significantly different properties and composition from glass actually made entirely from the ash. It contains at most 5% to 10% of this ash, if any.

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Editorial Forum

THE NEED TO KNOW: ANOTHER EMERALD FAKE

We had no sooner received the Winter '85 edition of *Gems & Gemology* with your editorial on fakes, when I walked a man with three rough "emeralds" weighing 52, 33, and 20 g, respectively. They came (we were told) from a "respected supplier" who had in turn obtained them from a mine in the Chitanti district of Zambia.

The crystals were in our possession for such a short while that no testing was possible. On eye examination, however, the "emeralds" appeared to be encrusted (it looked like a baked finish) in mica schist matrix and to have been water washed or tumbled. The color was a slightly bluish green with a few inclusions of what appeared to be biotite as well as some mica, exceptionally little *jardin*, and some very minor internal flaws.

We cut a "window" on the smallest specimen and this is where the fun started. On drying the rock, we noted that the paper had been stained a vivid yellow and that oozing out of the stone was a liquid which felt somewhat acidic (acetic acid to set dye?) to the hands. The balloon really went up when the stone was washed in lukewarm water and household detergent—it came apart completely, showing a green dye on the flat faces of what looked like a quartz material. Obviously the pieces had been glued together.

Our personal feeling is that someone read the literature on emerald and turned out a very credible imitation. We were subsequently told that this fake apparently came from Zimbabwe, where someone is producing them in quantity.

M. C. L. Backler
Pinetown, South Africa

MORE ON OLD PEARL-CLEANING RECIPES

The experiments of Nassau and Hanson (Winter 1985, pp. 224–231) confirm the validity of the old Chaldean recipes compiled by Bolos of Mendes (among others) between 200 and 100 B.C. Although many of these old

manuscripts were lost or destroyed, especially during Diocletian's repression of Egypt (296 A.D.), the information was passed on through a combination of verbal and written communications. It was not until the mid-19th century that such practices came into disrepute. In 1858, Barbot wrote that, regarding the feeding of pearls to chickens, he was inclined to believe that "this practice should be considered an old wives' tale."

The use of an acid to remove the external layer of a pearl is also an old method, passed on in later years in recipes published by Anselmus Boetius de Boot (1609) and Placide Boué (1832). This treatment became suspect early in the 20th century, though, and in 1919 Leonard Rosenthal wrote: "Must it be said that we tremble to think of readers who would submit their pearls to the treatment prescribed by the well-known doctor (de Boot)?"

If the results obtained by Nassau and Hanson (e.g., on pearl no. 10) were not always as good as hoped, the cause is probably the thinness of the nacre layers in a Japanese cultured pearl, as compared to the thickness of nacre in a natural pearl, for which the recipes were intended. Even a natural pearl must be carefully examined before peeling. The general consensus has been that it is not possible to peel cultured pearls, but the thickness of nacre in South Sea cultured pearls would appear to be sufficient to permit peeling. There are, in fact, two men in Paris and one in New York (who studied in Paris) who know how to peel pearls and feel that it is still a valid technique.

It should also be noted that, contrary to the comment on p. 225 of Nassau and Hanson (1985), Halleux did not compare the cleaning of pearls to that of a "fake gemstone." What he did was to use a dirtied imitation diamond and a duck to demonstrate the cleaning power of gastric juices in general.

J.-P. Poirot
Director, Public Service for the
Control of Diamonds, Pearls,
and Precious Stones
Paris Chamber of Commerce
and Industry
Paris, France

CHINA'S BOUNDARIES

I felt that our cooperative paper ["A Survey of the Gemstone Resources of China," *Gems & Gemology*, Spring 1986, pp. 3–13, coauthored by Dr. Peter C. Keller] had an outstanding layout. However, I am sorry to have found the map showing the location of major gem occurrences in the People's Republic of China to be unacceptable because of the following political mistakes:

- A. Chinese on both sides of the Taiwan Straits accept Taiwan as a province of China, a fact that has also been recognized by your government. Taiwan, however, is colored as China's neighboring country on the map.
- B. There are some boundary sections that are unacceptable to China. For example, the eastern section of the boundary between China and India follows the illegal McMahon Line, and the boundary section west to Xingjiang and Xizang

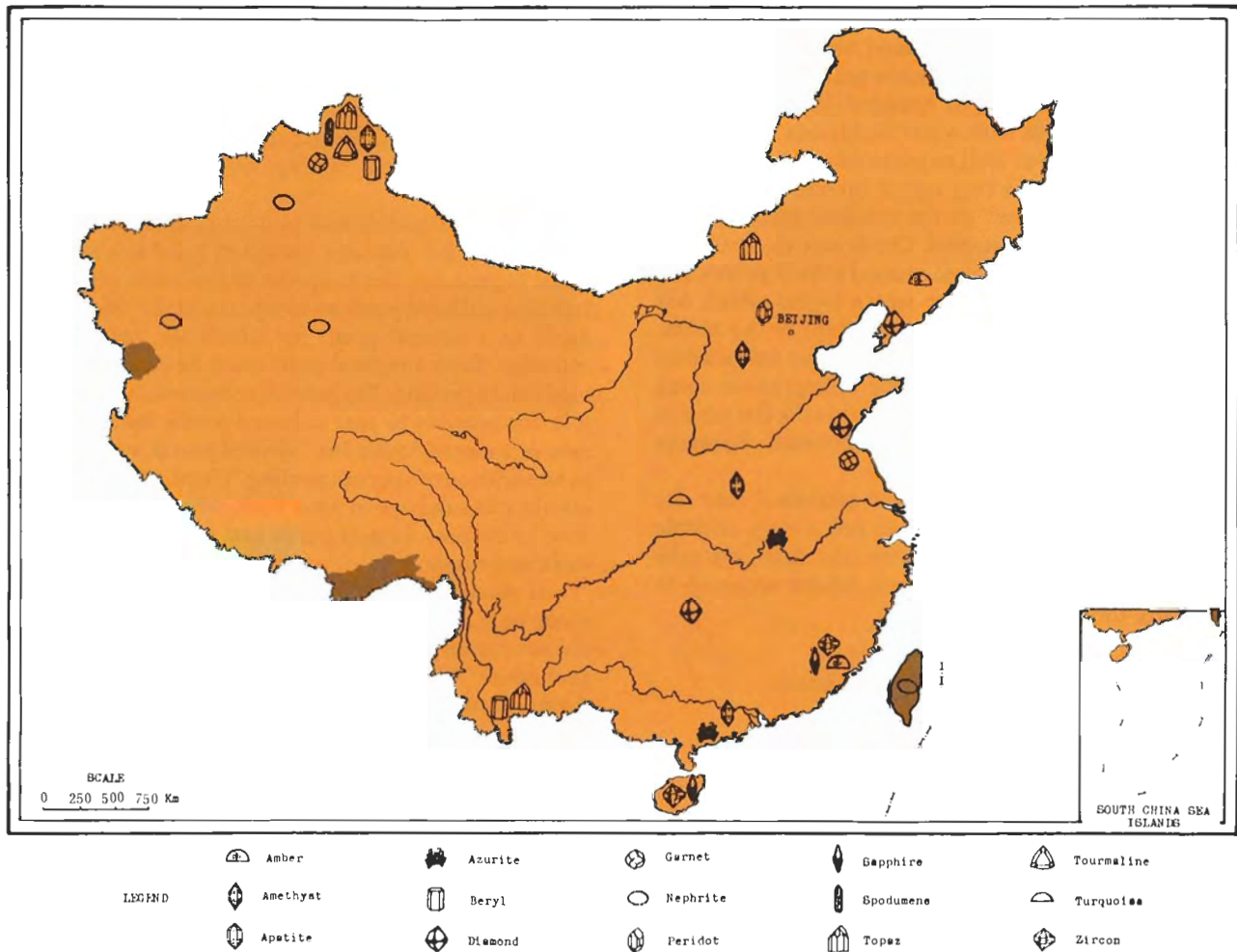
(Tibet) takes the Aksayqin area out of China's territory.

I had sent a map to replace the draft you sent, and hereby suggest that you include it in the next issue of *Gems & Gemology* as a corrigendum.

Wang Fuquan
Geological Museum
of China, Beijing

In the process of incorporating the information provided by Dr. Wang and the additional localities supplied by Dr. Keller into a more comprehensive map, we unfortunately did not pay adequate attention to the political boundaries of the map Dr. Wang had provided. We regret any embarrassment that this may have caused Dr. Wang, and direct our readers' attention to the map draft originally submitted by him, reproduced here as figure 1.—Editor

Figure 1. Map of the principal gemstones of China prepared by Dr. Wang Fuquan. For clarification, we have shaded the areas discussed in Dr. Wang's letter.



WHAT IS A SYNTHETIC?

Many modern gemologists define *synthetic* (noun) as a man-made substance which has the same physical properties and chemical composition as a naturally occurring mineral. This is incorrect.

The correct definition of the noun *synthetic* is something that is man-made rather than naturally occurring. The operative word in this definition is *man-made*. Consequently, that which is not man-made is, by definition, natural.

Acceptance of the faulty definition in the first paragraph leads to the statement made in the *Gem News* column (Summer 1985, p. 119) concerning Alexandrium and Laserblue: "They are not classified as synthetics because they do not duplicate minerals."

How then does one classify these substances? The report states that Alexandrium is a lithium aluminum silicate and Laserblue is a borosilicate. This statement is also incorrect. The terms *silicate* and *borosilicate*, by definition, incorporate the concept of a defined crystal structure. These new materials are amorphous. In simple language, these materials are glasses. Also, since

they are man-made, they are, by definition, "synthetics."

Gemologists should stop using the word *synthetic* as a noun—it serves no useful purpose. Rather, *synthetic* should *always* be used as an adjective in conjunction with the noun it modifies. Under these circumstances, there can never be any misunderstanding.

Although the definition expressed in the first paragraph is incorrect as a definition of the noun *synthetic*, it is correct as the definition of a "synthetic mineral." Consequently, we can apply it to the two glasses and rightly conclude that they are not synthetic minerals.

As to what they are, there are many answers. They may be called synthetic materials, synthetic glasses, or even simulated gems. In the gemological sense, these materials are "synthetics," but not synthetic gems or synthetic minerals. In the commercial sense, they are salable products; however, since they are merely glass, fancy names or pseudo-compositions cannot increase their intrinsic worth.

W. W. Hanneman, Ph.D.
Castro Valley, CA

Continued from p. 127

formed, and describes the changes that inclusions undergo after they are sealed in their hosts. The preparation of samples for study and the destructive and nondestructive methods of inclusion analysis presently in common use are discussed. Ways of interpreting the data obtained from fluid inclusions are outlined, and each of the various geologic environments, from sedimentary to the upper mantle, is detailed in its own separate chapter. Even extraterrestrial environments are discussed in a chapter that highlights inclusions in both lunar rocks and meteorites. The book also contains comprehensive subject and locality

indexes and a bibliography of over 1,700 entries.

From the gemologist's viewpoint, the one drawback to this volume might be the fact that the microscope techniques as well as much of the testing methodology (particularly the destructive techniques) employed by Dr. Roedder and others in their investigation and documentation of fluid inclusions are not directly applicable to routine gemology. Even so, the chapters providing a glimpse at these techniques are fascinating. They not only enlighten the gemologist to the complexity of the inclusionist's problems, but they also introduce the sophisticated instrumentation often needed to genetically interpret

fluid inclusions. Any gemologist who has ever enjoyed looking through the microscope will appreciate Dr. Roedder's effort.

Considering the complex nature of today's synthetic and treated gemstones, it is wise for the gemologist to learn as much as possible about inclusions in gem materials. This excellent book provides a solid foundation for the study of fluid inclusions in all materials, and should be read by every serious gemologist. With over 400 black-and-white photographs and over 200 line drawings and charts, this large volume is a real bargain at \$15.00.

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Devitrified GLASS

Cobalt-Bearing

Recently submitted to the Los Angeles laboratory for identification was the 2.89-ct black free-form cabochon illustrated in figure 1. Our client explained that it was representative of material being exported from Hong Kong as black "onyx" (dyed black chalcedony). When viewed with the unaided eye in sunlight or artificial overhead illumination, the piece appeared to be opaque and black. However, when examined under magnification with dark-field and fiber-optic illumination, the edges of the cabochon appeared to be semitransparent to translucent, and blue in color. Also very prominent was the dendritic structure (figure 2) that is characteristic of man-made devitrified glass. This pattern is well known to gemologists, as it is typical of the excellent devitrified glass imitation of jadeite jade that is known as "metajade." Patterns such as these, which are the result of devitrification (the partial change of a substance from an amorphous glassy structure to a crystalline, or partially crystalline, structure after solidification) should always alert the gemologist to the probability of glass.

A spot refractive index of 1.50 was obtained. The material was inert to long- and short-wave ultraviolet radiation. Since the cabochon was nearly opaque in most lighting conditions, no reaction was expected, or observed, in the polariscope. The specific gravity was estimated with heavy liquids to be approximately



Figure 1. This 2.89-ct black free-form cabochon, represented as dyed black chalcedony, was found to be cobalt-bearing devitrified glass.

2.60. The hardness was estimated to be between $5\frac{1}{2}$ and $6\frac{1}{2}$ on the Mohs scale. When the cabochon was placed on the iris diaphragm of the spectroscope unit, or over the end of a fiber-optic light source, the entire stone "glowed" bright red because of the very strong red transmission.

To view the absorption spectrum, we placed a fiber-optic light tube directly behind the cabochon in order to pass enough light through this very dark material. With the spectroscope, we observed a strong cobalt spectrum that was essentially the same as that for cobalt-bearing flame-fusion synthetic blue spinel. However, the glass absorbed light up to nearly 480 nm and exhibited an overall dark absorption pattern, which is to be expected in stones that are extremely dark in color.

Although we have seen opaque black glass imitations colored with



Figure 2. At 20x magnification, the cabochon shown in figure 1 revealed a dendritic pattern typical of man-made devitrified glass. Oblique illumination.

major amounts of tin oxide and remelted with manganese oxide and "hammer slag" from the production of iron, this is the first time that we have encountered a black-appearing cobalt-bearing devitrified glass. Perhaps a major motivation for simulating dyed black chalcedony is that the devitrified glass can be molded into a particular shape, requiring repolishing only on the top. The back of the devitrified glass cabochon described here did show evidence of molding.

RK

With an Unusual Inclusion

The New York laboratory recently examined two translucent green oval cabochons that were being represented as natural glass from Mexico.

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

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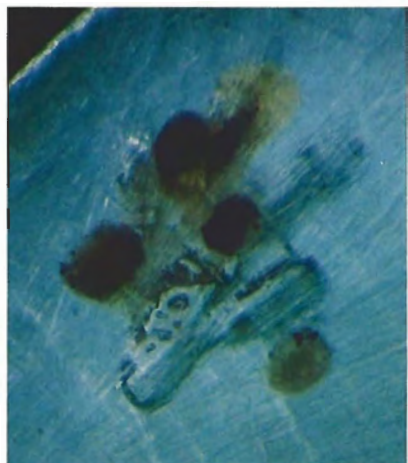


Figure 3. This distorted gas bubble in devitrified glass resembles a partly resorbed crystal, such as is found in natural glass. Magnified 35x.

Yet the properties were the same as those for devitrified glass of this color, and the stones also showed the dendritic pattern typical of man-made glass.¹ However, there was an unusual inclusion (figure 3) near the surface on the back of one of the cabochons that resembled a partly resorbed crystal, suggestive of natural origin, although the high relief and the rounded ends raised the possibility that it might be a distorted gas bubble. Since the stones had been donated to the laboratory and the inclusion was so close to the surface, we scraped into the inclusion and found that it was hollow, proving that it was indeed only a distorted gas bubble. RC

LAPIS LAZULI, Dyed and "Sealed"

Over the years, the New York laboratory has been asked many times to check for dye and, more recently, for evidence of oil or paraffin in lapis lazuli (see, for example, Gem Trade Lab Notes section, Summer 1981 and Winter 1985). Heretofore, when acetone applied with a cotton swab has produced evidence of dye, the dye has been detected primarily in the cracks

and porous areas of the stone. The effect of the dye is to darken light areas and provide a more uniform appearance. Some of the dyed stones are further "sealed" with some type of oil, wax, or the like. However, some paraffin-treated lapis (whether dyed or undyed) does "sweat" when tested with a thermal reaction tester.

Recently, a strand of 7-mm violet-blue beads known to be dyed (figure 4) was donated to the laboratory. Unlike most of the dyed lapis we have examined, however, these beads were so heavily saturated that they virtually owed their color to dye. When exposed to long-wave ultraviolet radiation, some of the beads showed a patchy red fluorescence; with short-wave, only about half showed the chalky green fluorescence characteristic of natural lapis lazuli. Surprisingly, the "swab" test was not as revealing with these beads as with the selectively dyed stones we have previously seen. However, the thermal reaction tester produced evidence of paraffin treatment, so it may be that the paraffin "seal" must be removed before the dye will stain the swab. Under magnification, a few of the beads showed purple dye in the cracks, while others showed the

same unnatural purple color in patches not associated with cracks or otherwise obviously porous areas. Under a Chelsea color filter, the beads all appeared a definite brownish red, much brighter than any natural-colored specimens we have tested. RC

OPAL

Assembled Opal Beads

Anthony de Goutière, a graduate gemologist in Victoria, B.C., Canada, thought our readers might be interested in an unusual opal bead necklace he examined (figure 5). The necklace is made up of cubic and roughly spherical opal beads (7-15 mm in diameter) separated by transparent colorless faceted rondelles. As figure 6 shows, however, the beads were actually assembled by attaching slices of opal to some sort of shaped backing material with black cement. These pieces were then cut and polished into shape.

The owners of the necklace could not supply any information regarding its history, but guessed that it dated to the 1930s. This manufacturing technique represents an inter-

Figure 4. These 7-mm lapis lazuli beads were heavily dyed and then coated with paraffin.





Figure 5. The graduated (7-15 mm in diameter) opal "beads" in this necklace were found to be assembled.

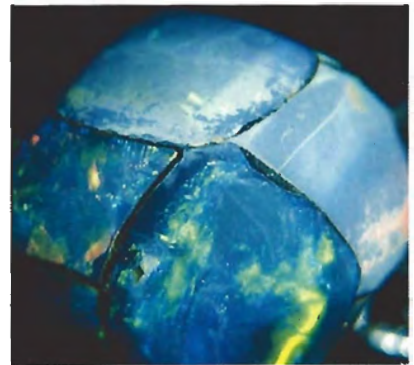


Figure 6. With 3× magnification, it is evident that a black cement was used to attach slices of opal to a shaped backing material to form the opal "beads" shown in figure 5.

esting way of using thin slices of opal to create relatively large beads. CF

Green Opal from Brazil

A stone dealer recently brought to the Los Angeles laboratory a selection of rough and cabochon-cut green opals from Brazil. Figure 7 shows the three sample stones (ranging from approximately 1 to 2 ct) that were donated to GIA. Both the rough and cut material was fairly translucent, and the color varied from light to

dark yellowish green. Prominent dendritic black inclusions were easily visible to the unaided eye. At first glance, the material resembled translucent green grossularite garnet. The refractive index was determined to be 1.43 (spot reading). Hydrostatic determinations of all three stones were made, with the average specific gravity at 2.03 ± 0.01 . There was no reaction to either long- or short-wave ultraviolet radiation. The darkest cabochon showed a peculiar absorp-

tion spectrum (figure 8) that was visible only through the longer optical path provided by the length of the stone. There was general absorption up to 500 nm, an absorption band at 590–620 nm, two distinct lines at 640 nm and 670 nm, with a cut-off at 690 nm. KH

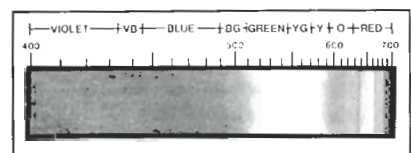
Figure 7. At first glance, these green opal cabochons (weighing 0.99, 2.22, and 1.84 ct, respectively) from Brazil resembled translucent green grossularite.



Cultured PEARLS, Miscellaneous Oddities

The New York laboratory recently examined the 13-mm cultured pearl shown in figure 9. At first it was thought that the peculiar circular area around the drill hole might be an insert. However, when viewed from the side, this circular area proved to be raised above the surface of the pearl. It seems to match the size and configuration of the mounting cup

Figure 8. The absorption spectrum for the darkest green opal cabochon shown in figure 7.



that the pearl was once attached to. It is possible that the area around the cup was eroded by skin acid during wear, although the luster of the pearl does not seem to have been harmed.

Some years ago, the New York laboratory was shown a group of pear-shaped pearls with oversized drill holes (figure 10). We subsequently proved that they were freshwater mantle-tissue-nucleated cultured pearls on the basis of their X-ray fluorescence and because a few still retained vestiges, seen in the X-radiograph, of the "void" caused by the mantle-tissue implant. Not all pearls in a freshwater tissue-nucleated pearl necklace will show a void—some of the voids may be eliminated by the drill holes. These pearls create a problem when they are offered as natural pearls, the seller hoping that the drill hole has eliminated the evidence of tissue nucleation. The laboratory has encountered such pearls in old jewelry from which the original natural pearls have been removed and these pearls substituted. RC

Cat's-Eye RUTILE

A local gemologist and dealer in pearls and rare gemstones asked the Research Department of GIA—Santa Monica to identify two cat's-eye stones (2.74 ct and 1.43 ct) that his firm had acquired in Sri Lanka. The stones were opaque and appeared to be black, although the sharp eyes in each were brown (figure 11). Gemological tests done by the client revealed the refractive index to be over the scale (greater than 1.81), and the specific gravity to be considerably heavier than the 3.32 liquid. The stone gave no reaction when exposed to either long- or short-wave ultraviolet radiation. The streak was brown and the hardness seemed to be about 6 or a little higher. The X-ray diffraction pattern obtained from a minute amount of powder scraped from the back of one stone matched that of rutile.

It is interesting to speculate on

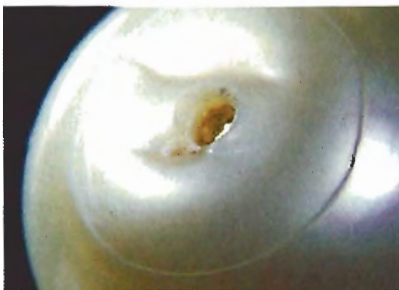


Figure 9. This unusual circular area around the drill hole of a 13-mm cultured pearl is actually raised above the surface of the pearl. Magnified 10×.

how this particular rutile manages to exhibit such a sharp cat's-eye. Since the material is essentially opaque, it is unlikely that the chatoyancy is the result of reflection of light from parallel acicular inclusions, as in chrysoberyl and other materials. Although, to our knowledge, rutile has not previously been reported to occur in a massive fibrous form, this would seem to be the only explanation for its ability to produce a cat's-eye effect. CF



Figure 11. This unusual cat's-eye rutile weighs 1.43 ct. Magnified 3×.

"Cobalt-Blue" SPINEL, an Update

The Los Angeles laboratory recently received for identification two natu-

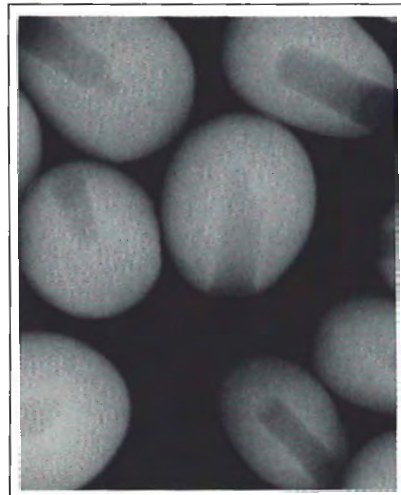


Figure 10. Oversized drill holes are often used to hide evidence of mantle-tissue nucleation in freshwater cultured pearls.

ral blue "cobalt-colored" spinels. Figure 12 shows one of these stones, which weighs 2.21 ct and is an intense "cobalt blue." The other stone weighs 5.31 ct and is dark violetish blue. These two stones exhibit essentially the same gemological characteristics as the 2.56-ct natural spinel mentioned in the Gem Trade Lab Notes section of the Winter 1982 issue of *Gems & Gemology*, and the natural blue cobalt-bearing spinels discussed in great detail in an article by J. E. Shigley and C. M. Stockton that appeared in the Spring 1984 issue of *Gems & Gemology*. The absorption spectra of the stones Shigley and Stockton studied have characteristics that are generally attributed to cobalt and iron. The samples used in that study, which included both rough and cut stones, were reportedly from the Okkampitiya mining region of Sri Lanka. These unusual natural spinels represented a type that was new to most gemologists, in that blue coloration caused by cobalt was previously believed to occur only in synthetic, not natural, spinel.

Although this type of natural blue "cobalt-colored" spinel is very unusual and may be encountered only rarely by the jeweler-gemol-



Figure 12. A 2.21-ct natural "cobalt-colored" blue spinel.

ogist, it can be readily identified by its characteristic properties. The specific-gravity values for the two spinels that we recently examined were within the expected range for both natural and synthetic blue spinel. The refractive index, 1.720, is consistent with other natural blue spinels. The two spinels were inert to both long- and short-wave ultraviolet radiation. This is in contrast to flame-fusion synthetic "cobalt-blue" spinel, which often exhibits a strong chalky whitish green fluorescence to short-wave ultraviolet radiation and a strong red fluorescence to long-wave ultraviolet radiation. The color-filter reaction of this type of natural spinel (weak to strong red) can overlap with that of its flame-fusion synthetic counterpart. Examination of the two spinels with a polariscope revealed that they were singly refractive with very little, if any, anomalous double refraction. This is in contrast to the strong "cross-hatched" patterns and/or "snake-like" bands present in flame-fusion synthetic blue spinels. When the 2.21-ct spinel was placed over the opening of the iris diaphragm on the spectroscope unit, no colored transmission was observed, whereas a very weak red transmission was seen in the 5.31-ct stone. Examination of several other natural blue cobalt-bearing spinels has revealed that some may exhibit a strong red transmission, as do many

flame-fusion synthetics of this color. With the spectroscope, we observed bands at approximately 434, 460, 480, 559, 575, 595, and 622 nm (for an illustration of a similar spectrum, see the article in the Spring 1984 issue of *Gems & Gemology*). The most diagnostic spectral features are the bands at 434, 460, and 480 nm, which do not occur in the synthetic material. The 2.21-ct spinel con-

tained several well-formed transparent crystals which showed moderate interference colors under polarized illumination. These crystals had the same appearance as those observed in other natural "cobalt-blue" spinels. In addition, small cavities and fractures with yellow stains were also present. The 5.31-ct stone contained a group of white, irregular, thread-like inclusions along a heal-

Figure 13. Testing with a hot point revealed that the surface of this turquoise carving (12.4 × 11.0 × 8.6 cm) had been treated with paraffin.



ing plane; some were stained brownish yellow by iron. We have also observed this type of inclusion in other natural "cobalt-blue" spinels.

RK

TURQUOISE, with Simulated Matrix

Recently brought to the Los Angeles laboratory for identification was the opaque greenish blue carving of two Oriental women illustrated in figure 13. Testing identified the carving as paraffin-treated turquoise. A hot point on a low setting caused the paraffin to melt profusely. When the piece was examined with magnification, both the color and structure were found to be typical of porous turquoise from China (porous turquoise from any locality can be paraffin treated). A spot refractive index of 1.58, which is low for turquoise,



Figure 14. Black dyed paraffin was used on the turquoise carving shown in figure 13 to simulate natural matrix. Magnified 5x.

was obtained on most areas of the carving. We scraped away the paraffin on a small area at the base of the carving and obtained a refractive index of 1.61, which is typical for turquoise.

In addition to the colorless paraffin treatment, matrix was simulated by the use of a black dye in the paraffin (see figure 14). The black matrix was cleverly daubed on to many "flat" surfaces of the carving and was only rarely added to natural matrix depressions.

RK

FIGURE CREDITS

The photos in figures 3 and 11 were taken by John I. Koivula. Shane McClure provided the photomicrographs used in figures 1, 2, and 12-14. Dave Hargett was responsible for figures 4 and 9, and Chuck Fryer took figure 7. Figures 5 and 6 are courtesy of Anthony de Goutière. Bob Crowningshield gave us figure 10, and Karin Hurwit prepared figure 8.

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GEM NEWS

John I. Koivula, *Editor*
Elise Misiorowski, *Contributing Editor*

COLORED STONES

Tucson 1986. In addition to the many extraordinarily fine natural gemstones such as rubies, emeralds, sapphires, tanzanites, garnets, aquamarines, tourmalines, topaz, and the like, usually seen at Tucson, this year's show featured many other interesting gem materials. Robert E. Kane, gem identification and research supervisor for GIA's Gem Trade Laboratory in Los Angeles, supplied the following report on some of the more unusual materials seen at the February 1986 Tucson Gem and Mineral Show for *Gem News*.

Cat's-eye kunzite. Chatoyant semitranslucent to opaque kunzite cabochons and rough from a deposit in South Dakota were displayed.

Covellite. Several firms were selling massive forms of covellite rough, as well as cabochons and faceted tablets. Covellite (CuS) is generally dark indigo blue in color, sometimes with a purple surface tarnish. Covellite has a submetallic luster, a specific gravity of about 4.6, a shade or spot refractive index reading of 1.45, and a hardness of 1.5–2. It is frequently intergrown with small veins of "brassy" metallic-appearing minerals such as pyrite and chalcopyrite. Covellite cabochons are usually inexpensive and sold as a collector's stone. Because of its softness—it can be scratched with a fingernail—covellite is not used in jewelry.

Lepidolite. One dealer had about 50 cabochons of lepidolite, some as large as 20 ct. Most of the cabochons were opaque, ranging in color from light to dark pinkish purple, and nearly all appeared to be identical to the lepidolite "matrix" that occurs in massive quantities at several of the tourmaline deposits in Pala, California. A few of these stones, however, were translucent. A medium-dark pinkish purple stone revealed shade refractive indices of around 1.560–1.590, a specific gravity of about 2.8, and a hardness of approximately 3. It was inert to long-wave ultraviolet radiation, and fluoresced extremely weak to short-wave U.V. rays.

Magnesite dyed blue to imitate turquoise. One dealer was selling necklaces of tumbled nodules of dyed blue magnesite from Africa. This material can be identified by the following:

- Spot refractive index readings of 1.51 and 1.70. Extremely high birefringence suggests a carbonate.
- The specific gravity of magnesite, approximately 3.0, is too high for calcite (2.71) or dolomite (2.85), both of which are also frequently used to simulate turquoise. Once the material has been identified as magnesite, it is immediately evident that it is dyed, since blue magnesite does not occur naturally.

Not only is the magnesite dyed, but the recessed matrix areas in these tumbled nodules are filled with a wax-based black material (probably added during the polishing process) to imitate spiderweb turquoise.

Pectolite. A large selection of rough and cabochon-cut blue pectolite from the Dominican Republic was displayed by a dealer from Santo Domingo who claims to control the entire supply of this material from that source. This attractive translucent-to-opaque blue ornamental mineral usually shows one or more fibrous radial patterns. It has been known for several years by the trade name "Larimar," but this is the first effort we have seen to market it on an international scale.

"Rainbow" moonstone. Several dealers had cabochons from India that were described as "rainbow" moonstone. The cabochons were small, ranging from 1 to 2 ct each. This unusual type of "white" moonstone displays an attractive adularescence of orange, pink, green, and blue, in contrast to the predominantly blue-white adularescence generally associated with moonstones of this body color. These stones were always displayed on a black background, which accentuated the multicolored adularescence, and were most impressive when several were placed together.

Spurrite. Numerous pieces of rough and a few polished slabs of an attractive translucent to opaque, medium to dark purple gem material were displayed by a dealer in Tucson who sells gems and minerals from Mexico. He said that he had just over 100 kg of rough. A polished slab of this material was tested, and revealed shade refractive indices of 1.640–1.680, a hardness of around 5, and a specific gravity near 3.0, all of which matched those properties recorded for the mineral spurrite.

X-ray powder diffraction analysis by C. W. Fryer of



Figure 1. This rare natural twin star spinel weighs 2.12 ct. Note the twin plane running down the center of the stone. Photo © Tino Hammid.

the GIA Research Department confirmed that this attractive purple gemmy material is spurrite. *Dana's Textbook of Mineralogy* states that spurrite, $\text{Ca}_3(\text{SiO}_4)_2(\text{CO}_3)$, occurs in contact zones between limestone and diorite in the Valardena mining district of Mexico, as well as in Ireland.

Taaffeite. Two unusual taaffeite crystals were examined. One, a distorted crystal weighing 46.17 ct, is the largest known piece of taaffeite rough ever recorded. The other weighed 2.81 ct and had several fairly well developed crystal faces, which has never before been reported in taaffeite.

The Tucson show always provides an opportunity to see and examine rare collector stones that have been cut. In addition to those already listed above, excellent examples of the following were also seen this year: ekanite, phosphophyllite, proustite, friedelite, haüyne, pyrrargyrite, bustamite, light blue and brown sillimanite (fibrolite), and purple scapolite.

Collectors, retailers and dealers say that the Tucson show helps pinpoint market trends in colored gemstones, supplies, and price changes, and provides an opportunity to see and purchase all types of rough and cut gemstones, jewelry, and mineral specimens, as well as lapidary equipment and tools. Another important aspect of the Tucson show is the opportunity for structured education. In addition to GIA's lectures and seminars, other groups such as the Accredited Gemologists Association (AGA), the International Society of Appraisers

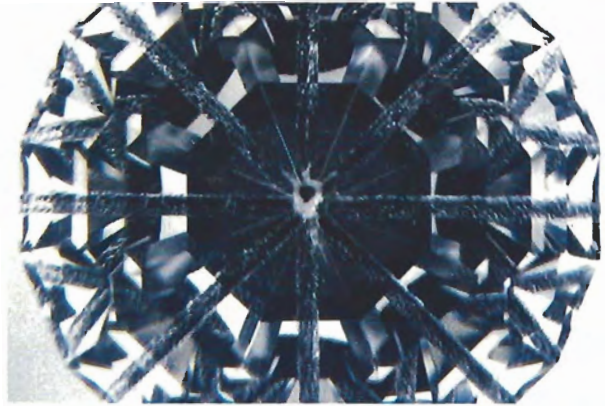


Figure 2. When this 18.57-ct rock crystal quartz was cut, a single included acicular black tourmaline crystal was carefully positioned so that its reflection would create the wagon-wheel pattern evident here. Photo by John Koivula.

(ISA), and the American Gem Trade Association (AGTA) present many industry-related seminars and short courses.

Twinned star spinel. One of the most striking gems we have seen in a long time is shown in figure 1. This pinkish purple natural star spinel weighs 2.12 ct and belongs to David Myerson of Northridge, California. Fine star spinels are not particularly common, and this one is a rarity among the rare. The gem is divided down the middle by a twin plane and its surrounding contact zone. This contact zone is darker than the rest of the stone and contains no star-producing inclusions. As a result of the contact twinning, two complete and distinct stars are readily visible, one on each side of the twin plane, even when just a single light source is employed. This is the only twinned double-star spinel we have ever encountered.

Wagon-wheel quartz. Don Riffe, of Wight Jewelers in Ontario, California, gave us a most unusual faceted rock crystal quartz for examination. It weighed 18.57 ct (15.88 × 13.69 mm) and was well fashioned in a modified round step-cut. The unusual feature of this quartz is that it contains a single acicular crystal of black tourmaline. The cutter, John Boardman, has positioned the tourmaline inclusion so that it runs from the culet through the entire depth of the stone up to the center of the table. As shown in figure 2, the black tourmaline inclusion is reflected in a spoke-like pattern in the quartz, creating the appearance of a wagon wheel. In the past, the editors have seen a few similar stones that have used either tourmaline or rutile as the reflecting crystals. Good rough to cut such stones is difficult to obtain, and is generally referred to as single-needle quartz.

Sams Collection now on display at the Houston Museum of Natural Science. The Houston Museum of Natural Science recently purchased the Perkins and Ann Sams collection of minerals, to be housed as a permanent exhibit in the new Lillie and Roy Cullen Gallery of Earth Science. The collection encompasses some 500 mineral specimens, including a superb imperial topaz crystal from Brazil; a grouping of fine tourmaline specimens; cerussite and azurite from Africa; emerald, ruby, and diamond crystals; and fine pieces of Japanese stibnite, German manganite, and Bohemian cassiterite. A particularly fine emerald crystal from the collection is shown in figure 3.

For further information, contact the Houston Museum of Natural Science, 1 Hermann Circle Drive, Hermann Park, Houston, TX 77030; (713) 526-4273.

GIA GemFest scheduled. GIA will hold its third annual GemFest on August 14 and 15, 1986, at their headquarters in Santa Monica. GemFest is a program of seminars encompassing gemology, jewelry manufacturing arts, jewelry sales, and business. For registration and further information, contact GIA GemFest, 1660 Stewart Street, Santa Monica, CA 90404; (213) 829-2991.

Winners of the Scheutz Award Design Contest announced. The George A. Scheutz Memorial Fund Jewelry Design Contest added a new category this year for its annual competition hosted by GIA. For the past 10 years, the competition has featured men's jewelry and accessories only. This year, women's colored stone jewelry was added. The winning entries, submitted in the form of color renderings, are: a woman's ring of 18K yellow gold and lapis lazuli designed by Catherine O. Villeneuve of Villeneuve-Lamarche, Montreal, Quebec; and a man's 18K yellow-gold ring inlaid with onyx and set with a quadrillion-cut

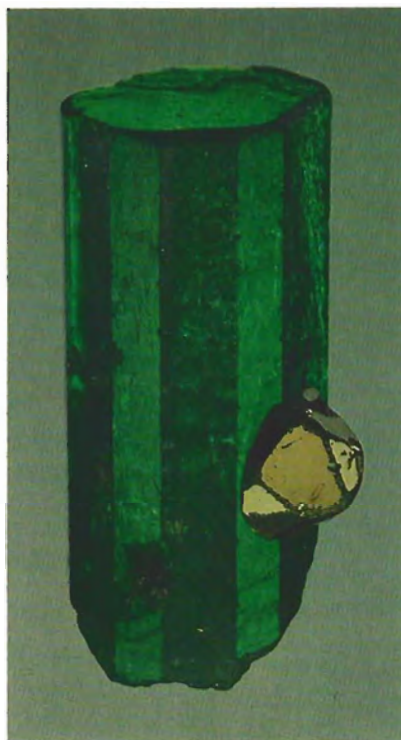


Figure 3. This fine emerald with pyrite specimen (45 mm high)—from Muzo, Colombia—is part of the famous Sams Collection now housed in the Houston Museum of Natural Science. Photo © Harold & Erica Van Pelt.

diamond, designed by Vikki Jirikow of Playa del Rey, California.

The deadline for the 1987 competition is February 28, 1987. For further information, contact the Jewelry Manufacturing Arts Department at GIA—Santa Monica.

Committee formed by ASA and AAA to establish uniform appraisal standards. The American Society of Appraisers and the Appraisers Association of America have announced the establishment of a joint committee to create and produce uniform standards of appraisal practice specifically for the appraisal of personal property, in order to provide guidelines that can be used by the public, the courts, government agencies, commercial

institutions, and members of the appraisal profession. The committee will also formulate the educational curricula for appraisers of personal property leading to academically recognized bachelors' and masters' degrees in Valuation Sciences.

The India Gems & Jewellery Fair will be held at the Taj Mahal Hotel, in Bombay, India, September 4–8, 1986. Organized by the Gem & Jewellery Export Promotion Council and the Hindustan Diamond Company, Ltd., the fair will feature unmounted diamonds, colored stones, and pearls, as well as traditional, antique, and contemporary jewelry. For further information contact: I.G.J. Fair 1986, c/o Hindustan Diamond Company, Ltd., 15, Atlanta, Nariman Point, Bombay, 400 021 India. Telex: 011-4710 HDCL IN.

INTERGEM '86, the International Trade Fair for Gems & Jewellery, will be held on September 26–29, 1986, in Idar-Oberstein, West Germany. The exhibits range from mineral specimens and gem rough to finished jewelry, and products related to the jewelry industry. For further information contact: INTERGEM GmbH, Messeverein e.V., Postfach 12 21 80, D-6580 Idar-Oberstein, West Germany.

The Fourth Hong Kong Jewellery & Watch Fair will be held September 13–16, 1986, at the Regent, New World, and Sheraton Hotels and the Golden Mile Holiday Inn. Over 400 exhibitors from 22 countries around the world will offer a wide range of products for all aspects of the gem, jewelry, and watchmaking industries. Seminars on the international market situation and various other topics will be held concurrently with the fair. For further information contact: Headway Trade Fairs Ltd., 628 Star House, 3 Salisbury Road, Kowloon, Hong Kong. Tel.: 3-697993; telex: 41249 HX.

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

La couleur des minéraux et des gemmes (The color of minerals and gems). E. Fritsch, *Monde et Minéraux*, Vol. 22, Nos. 67, 69 and 70, 1985, pp. 20–25, 12–17, and 12–22.

While the colors of gems and minerals contribute greatly to their appeal, the causes of these colors provide clues to the genesis of the different materials. An understanding of color origin also provides a foundation for the better use of spectral and luminescence tests for gem identification. This trio of articles by Dr. Emmanuel

Fritsch is an excellent review of how color arises in gems and minerals, with easy-to-understand explanations of atomic-level behavior. In the first article, Dr. Fritsch discusses single-element color origin associated primarily with transition-metal ions, including explanations of valence states, site coordinations, and distortions. Examples of how each of these variables affects color and the optical absorption spectrum are clearly described, and a list is provided of common transition-metal ions and their coordinations, together with the color generated by each and the minerals in which each occurs.

The second article covers the more complex cases of charge transfer and interband transitions, with explanations of the molecular orbital and band gap theories necessary to understand these color origins. Normally relegated to the realms of advanced physics and chemistry, these scientific theories take on a more elementary tone with Dr. Fritsch's explanations and the numerous graphs and drawings that accompany them. The third article concludes the series with discourses on color centers, diffraction, iridescence, Tyndall effect (scattering), and diffusion, including chatoyancy and asterism.

On the whole, this series of articles provides an excellent overview of the causes of color in gems and minerals, with intelligible explanations of complex concepts. Lavish color photographs by Nelly Bariand and numerous helpful diagrams accompany the text.

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 will be of greatest interest to our readership.

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

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names.

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Many of the illustrations, however, are neither numbered nor directly referenced in the text, which is irritating and results in a lot of looking back and forth for associations. Nevertheless, the major drawback of the article for many *G&G* readers will be that it is entirely written in French. It is to be hoped that Dr. Fritsch will soon render a version in English. CMS

Crystal chemistry of zincian spinels (gahnospinel) from Sri Lanka. K. Schmetzer and H. Bank, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 8, 1985, pp. 353–356.

The chemical composition, density, and refractive index of zincian spinels from Sri Lanka have been investigated. All samples were transparent gemstones of a blue, bluish violet, or violet color caused by the presence of Fe^{2+} substituting for Mg^{2+} in the tetrahedral site. These stones are members of a compositional series between spinel (MgAl_2O_4) and gahnite (ZnAl_2O_4) in which the molecular percentage of gahnite varies from 0.2% to 50.35%, with minor amounts of a hercynite ($\text{Fe}^{2+}\text{Al}_2\text{O}_4$) component (1.7% to 5.37%) also present. Density increases with zinc content from 3.60 (pure spinel) to 4.05 (50% gahnite), while the refractive index also increases correspondingly from 1.716 to 1.752.

This study confirms what is already known about this material, and substantiates the existence of a complete solid-solution series in the spinel-gahnite compositional range. Emmanuel Fritsch

Farbloser Skolezit aus Indien (Colorless scolecite from India). H. Bank, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 3/4, 1985, pp. 167–168.

Colorless, transparent crystals represented as natrolite were identified as scolecite by refractive indices of n_x 1.512, n_y 1.518, n_z 1.523, and a birefringence of 0.011. The specific gravity is given as 2.21. Scolecite usually occurs as radiating fibrous masses in volcanic rocks in Rio Grande do Sul, Brazil, and in Poona, India. MG

The nature of water in chalcedony and opal-C from Brazilian agate geodes. H. Graetsch, O. W. Flörke, and G. Miehe, *Physics and Chemistry of Minerals*, Vol. 12, 1985, pp. 300–306.

Chalcedony and opal-C (cristobalite) in Brazilian agates (Rio Grande do Sul) have been investigated for their water content and speciation using differential thermal analysis (DTA), gravimetry (DTG), and infrared spectroscopy, together with water titration, and specific surface and density measurements.

Chalcedony and opal-C contain molecular water adsorbed in multilayers on the crystal surfaces, fully hydrating the open porosity. They also exhibit two types of differently bonded O-H groups (hydroxyls): The Si-O-H groups (silanoles) of type A are weakly hydrogen

bonded to the silica framework at structural defects, while type B involves surface silanole groups that are most likely hydrogen bonded to similar neighboring groups. Type B represents only one-third of the chalcedony silanole groups, but it represents almost all of the "water" in opal-C. All crystal surfaces are covered with silanole groups hydrogen bonded to molecular water.

Chalcedony bands ranging from translucent gray to milky white were found to correspond to a decrease in total water content, molecular water content, and specific surface, together with an increase in density.

Molecular water content also decreases with hydrothermal treatment, which indicates a variable low-temperature formation for this Brazilian agate: below 250°C and 0.5 kilobars, and possibly also at room temperature and pressure. Emmanuel Fritsch

Zirkon-Katzenauge aus Sri Lanka (Cat's-eye zircon from Sri Lanka). H. J. Müllenmeister, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 3/4, 1985, pp. 165–166.

The author reports on the identification of a cat's-eye zircon that had been represented as a moonstone from Sri Lanka. The specific gravity was determined to be 4.62, and the spectroscope revealed an absorption spectrum identical to that of zircon. The radioactivity of the sample is also mentioned. MG

Zur mineralogischen und chemischen Zusammensetzung des Schmucksteins Verdit aus Südafrika (Mineralogical and chemical composition of the gemstone verdite from South Africa). F. Rost, J. Wannemacher, and O. Krebs, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 9, September 1985, pp. 427–432.

Verdite is a green opaque rock that has been used for centuries by South African natives for mystical purposes. However, it was only "rediscovered" as a gemstone at about the turn of this century.

Five verdite specimens from the Baberton District, Transvaal, South Africa, were studied using chemical analysis and X-ray diffraction, together with conventional microscopic observation. Fuchsite (chromemuscovite) is the most important mineral and the main chromium-bearing phase (2% to 4% Cr_2O_3), and therefore gives verdite its bright green color. Both colorless chlorite (clinochlore) and a plagioclase feldspar (near albite) may be present in significant amounts. A relatively constant TiO_2 content of about 1% is due to the presence of rutile crystals or their alteration products. The iron content is always very low ($\leq 0.1\%$ Fe_2O_3). Unusual inclusions are light-colored tourmaline and, in the absence of a calcium-containing plagioclase, margarite (a calcium-containing mica).

Verdite occurs as a secondary rock in basaltic extrusions in many South African localities. The high

chromium content is attributed to enrichment through hydrothermal solution circulations, leaching, and concentration of this element from the underlying komatiites. *Emmanuel Fritsch*

DIAMONDS

Diamond exploration in Western Australia. C. L. Geach, *Geology Today*, Vol. 2, No. 1, 1986, pp. 16–20.

In the early 1970s, major discoveries of diamonds were made in Western Australia in two principal areas—between Derby and Kununurra in the northern part of the state (Argyle and Ellendale), and a smaller area farther south near Carnarvon. These finds are important not only for their magnitude but also for the fact that the host rock of the diamonds is not kimberlite as in South Africa but rather lamproite.

Lamproites are a group of fine- to medium-grained ultramafic to mafic rocks that are rich in K, Ti, and Mg. The mineral content of lamproite thus differs from that of kimberlite (as, consequently, do the mineral inclusions in the diamonds that each hosts). Kimberlites contain olivine, garnet, ilmenite, phlogopite, calcite, clinopyroxene, and serpentine. In contrast, lamproites consist of leucite, phlogopite, clinopyroxene, amphibole, olivine, and sanidine.

At the more northern, and more economically important, of the two recent diamond discoveries in Western Australia, the deposits are located in belts of highly deformed sedimentary and metamorphic rocks. These belts rim the Kimberly craton, a large area of ancient granitic rocks of Precambrian age. This geologic setting is entirely different from that of other known diamond-producing areas. The present article summarizes the radical changes in conceptual thinking and in the strategy of diamond exploration in Western Australia that resulted from this new kind of diamond occurrence. The major difficulties encountered in bringing a new deposit from initial discovery to eventual full production, especially the length of time required, are also discussed. *JES*

Famous diamonds of the world (XVIII): the Star of Sierra Leone. I. Balfour, *Indiaqua*, Vol. 37, No. 1, 1984, pp. 129–131.

This installment on famous diamonds recounts the discovery and eventual disposition of the largest diamond ever recovered from an alluvial source: the Star of Sierra Leone. On February 14, 1972, the 968.9-ct rough diamond was recovered from the picking table at the separation plant operated by the National Diamond Mining Company of Sierra Leone (Diminco) near the Kono-area diamond fields.

Diminco asked that De Beers CSO handle the sale of the stone via a sealed bid. However, when the bids were opened on July 18, 1972, none of them had reached the diamond's reserve price. In October of that year, Harry

Winston acquired the stone, having paid "in the vicinity of several million dollars" for it, well in excess of any of the previous bids.

The original rough yielded 17 stones totaling 238.48 ct. The largest stone to emerge from the initial cutting was a 143.20-ct emerald cut. However, the stone was flawed, and Winston eventually had it recut into seven stones, the largest of which was a 53.96-ct flawless pear shape. *BFE*

Over the years with De Beers. R. Shor, *Jewelers' Circular-Keystone*, Vol. 157, No. 2, 1986, pp. 340–343.

In the past 15 years, De Beers has increased its advertising budget almost 10-fold, and as the socio-economic climate of the United States has changed, so has the focus of their ads.

In this fascinating article, Mr. Shor shows that while De Beers's ads have retained the image of romance and elegance, they have slowly shifted focus among various consumer groups, almost imperceptibly guiding the baby-boomers to adulthood. In the early 1970s, the main visual thrust of their advertising was aimed at mid- to high-income customers, but was tempered with the message "A gift of diamonds need not be expensive. Your jeweler can show you exciting pieces under \$200." De Beers also created the concept of the eternity ring, which was originally aimed at former flower children who had begun their pursuit of success. Later renamed the anniversary ring, it now accounts for 25% of all diamond jewelry sales.

Today the message is "Show her it's not lonely at the top. A diamond of a carat or more." Men's diamond jewelry is also being promoted to a new, consumption-conscious generation.

The changes have not come cheaply. In 1985, De Beers's advertising budget soared to \$34 million, with 44% invested in television spots (compared to \$4 million in 1970 and no television ads). But this campaign has paid off: During the last 15 years, sales have jumped from \$800 million to \$8 billion per year.

Patricia A. S. Gray

GEM LOCALITIES

The occurrence of botryoidal and gem-quality nephrite in Monterey County, California. T. R. Paradise, *Journal of Gemmology*, Vol. 19, No. 8, 1985, pp. 672–681.

Mr. Paradise briefly discusses the geology, mineralogy, and gemology of the nephrite occurrence at Jade Cove, in Monterey County, California, and how to successfully locate the nephrite at the site.

Nephrite, an isomorphic product of the actinolite-tremolite series, usually consists of randomly oriented interlocking and interwoven fibrous crystals. However,

the material found at the Monterey occurrence formed in botryoidal masses. These flattened, oval-shaped masses typically consist of only two to 10 nodules each, and are easily separated from the surrounding minerals, which are massive in form. Some of these nodular bundles have been so weathered that they are covered with a layer of reddish brown oxidized material or "skin" which may deceive uninformed collectors. The nephrite also occurs as polished pebbles.

Jade Cove is located between Plaskett Point and Cape San Martin, about 100 km south of the city of Monterey. The nephrite can be found in the detritus below the greenish colored cliff areas, which represent the serpentine from which the nephrite has eroded.

David C. LeRose

Les quartz sceptres de Denny Mountain (The quartz scepters from Denny Mountain). B. Jackson, *Monde et Mineraux*, Vol. 23, No. 71, 1986, pp. 20–23.

Four years ago, the most spectacular (up to 10 cm long) amethyst double scepters in the world were found by the author and an associate at Denny Mountain, near Seattle, Washington (a scepter is a crystal that has a second, wider crystal overgrown in a parallel way at its termination). At this locality, quartz crystals are formed along veins caused by the percolation of hydrothermal solutions through an iron-bearing skarn. This article describes in a very lively style this unusual mining enterprise. The quartz vein is located on a cliff in Red Wall Canyon, a very dangerous area where nine mountain climbers have died within the past few years. Jackson describes the hazards involved in mining the deposit. Even the men and equipment had to be brought in by helicopter. After 10 weeks of unrewarding digging, 40 specimens of this unusual material were recovered from this attempt.

Emmanuel Fritsch

Les tourmalines de l'île d'Elbe (Tourmalines from Elba Island). S. Lareida, *Monde et Mineraux*, Vol. 23, No. 71, 1986, pp. 4–7.

The tourmaline deposits of Elba (Italy) are located in the western part of the island, near Monte Capanne. They are found in hydrothermal pegmatite veins that intrude the granodiorite massif. The article emphasizes the coloration of Elba's tourmalines, which are often color zoned perpendicular to the principal axis; most notable of these zoned crystals is the "Moor's head" (a clear prism with a black termination).

Light violet to pinkish to carmine red crystals contain no sodium, but have appreciable amounts of iron, lithium, and potassium. Brown to orange or yellow varieties have a high sodium content. Green ones exhibit the highest amount of manganese and sodium. There are also blue, black, and colorless stones.

The history of tourmaline exploitation on Elba is

detailed, starting with the discovery of the first deposit in 1825. Included are famous finds such as the "Grotta d'Oggi," a grotto that yielded many spectacular tourmaline crystals.

Emmanuel Fritsch

INSTRUMENTS AND TECHNIQUES

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

The use of certain features in the ultraviolet spectra to identify natural and synthetic rubies was first suggested by Bosshart in 1981. He recognized differences in ultraviolet transparency between natural and synthetic rubies. He also suggested a numeric interpretation of the absorption spectra of these stones in terms of three measured parameters associated with the location of the minimum absorption in the ultraviolet. Graphic representations of these parameters revealed separate population areas for natural rubies of different origin as well as for synthetic rubies of various manufacture. This method was suggested to be valuable in distinguishing natural from synthetic ruby.

Since the publication of Bosshart's work, the diagnostic value of this identification method has been called into question by the appearance of some synthetic rubies whose parameter values fall near or within the population field of natural rubies on Bosshart's graphs. This uncertainty led to a thorough reexamination of the Bosshart method in the present study.

Spectroscopic and chemical (XRF) data were collected for some 900 rubies from 15 localities and nine manufacturers. Results of this study indicate that natural and synthetic rubies exhibit several types of absorption spectra that vary slightly in the location, shape, and intensity of their spectral features. Many of these spectra are illustrated in the 45 figures included in this article. Some of these spectra types appear to be unique for a particular natural or synthetic ruby, and hence are of diagnostic value when working with a ruby of unknown origin. It is concluded that the Bosshart method has two principal weaknesses as an identification test. The advantage of the method as a simple procedure using only three parameters is offset by the loss of further important information, such as the positions of weak absorption bands and shoulders, that is readily apparent from an examination of the spectral patterns themselves. In addition, a documented overlapping of population fields of Bosshart's parameters for various natural and synthetic rubies prevents a clear determination of the origin of a ruby. This is especially serious in the case of certain new synthetic rubies whose parameter values fall within the natural ruby field on Bosshart's graphs. Thus, the Bosshart method has limitations as a diagnostic test.

The author suggests that ultraviolet absorption

spectra can be of value in the identification of rubies of unknown origin. However, this requires a direct comparison of the spectrum of the ruby in question with standard spectra of natural samples of known origin and synthetic samples of known manufacture such as those illustrated in the article. In many instances this will provide a good indication of the ruby's locality or producer, or at least will reduce the number of possibilities. Even when the origin remains uncertain, examination of the spectra in combination with microscopic observations and, if necessary, with chemical (trace element) data, will often provide a clear determination. *JES*

Über die Problematik der Galliumgehalte als Hilfsmittel zur Unterscheidung von natürlichen Edelsteinen und synthetischen Steinen (On the problem of gallium as proof to distinguish between natural gemstones and synthetic materials). H.-W. Schrader and U. Henn, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 3/4, 1985, pp. 152-159.

The authors have proved that the presence of gallium (Ga) is not a conclusive test to distinguish the natural or synthetic origin of a gem. Neutron activation analysis (NAA) of 32 emeralds (22 natural, 10 synthetic), 18 corundums (8 natural and 10 synthetic), and 16 chrysoberyls (14 natural and 2 synthetic) yielded comparable amounts of gallium in both the natural gemstones and their synthetic counterparts. Therefore, the element Ga should no longer be regarded as a sure sign of the natural origin of a gem. *MG*

Touchstone testing of precious metals. W. Wälchli and P. Vuilleumier, *Aurum*, No. 24, 1985, pp. 35-45.

Touchstone testing is one of the oldest known methods of testing for precious metals. Its use is documented as early as 600 B.C. for checking gold coins. Today, it is primarily used by assayers to test and hallmark articles made of noble metals. This comprehensive article explains the procedures and tools needed to perform a number of tests used to determine the alloys of silver, and yellow, white, and colored golds; distinguish between solid and plated pieces; and differentiate between platinum, white gold, palladium, and steel. These tests have a wide variety of applications in the jewelry trade, ranging from evaluating antique jewelry to sorting semifinished manufactured pieces for fineness.

Essentially, the touchstone process is a comparison test whereby an unknown metal is rubbed on the touchstone and compared with rubbings from touch needles. Sometimes acids are applied to the two rubbings for further evaluation. The tools required are a touchstone, touch needles, blotting paper, and touch acids. Touchstones today are usually made out of black or dark red agate, of uniform color with no blemishes or veins, fine-grained with a matte finish. Touch needles are made from alloys of known composition, and the num-

ber required depends on the type of work being done and the degree of fineness that must be determined. Touch acids are essentially composed of "nitric acids of different strengths with or without the addition of copper or sodium chloride, or hydrochloric acid."

The text gives step-by-step instructions for performing the tests with 23 color photos as examples of what the rubbings and acid reactions should look like. The authors, both assayers with the Swiss Federal Bureau for the Control of Precious Metals, emphasize that touchstone testing "requires specialized knowledge and considerable experience that can only be acquired through practise." The authors' addresses are provided so that the reader can contact them for further information. *EBM*

JEWELRY ARTS

Antiques: alchemy of Art Nouveau. S. Birmingham, *Architectural Digest*, Vol. 42, No. 12, 1985, pp. 154-159.

This article is an abbreviated and generalized description of the exuberantly emancipated society that supported Art Nouveau around the turn of the last century. However, the text merely provides a backdrop for the six accompanying illustrations of exquisite French Art Nouveau jewelry. The captions for these jewels provide more information than the text, giving artist, date, materials used, dimensions, and a brief historical note for each. Among the pieces included is the celebrated snake bracelet and ring combination that was designed by Alphonse Mucha and fabricated by Georges Fouquet for Sarah Bernhardt's stage premiere of "Cleopatra" in 1890. The piece incorporates gold, enamel, opals, diamonds, and rubies in the exaggerated style that is representative of the period. The serpent motif was a popular one in this sensual era, when "anything that flowed, undulated, slithered, twined, or trembled in the wind" was translated into spectacular jewelry. Although the illustrations are superlative, Birmingham's article only serves to whet the appetite for more information about this brief, distinctive period. *EBM*

Geneva's Mr. Christie. D. Good, *Canadian Jeweller*, Vol. 105, No. 9, 1984, pp. 27-28.

The astonishing thing about this article is that it appeared at all. The author deserves high praise for lifting a corner of the veil of privacy with which Hans Nadelhoffer, president of Christie's, Geneva, usually surrounds himself. That he should also have allowed his photograph to be published puts an otherwise routine, if not actually dull, trade magazine interview into a special class.

For jewelers and gemologists who have enjoyed Dr. Nadelhoffer's monumental and definitive work on Cartier, and who have marveled at his genius in organizing some of the greatest jewelry sales of this century, this

article will be of particular interest. The author briefly outlines Nadelhoffer's professional career and provides ample proof of the magnitude of his influence in the jewelry world. Only by personal acquaintance, however, can Nadelhoffer's innate modesty, gentility, and enormous personal charm be fully understood and appreciated. NL

Goldwork of the Iron Age in "barbarian" Europe. C. Eluère, *Gold Bulletin*, Vol. 18, No. 4, 1985, pp. 144–155.

Using classical references, and archeological and technological evidence, the author shows how the goldwork of the Celtic, Iberian, Illyrian, Thracian, Dacian, and Scythian tribes was influenced by Greek, Persian, and Etruscan goldwork during the Iron Age (700–100 B.C.). Gold jewelry from the preceding Bronze Age (2000–800 B.C.) was large and heavy. The changes in use, technique, and style that developed are due, the author postulates, to interaction via trade and/or conflict with the Mediterranean cultures. With these changes, the use of gold acquired certain defined purposes: as a designation of status, an honor to gods, and in hoarding as a store of wealth. Ultimately, the latter use was manifested as coinage.

The fact that barbarian Europe had abundant sources of gold and other ores is documented in classical texts which are quoted by the author. Elaborate burial mounds of chieftans have yielded similar examples of adornment and ritual vessels from several different cultural areas. These are described in detail and include neck rings and torques, bracelets, rings, fibulae, buckles, and other ornaments, along with swords, axes, and helmets of iron that have been decorated with sheets of gold. Ceremonial cups of sheet gold and caldrons of bronze suggesting religious rituals have also been found. Citing many examples, Eluère demonstrates how techniques (such as granulation and the use of solder) were developed, and styles (as shown by decoration motifs) and types of jewelry evolved.

Much scholarly research and careful condensation of facts went into the preparation of this article, which represents an important contribution to the literature on this subject. The article is richly illustrated with 14 photographs, a table showing the chronology and location of principal finds, and a map giving their geographic locations. EBM

Getting repped. V. S. Lynn, *Metalsmith*, Vol. 6, Nos. 1 and 2, 1985, 1986, pp. 18–23 and 34–35, respectively.

Based on hours of interviews with manufacturing jewelers and jewelry representatives (reps) in a variety of markets across the country, this two-part article presents the basic considerations of a jeweler/rep relationship. First, the author defines the various types of reps

and elaborates on the nature of the products they carry. Lynn also comments on why most manufacturing jewelers prefer to hire intermediaries, noting that salespeople must be outgoing, congenial, aggressive, persistent, and able to handle rejection.

Some key ingredients for a successful relationship with your rep(s) include the manufacturing jeweler's ability to think and design ahead, ready access to a substantial amount of cash, and a real sense of commitment between both parties. Many jewelers believe that stockpiling their finished pieces is expensive and risky, but that it is also crucial that they are able to meet their manufacturing obligations on time.

Other sections cover how to find a rep, and what to look for in the person who will be largely responsible for your commercial success. Interestingly, the majority of jewelers reported that they must really like their reps and feel that they are genuinely interested in the lines they carry. Lynn also stresses the importance of checking the rep's references through other artists and store accounts.

Novice manufacturing jewelers can benefit greatly from a good rep, who can and often will help guide them through sometimes initially turbulent business maneuvers. A good rep provides valuable feedback from the marketplace, and can help a jeweler develop his or her professional identity.

The second (and shorter) part of this article deals with jeweler/rep contracts, what they can and should cover, and how jewelers protect their freedom to represent themselves at gallery shows and sales. This section also talks about reps' territories, the methods of commission payment, and the length of their contracts. It also offers good advice on how to handle a rep who doesn't sell or one who "loses" samples.

As a whole, this article provides a great deal of practical information for the manufacturing jeweler who wants to expand his or her business through representatives. SAT

A perfect match. A. DiNoto, *Connoisseur*, Vol. 216, No. 891, 1986, pp. 118–123.

A young designer named Kai-Yin Lo has catapulted from director of public relations at the Mandarin Hotel in Hong Kong to the heady realm of high-fashion jewelry design. Her work is characterized by strong, simple designs, a sensitive use of color, and an eye-catching symbiosis of antique and modern elements. "I draw on the vast and marvelous reserves of Chinese motifs and . . . adapt and synthesize," she explains.

Kai-Yin sold her first collection to Cartier, and then went on to form her own company. Kai-Yin & Co. Ltd. now provides jewelry and accessories to 150 retail outlets on four continents, including some of the finest department stores and boutiques. She features several distinct lines, with items priced from \$20 to \$20,000.

Recently, Kai-Yin became the first well-known jewelry designer to be accepted by Chinese Arts and Crafts in Hong Kong, the official outlet for higher-grade goods from mainland China, and is anticipating coproducing with them.

Incorporated into many of her striking designs are an assortment of small objects, ranging from a tiny 18th-century Mongolian leather purse to exquisitely carved beads and baubles of antique jade, turquoise, amber, or ivory. In the past few years, however, she has noticed that the master carvers are vanishing, and the old materials are becoming increasingly rare—and expensive. "Gone are the days when I could buy antique turquoise by the kilo," she laments. Nevertheless, Kai-Yin's versatility and the "wearable splendor" of her pieces seem to assure her a place in the sun for some time to come. SAT

Thomas McPhee, gem carver. D. Luckow, *Canadian Jeweller*, Vol. 107, No. 1, 1986, pp. 36–37.

Thomas McPhee, of Rare Earth Gems in Vancouver, British Columbia, has taken the gem-carving craft by storm. Although he has only been working with stone for the past two and a half years, his overwhelming success at the 1985 Tucson Gem and Mineral Show, and subsequent encouragement by Roland Naftule, past president of the American Gem Trade Association, have boosted the young Canadian carver into the limelight. His most popular works include carvings of faces, masks, animals, and birds of "exceptional quality and artistic design." McPhee carves almost any type of gem material, although tourmaline is by far his favorite. The largely self-taught artisan is presently working on a collaborative jewelry line which will include his own carvings in pendants, rings, bracelets, and brooches. Another line featuring small carved gemstone boxes and rock crystal bowls is also in the works. SAT

JEWELRY RETAILING

The story of love and wedding rings. D. Scarisbrick, *Aurum*, No. 24, 1985, pp. 46–53.

Scarisbrick traces the history of wedding rings from the days of the Roman Empire to the 20th century. Around 23–79 A.D., it was customary to exchange rings at the close of a business transaction, signifying the good faith of each party. This custom came to be applied to marriage contracts as well; after the dowry was settled, the prospective groom placed a simple iron (or gold for nobility) band on the fourth finger of the left hand of his betrothed. In fact, many rings were shaped to form two clasped right hands, symbolizing the contractual handshake. This design continued to be popular throughout the centuries, and can still be found on many modern Irish wedding rings.

Several other interesting rings are also discussed in

chronological order. During the Renaissance, the bezel of many Jewish wedding rings was set with a miniature gabled roof, symbolizing the Talmudic saying "His wife is his house." The 17th century saw the rise of the gimmel, twin hoops linked together by hearts or hands. In the 18th century, romantic inscriptions, most often in French, decorated the outside of many wedding rings, intertwined with cupids, hearts, or doves tying fast a lover's knot. The venerable Queen Victoria popularized rings in the form of coiled serpents, representing eternity. It was only after diamonds were discovered in South Africa in 1866, and were subsequently promoted by N. W. Ayer, that diamond engagement rings became the fashion, usually paired, ironically, with simple gold wedding bands.

The text is sumptuously illustrated with many fine examples of wedding and betrothal rings, as well as with reproductions of medieval drawings depicting the wedding rite. SAT

SYNTHETICS AND SIMULANTS

Neue Untersuchungen an in Japan hergestellten synthetischen Amethysten (New investigations conducted on Japanese-made synthetic amethysts). Th. Lind and K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 3/4, 1985, pp. 160–164.

In general, the distinction of natural and synthetic amethysts is determined with the conoscop (a kind of polarizing microscope), a gemological microscope, and in complicated instances by the use of infrared spectroscopy. Characteristic features of synthetic amethysts, particularly those made in Russia, have appeared in recent gemological publications. However, the increased amount of amethysts synthesized in Japan that are now available in the trade prompted the authors to investigate this material in detail. The new product from Japan often contains feathers that consist of liquid-filled and two-phase inclusions, sharp growth zoning parallel to one rhombohedral face, and twin structures. The twinning is readily distinguishable from the polysynthetic lamellae twinning seen in natural amethysts. The six color photographs provided with the article are useful to the gemologist. MG

Quantitative Kathodolumineszenz—ein neues Verfahren zur Unterscheidung echter von synthetischen Smaragden und Rubinen (Quantitative cathodoluminescence—a new process of distinguishing between natural and synthetic emerald and ruby). J. Ponahlo and T. Koroschetz, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 3/4, 1985, pp. 132–142.

Recent developments in the technical aspects of manufacturing synthetic stones have yielded enormous prog-

ress, which in turn causes difficulties in separating natural from synthetic stones with standard gemological or mineralogical methods. In their search for a solution to this problem, the authors report on microphotometric measurements of luminescence intensities emitted from emeralds and rubies during bombardment with fast-moving electrons (cathode rays).

The method, conducted on a luminoscope, is called "quantitative cathodoluminescence" (CL). The integral photocurrent intensity of the cathodoluminescence is plotted against the power of excitation. The natural emeralds exhibit a very small linear increase in intensity, whereas synthetic emeralds show a manyfold greater increase. In general, the rubies yield an exponential increase in luminescence intensity when the power of the excitation is raised. The authors compared Thai rubies as natural samples with synthetic rubies by manufacturers such as Chatham, Kashan, and Knischka. The CL intensities of the synthetics are comparatively higher than those of rubies from Thailand.

Quantitative cathodoluminescence seems to offer a relatively safe method of differentiating between natural and synthetic emeralds, as well as between Thai rubies and their man-made counterparts, especially the Kashan synthetic ruby. Measurements are now being carried out on rubies and emeralds from other sources and producers as well as on sapphires and alexandrites. However, detailed results on the latter are not included in the article. The paper includes six color photographs and two diagrams to show comparative luminescence of synthetic and natural emerald and ruby. MG

Seiko synthetics. G. Brown, *Australian Gemmologist*, Vol. 15, No. 11, 1985, pp. 418–420.

Adapted from technical information supplied by Suwa Seikosha Co. of Japan, the article reports on the production and properties of five synthetic gem materials manufactured by their subsidiary, Hattori Seiko Co., Ltd.

The Seiko synthetic emerald is produced by a flux-growth process, reportedly using a new flux that results in a purer crystal than is possible from older flux-growth methods. Gemological properties of this material are within the ranges for other flux-grown synthetic emeralds, with the exception of the reaction to ultraviolet radiation, which is a greenish color to both long- and short-wave U.V.

Synthetic ruby, blue sapphire, orange-pink sapphire, and alexandrite chrysoberyl are all produced by a floating zone method, which is described and illustrated. This method of synthesis reportedly produces crystals of uniform color and luster, with no chemical impurities and a minimum of gas bubbles. The synthetic ruby is grown in an inert atmosphere; the atmospheres

used in the production of the other materials are not specified.

These floating zone-produced materials are all characterized by the presence of internal, irregular flow lines, which are evident in a characteristic swirled color distribution. This diagnostic feature is most prominent in the synthetic ruby; immersion may be required to detect it in the other materials. Also characteristic of the synthetic ruby is rectilinear parting. Fluorescence can be of diagnostic value in some cases, since both the synthetic orangy pink sapphires and the synthetic alexandrite glow a strong red to long-wave ultraviolet radiation. Other gemological properties overlap with those of the natural materials.

A comprehensive table summarizes the gemological properties of the Seiko synthetics and of their natural counterparts. RCK

Die synthetischen "Ramaura-Rubine" und ihre Erkennungsmöglichkeiten (The synthetic Ramaura ruby and its identification characteristics). W. Galia, *Uhren Juwelen Schmuck*, Vol. 2, No. 2, 1986, pp. 154–157.

The author first encountered the new "Ramaura" synthetic ruby in 1984 and introduced it to the trainees at Königstein gemological education center in Germany. The production method is said to be spontaneous nucleation (no seed) involving flux, with crystallization taking place at a temperature of about 1250°C, which is higher than usual for flux ruby crystallizations.

The crystal form and color reported here for Ramaura synthetic rubies are identical to the details published by Kane (*Gems & Gemology*, Fall 1983). The important gem microscope observations indicate the presence of flux residue often as lacy patterns and trigonal growth marks parallel to the (0001) face. The article includes 15 color photographs that show rough crystals, faceted Ramaura rubies, and various types of inclusions. MG

TREATMENTS

Oven fresh sapphires. T. Themelis, *Lapidary Journal*, Vol. 39, No. 11, 1986, pp. 49–53.

This article reports on the author's personal observations of heat treating sapphire in Sri Lanka. Material treated included "Geuda" rough, other corundum containing various amounts of silk, and material previously treated unsuccessfully. After trimming to remove major inclusions, the corundum is placed in a crucible consisting of a perforated, high alumina-content brick. This is placed in a furnace that is no more than a steel drum lined with bricks. The burner unit consists of a main blower, a controller, and a pump.

The loaded crucible is placed in the oven and the temperature is then raised to about 1800°C over a four-

hour period. At this point, the oven is "hermetically" sealed to create a reducing atmosphere. Heating continues for eight to 10 hours or longer. Two or three times during heating the temperature is lowered and the furnace opened for a visual inspection of the corundum. The temperature is then lowered over a four-hour period and the oven is allowed to cool an additional 24 hours before it is opened and the stones are removed. Recovery of usable material is estimated at 25% of all material treated.

There are a number of statements in this article that must be questioned. The dimensions listed for the opening in the furnace ("about six feet to a side") and of the crucible (6' x 6' x 4') would appear unlikely. The iron and titanium color-causing agents are described as "blue colored atoms." The statement that pyrometers are not used "since the process is performed in a totally enclosed environment" seems an unlikely explanation. The chemical formula for ilmenite— FeTiO_3 —is incorrectly written TiFeO_3 . The melting temperature of quartz is given as 1825°C, whereas it should be 1610°C. Finally, the author also quotes the melting points of the elements titanium and iron when it is not the pure elements, but the oxides, that are involved in the reaction under discussion. RCK

MISCELLANEOUS

The geologic history and structure of the Himalayas. P. Molnar, *American Scientist*, Vol. 74, No. 2, 1986, pp. 144–154.

The Himalayas make up the world's highest and youngest mountain belt. They are between 250 and 350 km wide and extend from Afghanistan to Burma. Besides containing some of the most majestic scenery on earth, this mountainous region has been an important source of gemstones from antiquity through modern times. This article presents a general summary of the geology and geologic history of the Himalayas that would be of interest to anyone who wants to know more about this gem-producing region. It is well illustrated with color photographs and color diagrams, and is written in a readable, nontechnical style.

The Himalayas are of great scientific interest today because they represent a classic "modern" orogenic belt that exhibits many features consistent with the recent geologic theory of plate tectonics. According to this theory, blocks of continental crust have moved relative to one another throughout geologic history. This movement is caused by the movement of material in the underlying mantle. Collisions of two continental blocks result in the formation of mountainous orogenic belts.

Recent geologic studies have suggested that the Indian subcontinent, after splitting away from an earlier large landmass called Gondwanaland, drifted north-

ward to collide with the Asian landmass beginning about 40 million years ago. This collision produced the Himalaya orogenic belt. The northward movement of India continues at a rate of about 5 cm per year. The resultant shortening of the crust is accompanied by extensive faulting, earthquakes, and the continental uplift of the Himalayas themselves, which is occurring at the rate of up to several millimeters per year. JES

Editor's Note: For another general overview of the Himalaya Mountains, see Geology Today, 1985, Vol. 1, No. 6, pp. 169–173, "The Himalayas," by B. F. Windley.

Gold boom in Mali. G. Philippart de Foy, *Europa Star*, Vol. 152, No. 5, 1985, 5 pp.

In the African nation of Mali, one of the poorest countries in the world, even the smallest amount of gold is treasured. In February 1982, a woman gathering wild plants along the banks of the Niger River discovered a gold nugget caught in the plant roots. Two days later the word was out and the gold rush at Bamako had begun. Today, hundreds of gold washers work the placer deposits. The men dig pits with primitive tools at about 2 m a day. Once through the alluvial covering, they dig out the gold-bearing layer and deliver it to the women at the surface. Here the gravel is washed in a hollowed-out gourd called a calabash. The shafts have no shoring, and accidents caused by the collapse of the workings are frequent. Although gold washing provides a living only for the lucky, it provides hope for everyone. GSH

The regulation maze. E. Salomon, *American Jewelry Manufacturers*, Vol. 33, No. 7, 1985, pp. 20–25.

This is an extremely important article for everyone involved in jewelry manufacturing. It outlines the regulations regarding toxic waste disposal that are being enforced with increasing severity. The most important point that this article makes is: "You must be familiar with your local requirements. Ignorance is no excuse for noncompliance!" Any company that is involved in plating and metal finishing of any sort is required by law to dispose of waste properly. Congress is exerting pressure on the Environmental Protection Agency to oversee the individual state authorities, who are in turn enforcing regulations through the sewer officials. The author emphasizes that environmental issues can be solved efficiently by educating ourselves to the laws that pertain, and by exploring alternative technologies that help to reduce waste through recycling and recovery methods. Charts are provided that list where to find out the laws that are in effect as well as the dates they are effective, together with discharge limitations and the various metal-finishing operations that must comply with these regulations. EBM

BIRTHDAY BOOK OF GEMS

By Harold and Erica Van Pelt, 128 pp., illus., publ. by Van Pelt Photographers, Los Angeles, CA, 1986. US\$18.95*

Previous editions of the *Birthday Book of Gems* have been enormously successful, and this one promises to be even more so. Like its predecessors, it is filled with color photographs that are typically superb Van Pelt productions, accompanied by instructive captions that make this appointment book even more valuable.

The historical pieces, such as Empress Marie Louise's diamond necklace, a pair of large diamond earrings once owned by the unfortunate Marie Antoinette, and the Hope diamond, are particularly intriguing. The necklace containing 52 faceted benitoites must surely rank as one of the rarest of ornamental objects. I especially liked the magnificent photograph of a pair of remarkable amethyst geodes, as well as the photos of carving work done by Idar-Oberstein artisans (and by the Van Pelts themselves) and the crystals and suites of cut tourmalines and beryls.

Another nice feature about this calendar book is that it is perpetual—if you hid it away and did not exhume it until the year 2000, it would still be as applicable as it is today.

JOHN SINKANKAS
Earth Science Literature
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THE NEW WORLD OF GOLD

By Timothy Green, 290 pp., paperback, publ. by Walker and Co., New York, NY 1984 (rev.), US\$12.95 *

The title page of this book indicates that it is "The inside story of the mines, the markets, the politics, the investors"—a tall order for a book of only 290 pages. Fortunately, Mr. Green has a remarkable talent for giving the reader a good overall view of the intricate and mysterious world of gold—extending from the mines in South Africa, Russia, Brazil, the

BOOK REVIEWS

Jeffrey M. Burbank, Editor

United States, and Canada through the markets in London, New York, Zurich, Hong Kong, and Singapore to the buyers throughout the world. His journalistic approach to the subject makes the information interesting and easy to read, unlike the dry, monotonous data normally presented in economic journals. The book is richly annotated with footnotes, references, and a bibliography for further reading.

The first part of Green's book, "The Gold Rush Days," gives the reader a brief historical account of the hardship men will endure in search of the yellow metal. Part 2 deals with "The Miners" or, more specifically, the mines themselves, which supply the world's seemingly insatiable demand for gold. Green places a special emphasis on the manipulations of the producers to control the sources of gold. I was particularly interested in the author's views on the impact of Russian gold on the international market, and how Russia uses its gold to advantage. Part 3, "The Markets," is just that—except for a final section on gold smugglers that has all the intrigue and suspense of a first-rate spy novel. The reader also gets some insight into why London historically has been, and continues to be, the focal point of the international gold market, and why Zurich or Hong Kong might be the best place for the small investor to purchase gold.

This is not a book for someone looking for technical information on gold alloys, solders, wire sizes, and so forth. But if you're interested in the political motivations of the producers, dealers, and countries to manipulate the price of gold to their advantage, then you'll find this book

well worth reading. Mr. Green concludes with a summary of the dominant factors affecting the price of gold, the complexities of the market, and the interdependence of everyone in the chain, from the suppliers to the ultimate consumer. He also emphasizes the important part that politics plays in the world spot price of gold. This book is a must for anyone interested in investing in gold, and would be very useful to jewelers or goldsmiths who are required to make intelligent decisions regarding when and when not to buy this precious metal.

WAYNE C. LEICHT
Kristalle
Laguna Beach, CA

DIAMOND, RUBY, EMERALD, AND SAPPHIRE FACETS

By Gary Grelick, 56 pp., illus., privately published, 1985. US\$5.00*

The stated purpose of this publication is to "give the layman a working knowledge of diamonds, rubies, emeralds, and sapphires." The author seeks to accomplish this by supplying information regarding optical and physical properties, nomenclature, formation, sources, and identification of the four gemstones. Mr. Grelick also includes an explanation of the four C's in reference to diamonds. The subject matter is presented in a simplified, easy-to-understand manner; however, there are quite a few inaccuracies and even more typos and grammatical errors. For example, the author states that "a Colombian emerald is light green in color. . . ." To most gemologists, a beryl with a light green color would not be considered emerald, so how could the source of the world's finest emerald owe its fame to light green material? Mr. Grelick also mentions that iron is not found as an impurity in any natural emerald, and that this fact can be used as a basis for separat-

*This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404.

ing natural emerald from the non-fluorescent, iron-bearing Gilson synthetic. This is simply not true. Iron can be an impurity in natural emerald, which can therefore exhibit the same properties (e.g., absorption pattern) as the iron-doped Gilson.

In discussing the identification of natural sapphire, the author states that "the inexperienced gemologist will often find it particularly difficult to separate a natural green sapphire from a synthetic green zircon." It is doubtful that even an experienced gemologist has seen synthetic green zircon (or synthetic zircon of any color) since this is not a material synthesized on a commercial basis. This statement is confusing and inaccurate.

In addition to the bothersome number of typos and grammatical errors, the eight photographs of the aforementioned gemstones and their captions are very disconcerting. The photos themselves are surprisingly unimpressive, as the featured stones are not particularly attractive, nor are they displayed well. Also, the captions do not identify the pictured stones in their respective orders or numbers. Although the intent of this book is clearly an honorable one—to furnish the uneducated consumer with a quick and ready reference—it falls far short of its promise.

DEBORAH HISS
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ART NOUVEAU JEWELRY

*By Vivienne Becker, 240 pp., illus., publ. by E. P. Dutton, New York, NY, 1985. US\$50.00**

This book is simply excellent. Beautifully written and lavishly illustrated with superlative photographs, *Art Nouveau Jewelry* is an outstanding reference for anyone interested in jewels of this period.

In the preface, the author states her intention to present a "broad panorama" of Art Nouveau through its jewelry, as well as to explain the history of its roots and rapid growth at the turn of the last century. Becker

also sets out to interpret the "strange and unprecedented characteristics" that these jewels exhibit. The introduction provides an overview of the Art Nouveau style as it developed internationally, putting into perspective the artistic, social, and economic forces that gave birth to the Art Nouveau movement.

In the late 19th century, many artists felt dissatisfaction with the dehumanizing effect that factories and industry had on art—and on life in general. Their idea was to infuse everyday objects with art, thereby creating a source of contentment for the artist and user alike. This return to craft, which was incorporated into every aspect of turn-of-the-century life, found its ultimate expression in jewelry. The designs reflected a freedom of expression that was a reaction to the staid and restrictive Victorian period. The flowing Art Nouveau line expressed movement and youthful vitality, as shown in a woman's billowing hair, sensuous plants, and sinuous animals. Perhaps the greatest impact on design at this time was the opening of trade with Japan and the importation of Japanese art and artifacts into Europe. The simplicity and naturalism of Japanese design was adopted by the artists of Europe and was incorporated into every artistic medium, particularly jewelry. The artists borrowed not only the designs but also the ideas for techniques and use of materials. Becker lucidly puts forth these important factors and continues by addressing each country in subsequent chapters, outlining the contributions made by each to the Art Nouveau movement as a whole.

Logic governs the layout of the book, which flows smoothly from introduction to final credits with the help of Becker's descriptive style. The text is well annotated, and the photographs and illustrations are well captioned. Brief biographical sketches of the jewelers along with a guide to their makers' marks are helpful additions, and, other than the peculiar choice of a lurid reddish orange for the cover, I can find no fault

with this impeccable book. Altogether, it is as beautifully designed and executed as the jewelry it describes.

ELISE B. MISIOROWSKI
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REVIEWS IN MINERALOGY VOLUME 12: FLUID INCLUSIONS

*By Edwin Roedder, 644 pp., illus., publ. by the Mineralogical Society of America, Washington, DC, 1984. US\$15.00**

On the cover of his new book, Dr. Edwin Roedder states that "*Fluid Inclusions* is an introduction to studies of all types of inclusions—gas, liquid, or melt—trapped in materials from earth and space, and of their application to the understanding of geologic processes." Although this description is precise, in some ways it is an understatement. *Fluid Inclusions* is the 12th volume in the Mineralogical Society of America's *Reviews in Mineralogy* series. It is the only single-author volume in this important series, and at 644 pages it is also the longest. The book's 19 chapters are very well organized and take the reader (in chapter 1) through the early history of fluid-inclusion study with the writings of such noted researchers as Robert Boyle, Henry Clifton Sorby, and Ferdinand Zirkel to (in chapter 19) the possible future of inclusion studies. Interestingly, Roedder notes that the first mention ever in the English language of inclusions was made by Robert Boyle in a gemological text titled "Essay about the Origine and Virtues of Gems" (1672). This fact solidly cements the close relationship that exists between inclusions and gemology.

Between the historic past and the possible future, Dr. Roedder details the various trapping mechanisms by which inclusions are

Continued on p. 107

GEMS & GEMOLOGY is an international publication of original contributions (not previously published in English) concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments, gem localities, gem substitutes (synthetics), gemstones for the collector, jewelry arts, and retail management. Manuscripts may be submitted as:

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

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

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

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Previous Studies, Methods, Results, Discussion, Conclusion. Other heads and subheads should be used as the subject warrants. For general style, see *A Manual of Style* (The University of Chicago Press, Chicago).

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Daragh P.J., Sanders J.V. (1976)
Opals. *Scientific American*, Vol. 234, pp. 84–95.
Liddicoat R.T. Jr., Copeland L.L.
(1967) *The Jewelers' Manual*, 2nd ed. Gemological Institute of America, Santa Monica, CA.

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should be considered whenever the bulk of information to be conveyed in a section threatens to overwhelm the text.

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