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TABLE OF CONTENTS

EDITORIAL

FEATURE ARTICLES

NOTES AND NEW TECHNIQUES

REGULAR FEATURES

ABOUT THE COVER: This unusual quartz egg, measuring 3 in. × 5 in. (7.6 cm × 12.7 cm) is covered with 416 triangular facets and has been hollowed out so that the walls are only 3 mm thick. The techniques used by Harold and Erica Van Pelt to fashion this unusual art object are described by Dr. John Sinkankas in this issue. The egg is resting on a 363-ct aquamarine pedestal, and the quartz base sits on four 5-ct aquamarine cabochons. Photograph © 1982 Harold and Erica Van Pelt, Los Angeles, CA.

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IN TRIBUTE TO ROBERT M. SHIPLEY, JR.

Robert M. Shipley, Jr., the elder son of the founder of the Gemological Institute of America, passed away on September 10 after a long illness. He was 69 years old. Bob Jr., as he was known to many of his friends in the gemological field, was a great asset to his father in the early days of GIA. He came west from Wichita to join his father in 1933, and his expertise in the laboratory field and in the development of instrumentation for gemologists quickly became apparent. The younger Shipley soon became Director of the GIA Laboratory and was instrumental in establishing its reputation across the nation.

In many respects, Robert Shipley, Jr., was a genius in instrumentation. Prior to his efforts, gemologists were largely dependent on instrumentation from the mineralogical field. Shipley decided that dark-field illumination would be of great benefit for examining the interior of gemstones and that low-power stereoscopic magnification would be a boon to the gemologist. In 1937, he applied for a patent on the combination of binocular magnification with dark-field illumination for the examination of gemstones; the patent was granted in 1938. The stoneholder that he developed for that early DiamondScope is still in use today, almost unchanged from the original design.

When Edwin Land developed Polaroid, Shipley immediately saw the advantages over the expensive and small Nicol prisms and made, with Raoul Francouer, a French tool and dye maker, the first gem polariscope. Other instruments Shipley developed include the original optical colorimeter, an electronic colorimeter, a universal motion immersion stage, a vertical equivalent of the endoscope for testing drilled pearls, an analyzing refractometer, a pocket refractometer, and a gemological polarizing microscope.

Shipley also assisted his father in the preparation of GIA's Home Study courses, particularly the course on advanced gemology. He taught many classes and acted for a number of years as Director of Education as well as Research.

An officer in the Air Force reserve, Shipley was called to active duty in 1941. He served in the U.S. and England during World War II and was given a medical discharge in 1944. After World War II, he founded an instrument manufacturing company, which was sold to GIA around 1951. He then moved to Cloverdale, California, north of San Francisco, where he continued his inventive ways with a research laboratory. He developed tree shakers for the fruit industry of northern California and also equipment to pick up the fruit after it had fallen. He subsequently sold the research laboratory to a large midwestern manufacturing firm.

Robert Shipley, Jr., is survived by his wife Mary and two sons.

THE CHANTHABURI-TRAT GEM FIELD, THAILAND

By Peter C. Keller

With the recent drastic decline in production from the classic ruby mines of Burma, Thailand has become the world's major source of gem ruby. The majority of the ruby production, as well as some significant sapphire production, comes from the provinces of Chanthaburi and Trat in southeastern Thailand. This article reviews the geology of these alluvial deposits and describes the wide range of methods used to mine the corundum. Gemologically, the Thai rubies are distinguished by their violet overtone, inhibited fluorescence, and characteristic inclusions. Also discussed is the heat treatment of corundum to enhance color, which has become a major industry in Chanthaburi. The newest product, "golden" sapphire, is examined, including the apparent stability of the color produced and clues to the detection of the heat treatment.

ABOUT THE AUTHOR

Dr. Keller is director of education at the Gemological Institute of America, Santa Monica, California.

Acknowledgments: The author wishes to thank the many people who contributed to this article in a variety of ways. John Koivula and Chuck Fryer helped identify many of the inclusions. The trip into the mining region would have been very difficult if not for the generous office of Henry Ho, of the AIGS in Bangkok, and the two knowledgable guides, Narong Saeovi and Dick Hughes. Special thanks also go to Dr. George Rossman of the California Institute of Technology for sharing his insights into the heat treatment of corundum. This study was made possible by a grant from the Western Foundation of Vertebrate Zoology.

Thailand has been a world supplier of gem ruby and sapphire since the latter part of the 19th century, although the deposits were not thought to be as important as those of neighboring Burma. In 1963, however, the Burmese deposits were nationalized, and supplies of fine gems from these mines declined rapidly. The fact that so little is produced in Burma today has catapulted the Thai deposits into importance. An estimated 70% of the world's high-quality gem rubies come from Thailand. Of these, 85% to 90% come from the Chanthaburi-Trat district alone (Aranyakanon and Vichit, 1979). While the overall quality of these rubies is not as high as those found in Burma, exceptional stones are seen (figure 1).

The gem deposits of the Chanthaburi-Trat (formerly Krat) area are entirely alluvial, having eroded out of deeply weathered basalt flows. The region can, however, be divided into two mining districts based on the type of corundum produced. The first lies to the west, near the town of Chanthaburi (figure 2) and in the Chanthaburi Province. It includes the famous Khao Ploi Waen and Bang Kha Cha mining areas, known for their production of blue, blue-green, and yellow sapphires as well as black star sapphires. The second district, approximately 45 km to the east of Chanthaburi, in Trat Province, is the currently very active Bo Rai/Bo Waen mining area known for its significant production of ruby. In fact, Bo Rai/Bo Waen, together with the Pailin area 27 km to the northeast in Kampuchea (formerly Cambodia), comprises the most important ruby-producing area in the world today. Occasionally, green sapphires and color-change sapphires occur in this district as well.

In 1980, an estimated 39.4 million carats of ruby and sapphire were mined in the Chanthaburi-Trat area by an estimated work force of 20,000 miners (Stamm, 1981). It is difficult to translate this production figure into official export figures because the latter do not include tourist purchases that do not have to be declared at customs or smuggled material. In addition, the tremendous amount

Figure 1. Two fine Thai rubies, 3.41 and 3.04 ct. Photo courtesy of Jack Abraham, Precious Gem Resources, Inc., New York, NY.

of corundum from elsewhere, particularly Sri Lanka and Australia, that is brought to Thailand for heat treatment and thus sold in the gem markets of Bangkok undoubtedly has a major effect on any export statistics. The actual production and export figures are probably much greater than those estimated by the Department of Customs and the Department of Business Economics. It is very significant, however, that these figures have more than doubled since 1973 (Stamm, 1981).

Considering the importance of the Thai deposits, surprisingly little has been written about them. Bauer (1904) provides one of the best early descriptions and includes a detailed map of the deposits. Most of the relatively recent work done by the Geological Survey of Thailand has been published in Thai journals which are, for the most part, difficult to obtain in the United States. An excellent general study of the gem deposits of Thailand was done by Aranyakanon and Vichit (1979). This report included details on the Chanthaburi-Trat area. Charaljavanaphet (1951) did one of the earliest geological reports on the Bo Rai area. One of the most important geological studies of the corundum-related basalts in Thailand was by Vichit et al. (1978). Berrangé and Jobbins (1976) did a superbly detailed study of the gem deposits at Pailin, Cambodia, in which they included many references to the deposits in the Chanthaburi-Trat area. A summary of this work was recently published by Jobbins and Berrangé (1981). There have also been several articles by visitors to the area, most notably Moreau (1976), Chang (1969), and Pavitt (1973, 1976).

None of these papers, however, has put all the aspects of geology, mining methods, production, and gemological characteristics together into a single, comprehensive report. The purpose of this article is to fill this void, as well as to present an update on current activities in the Chanthaburi-Trat area, including the heat treatment of corundum, based on observations made by the author on a visit to the area in June 1982.

LOCATION AND ACCESS

The Chanthaburi-Trat mining district is located in southeast Thailand, approximately 330 km east-southeast of the capital city of Bangkok. The district extends from approximately 102°00′ to 103°00′ west longitude and 12°00′ north latitude to 13°00′ north latitude. The district is contiguous with the very productive Pailin ruby and sapphire gem field, 27 km northeast of Bo Rai in Kampuchea (Cambodia).

Access to Chanthaburi is quite easy now compared to the late 19th century, when, according to Bauer (1904), a 20-hour journey by steamer from Bangkok was required. The new highway has shortened the trip from Bangkok to Chanthaburi to three hours. Bo Rai is about an additional 45 km from Chanthaburi eastward via highway no. 3157. Currently, there are more than 20 active mining operations in the district, ranging from hand operations to highly mechanized ones.

HISTORY

Gem mining in the Chanthaburi-Trat area was first reported at Khao Ploi Waen, also known as "Pagoda Hill" or the "Hill of Gems," in 1850. Khao Ploi Waen is about 8 km southwest of Chanthaburi, near the village of Bang Kha Cha. In 1850, the Shans and Burmese were mining sapphires here (Pavitt, 1973). According to Bauer (1904), a missionary report dated 1859 stated that it was possible to collect a handful of rubies from the "Hill of Gems" in half an hour. Interestingly, the pagoda that Bauer cites still stands.

Bauer (1904) described the state of the ruby and sapphire deposits in the Trat Province (then known as Krat) in the 1870s and 1880s. He divided the district into two groups, roughly 50 km apart: Bo Nawang, an area of about 40 square kilometers; and Bo Channa, 50 km to the northeast and a little over one square kilometer in extent. Bauer noted that the mines at Bo Nawang were small, typically pits one meter deep, and sunk in coarse yellow-brown sand overlying a bed of clay. The rubies occurred at the base of the sand unit in a layer 15-25 cm thick. These mines have been worked since about 1875.

In 1895, an English company, The Sapphires and Rubies of Siam, Ltd., obtained the rights to mine in what was then Siam. This company was an extension of E. W. Streeter, a famous London jeweler with a Burmese gem-mining operation known as Burma Ruby Mines Ltd. The company was not successful in the Chanthaburi-Trat area (Bauer, 1904).

At Bo Channa, the mines were vertical shafts extending to a depth of 7 to 8 m until they reached a gem gravel 15-60 cm thick. The Bo Channa mines have been worked since about 1885. Both Bo Channa and Bo Nawang were worked by the Burmese. Bauer estimated that about 1250 miners worked the two areas at the time.

Since the introduction of the Siam Mining Act in 1919, all gem mining has been limited to Thai nationals. Today, about 2,000 people mine in the Khao Ploi Waen-Bang Kha Cha area, and at least 20,000 people work between Bo Rai, Bo Waen, Nong Bon, and the deposits at Pailin in Kampuchea. Interviews at Bo Rai revealed that at least 1,000 miners from the area cross into Kampuchea every day.

GEOLOGY

Because of the deep chemical weathering and subsequent rapid erosion that is typically associated with tropical climates, the corundum deposits of the Chanthaburi-Trat district occur exclusively in alluvial, eluvial, or residual lateritic soil deposits derived from underlying basalt flows. The gems have long been thought to have been derived from these basalts, although reports of in-situ occurrences are rare (Vichit et al., 1978).

While the precise age of the basalts has not yet been determined, they are thought to be relatively young; estimates range from Tertiary to Pleistocene (Leon Silver, personal communication, 1982). According to Jobbins and Berrangé (1981), the closely related Pailin basalts have been radiometrically determined to be 1.4 to 2.14 million years old. This places the basalts in Upper Pliocene to Lower Pleistocene age. They have been informally designated the Chanthaburi-Trat basalts by Vichit et al. (1978). These flows unconformably overlie the Devonian-age Kanchanaburi formation, which consists of phyllites and quartzites, and the Jurassic/Triassic Phu Kradung volcanic siltstones, sandstones, and conglomerates (Javanaphet, 1969). These units are undoubtedly comparable to the Devonian-age O Smoet formation and Triassic-age Tadeth Group that Berrangé and Jobbins (1976) discuss in their comprehensive study of the Pailin gem field. Other noteworthy geologic units in the region include granites and granodiorites of possible Cretaceous age and the Triassic-age Khao Sa-Bab granite which outcrops just east of Chanthaburi (again, see figure 2).

Outcrops of the Chanthaburi-Trat basalt are rare. The only notable outcrops are at Khao Ploi Waen and Khao Wao. At Khao Ploi Waen, the unit occurs as a dark, fine-grained to glassy vesicular basalt; the hill itself is thought to be a volcanic plug and is possibly a source for the gem-bearing basalt flows in the area (Taylor and Buravas, 1951). The plug at Khao Ploi Waen yields blue, green, and yellow sapphires as well as black star sapphires. Rubies are rare at this locality.

Invariably, the gem deposits are associated with basalt flows or at least remnant flows. The flow at Chanthaburi is only about 35 square kilometers. The basalts in the Bo Rai area are much more extensive. As expected, the basalt flows parallel to the gem deposits, trending in a north-south direction. The flow in the Bo Rai area is about 27 km by 4 km. This roughly delineates the Bo Rai mining district, which Vichit et al. (1978) estimate to consist of about 23 gem localities. Bo Rai produces ruby almost exclusively.

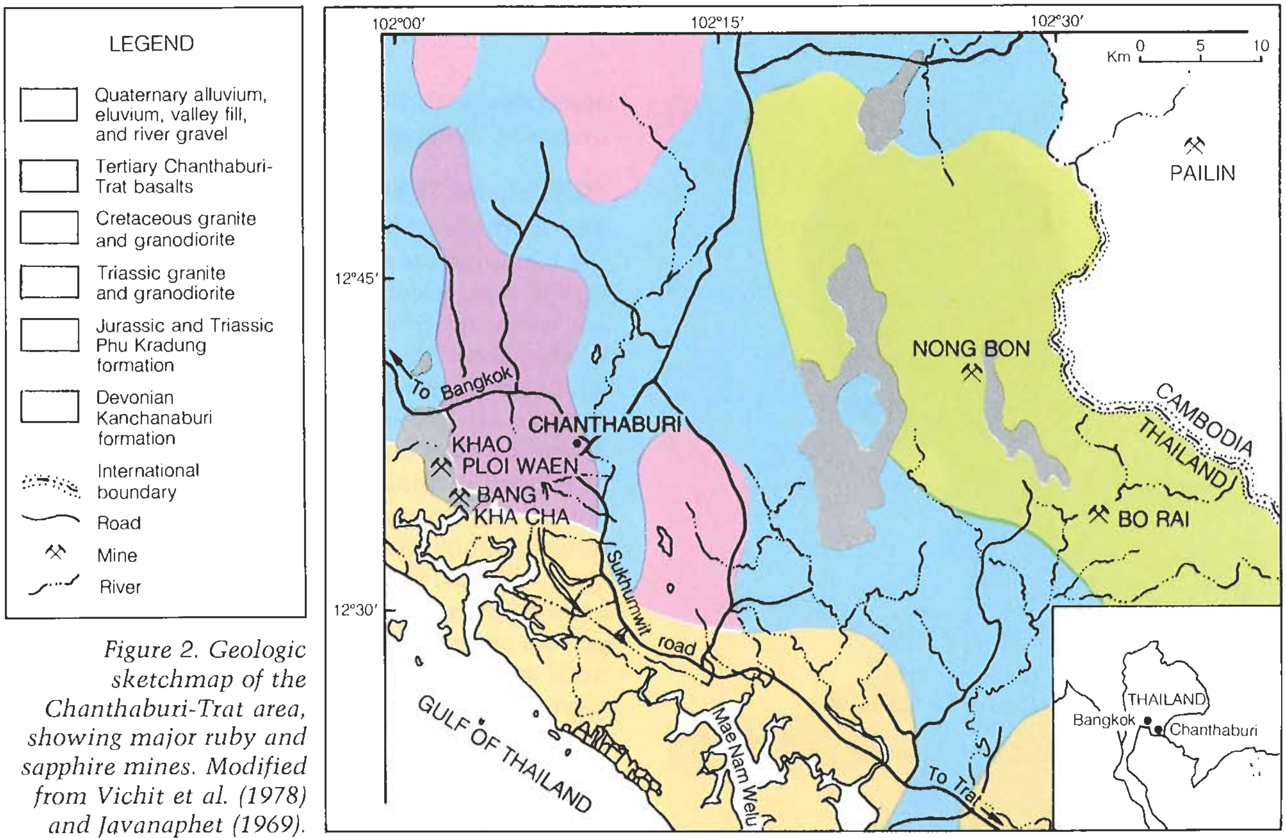


Figure 2. Geologic sketchmap of the Chanthaburi-Trat area, showing major ruby and sapphire mines. Modified from Vichit et al. (1978) and Javanaphet (1969).

From a petrographic point of view, the Chanthaburi-Trat basalts are fine-grained, olivine-bearing alkaline basalts; they have been called "basanitoids" by Vichit et al. (1978) and "basanites" by Berrangé and Jobbins (1976). These basalts locally contain spinel-rich lherzolite nodules, which may, in fact, be the ultimate source for the corundum. Lherzolite nodules are thought to form in the upper mantle of the earth, at depths of about 50 km, and may be unrelated to the magmas that brought them to the surface. The basalts contain augite, pyrope garnet, calcic plagioclase, zircon, spinel, and magnetite. The magnetite has been reported as megacrysts up to 6 cm in diameter. Spinel, which along with olivine and enstatite is typical of lherzolite, is locally abundant but rarely of gem quality.

The structural and historical geology of the Chanthaburi-Trat area is essentially identical to that outlined by Jobbins and Berrangé (1981) for the Pailin area of what is now Kampuchea, which could easily be considered part of the Chanthaburi-Trat district. Jobbins and Berrangé note that during the Himalayan orogeny of early to middle Tertiary times, the region, which is largely underlain by Jurassic-Triassic sandstones and Devonian phyllites, was uplifted and intruded by granites and granodiorites as represented by the Khao Sa-Bob granite. During the final stages of this orogenic episode, the area was also intruded by basaltic dikes which spilled onto the earth's surface in the form of extensive basaltic lava flows. Some volcanic features, such as the volcanic plug now exposed as a remnant at Khao Ploi Waen, were also formed at this time. Since this period of mountain building and volcanic activity, the area has been geologically quiet and the surface has been exposed to intense weathering and erosion as a consequence of the harsh tropical climate. Deep residual soil horizons formed over the basalts which, locally, have been eroded and redeposited to form the secondary gem deposits of the region. Because corundum is durable and heavy, it is an ideal mineral for concentration in these alluvial or eluvial deposits.

The gem deposits in the Chanthaburi-Trat area vary greatly in thickness, depending on the topography of the area and the bedrock. In the Chanthaburi area, sapphires are found on the surface at Khao Ploi Waen, and at a depth of 3–8 m in the area adjoining the hill and at Bang Kha Cha. In the relatively flat Bo Rai area, the gem gravel is at a depth of at least 4–10 m and varies in thickness from 0.3 m to 1 m. At Bo Rai, the ruby is

Figure 3. Primitive washing of gem gravels at Chanthaburi-Trat area.

associated with black spinel, olivine, and, in rare instances, blue, green, or color-change sapphires.

MINING METHODS

The methods used to mine ruby and sapphire in the Chanthaburi area reflect all levels of technological sophistication, from the simple rattan basket to the most advanced bulldozer. The mining in the Khao Ploi Waen area is typical of Thailand's most primitive extraction methods. Independent miners lease land from the local owners. A vertical shaft about 1 m in diameter is then dug to a depth of about 10 m, where the gem gravels are usually intersected. No ladder is used; the miner simply digs footholes into the side of the shaft. The soil is lifted to the surface using a large bamboo crane and rattan baskets. When the gem gravels are encountered, they are washed in artificial pools and sorted by hand in round rattan sieves (figure 3). According to Pavitt (1973), about 2,000 people work using these simple methods in the Khao Ploi Waen area alone.

Just to the south of Khao Ploi Waen, at Bang Kha Cha, which is famous for its black star sapphires and blue and green sapphires, a different style of mining is found. Here, the sapphires are recovered from the muddy tidal flats of the Gulf of Siam, which is located about 5 km to the south. The gem miners take boats out into the flats at low tide and fill them with the gem-bearing mud. They then take the mud to shore where it is washed with the standard rattan sieves. There are more sophisticated operations at Bang Kha Cha,

Figure 4. At Bo Rai, gem gravels are washed by high-pressure water cannons and transported up a pipe (seen to the right in photo) to a long sluice.

but the most technologically advanced mining can be seen at Bo Rai, the ruby mines located on the border of Kampuchea, where claims are generally about 1620 meters square, and the landscape is dotted with bulldozers and sophisticated washing equipment.

Large-scale mechanized mining was formally banned in Thailand in 1980 in response to pressure from farmers who claimed that the mining was destroying the topsoil. Even so, the majority of the ruby mining operations observed during the author's recent visit to Bo Rai used bulldozers to remove the overburden and high-pressure water cannons to wash the gem gravel that is then pumped into sluices from which the ruby is recovered (figures 4 and 5). According to Stamm (1981), "special" permits that allow mechanized mining are issued for 2500 baht (US$125) per month. In addition to the bulldozers and water cannons, the latest mechanical treatment includes a jig or "willoughby" table washer to concentrate the corundum at the end of the long sluice (figure 6). It is interesting to note that most of these so-called new mining methods at Bo Rai have been borrowed from the basic principles of alluvial tin mining used at Phukat, on the southern extension of Thailand.

Not all of the ruby mining in the Bo Rai area is mechanized; here, too, some is done by "pitminers" using only the traditional rattan sieve. These pitminers may work in small groups or on a few square meters of leased land. They commonly pay the government or landowner about 500 baht (US$25) per month and are permitted to keep what they recover. Other small miners search the already-worked tailings of the large, mechanized operations (figure 7). Usually these small miners are successful enough to support themselves and their families. The author noted several of them sorting and selling their ruby production in front of their homes (figure 8).

CHARACTERISTICS OF THAI RUBY AND SAPPHIRE

The rubies taken from the basalt fields of southeastern Thailand can generally be distinguished by their color and unique inclusions from those derived from the crystalline limestone terrain of Burma or from the graphite gneisses of East Africa. Gübelin (1940, 1971) has done detailed studies of inclusions that he found to be typical of Thai rubies. He observed the most common inclusions to be subhexagonal to rounded opaque metallic grains of pyrrhotite ($Fe_{1-x}S$); yellowish hexagonal platelets of apatite, ($Ca_5(PO_4)_3(OH,F,Cl)$); and reddish brown almandite garnets, $Fe_3Al_2(SiO_4)_3$. These inclusions were commonly surrounded by circular feathers (figure 9) and characteristic polysynthetic twinning planes (figure 10).

A parcel of over 500 rough rubies obtained by the author from mines in the Bo Rai area were examined for characteristic inclusions and any other distinguishing features. The parcel consisted of well-rounded fragments, generally under 5 mm, which exhibited color variations from

Figure 5. After the gem gravels exit the pipe, they are run over a long sluice. The heavier corundum concentrate collects in a jig at the end.

Figure 6. A jig or "willoughby" table washer, a device borrowed from the Phukat tin mines on the southern extension of Thailand, is very effective at concentrating ruby.

strongly violet to a classic "pigeon blood" red. Grains over a centimeter were rare. The refractive index (1.766–1.774) and specific gravity (3.97–4.05) of ruby do not differ with locality. The high iron content of the Thai rubies does influence their behavior when exposed to ultraviolet radiation, in that their fluorescence is inhibited significantly. The parcel examined exhibited the very weak fluorescence that would be expected for Thai rubies.

By far the most common inclusion in the parcel of rubies studied was subhedral to anhedral pyrrhotite (figure 11). These pyrrhotite inclusions were commonly altered to a black submetallic material (figure 12) that X-ray diffraction analysis by Chuck Fryer of GIA revealed to be goethite, FeO(OH). It is not surprising to see pyrrhotite inclusions in rubies from a basaltic terrain, since basalts are unusually high in iron. Furthermore, according to Carmichael et al. (1974), pyrrhotite appears to be the dominant primary sulfide in basaltic rocks.

In all the samples studied, no inclusions of almandite garnet or rutile were observed. Yellowish anhedral hexagonal platelets of translucent apatite were noted, although these were considered quite rare. A high percentage of the stones studied were totally free of diagnostic mineral inclusions, however; the most characteristic features in these stones were secondary stains of iron oxide that appeared in almost all fractures (again, see figure 11). Given the iron-rich nature of the presumed host basalt, as discussed above, this abundance of iron is to be expected. Typically, the brownish to purplish overtones of the rubies, and their weak fluorescence when exposed to shortwave ultraviolet and X-radiation, has been attributed to the characteristically high concentrations of iron found in the Thai rubies.

Sapphires recovered from the Khao Ploi Waen and Bang Kha Cha areas outside of Chanthaburi are quite different morphologically from the formless Bo Rai rubies. These sapphires show signs of transport, in that they occur as well-rounded hexagonal prisms. I would suggest, however, that the sapphires have not traveled as far

Figure 7. Independent miners often work the tailings of the more sophisticated operations in hopes of recovering any overlooked ruby. This photo was taken at Bo Rai.

Figure 8. Independent miners sorting rough rubies at Bo Rai. Note the bottle of "ruby oil," essentially a coloring agent, which is sometimes used to temporarily enhance the appearance of the gem rough.

as the rubies, which rarely exhibit any of their original hexagonal morphology. The sapphires are generally green, blue, yellow, or black—the black commonly exhibiting asterism. They range in diameter from less than a millimeter up to 10 cm. The average size observed was 3-6 mm. Large, hexagonal blue-green sapphire specimens up to 1720 ct have been reported from the Bang Kha Cha area (Pavitt, 1973). No gem-quality stones of this size have ever been reported, however.

HEAT TREATING "GOLDEN" SAPPHIRES

It is almost impossible to discuss the increased availability of fine ruby and sapphire from Chan-

Figure 9. Typical inclusions in Thai ruby are these circular features surrounding pyrrhotite. Magnified 60×. Photo by John Koivula.

Figure 10. Polysynthetic twinning, here observed under crossed polarizers, is commonly seen in Thai rubies. Magnified 25×. Photo by John Koivula.

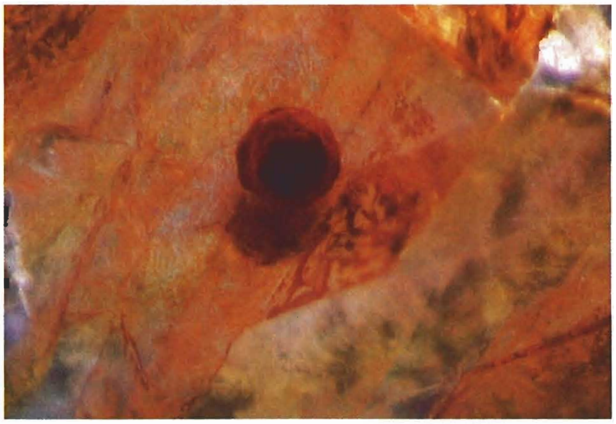


Figure 11. Typical subhedral inclusions of semialtered pyrrhotite in a Bo Rai ruby. Note the characteristic iron stains also. Magnified 50×. Photo by John Koivula.

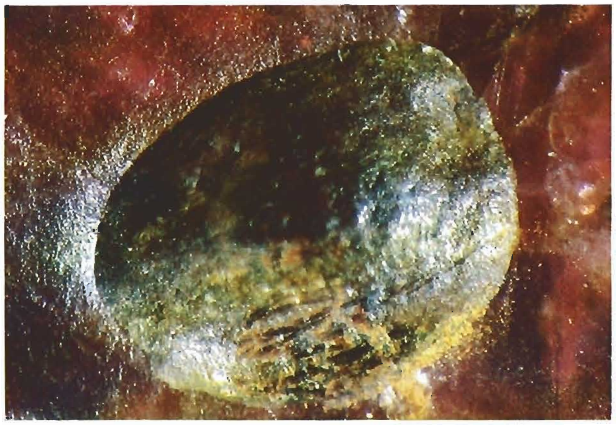


Figure 12. Large goethite inclusion found in an alteration product of pyrrhotite. Magnified 50×. Photo by John Koivula.

thaburi without considering as well the now-common use of heat treatment in that area. The heat treatment of corundum has developed into a major industry in Thailand, primarily in Bangkok and Chanthaburi. Estimates of the number of heat-treatment facilities run from the hundreds to the thousands. These facilities treat not only the local production, but large quantities of material from Sri Lanka, Australia, Kampuchea, and Burma as well. Nassau (1981) and Crowningshield and Nassau (1981) examined the technical aspects of heat treatment and its detection in ruby and sapphire in quite some detail. They limited themselves to those questions relating to enhancing asterism or improving the color of ruby and blue sapphire, however. Abraham (1982) discussed some of the practical aspects of this growing industry in Bangkok, but again limited his article to the commercially important blue sapphires, rubies, and sapphires exhibiting asterism.

On a recent visit to Chanthaburi, the author had the opportunity to interview Mr. Sammuang Koewvan and Mr. Jonk Chinudompong, two of the leading treaters. They were very cooperative and helpful, and essentially confirmed what Abraham (1982) presented in his recent article. The author was, however, especially interested in the relatively large amount of high-quality brownish to orangy yellow—referred to here as golden—sapphire that they were generating, largely from Sri Lankan rough (figure 13). (While significant quantities of blue sapphires have been heat treated for at least the last 10 to 15 years, and rubies for the last three to five years, the heat treatment of golden sapphires on a large scale appears to be relatively new.) To date, very little has appeared in the literature concerning these stones. Crowningshield (1982) reported that light yellow stones were produced by heat treating colorless sapphire seven or eight years ago, but that these were subject to fading. These stones were not the same as the orangy yellow ones observed in this study, which definitely did not fade on prolonged exposure (over several months) to light.

There was a great deal of concern on the part of the gem dealers in Thailand about these sapphires because such a golden color may also be produced by irradiation, and the irradiated stones have been found to fade rapidly when exposed to heat or ultraviolet radiation. Because of this concern, dealers routinely place a suspect stone under a flame for one minute. If the stone has been irradiated, it will fade. If, however, the sapphire has been heat treated, it will temporarily darken and, upon cooling, return to its golden color. (In a recent personal communication, Robert Crowningshield noted that the GIA Gem Trade Lab in New York prefers to place a suspect stone in sunlight for approximately four hours, since natural yellow sapphires from Sri Lanka may temporarily fade at a fairly low temperature.) In a paper by Lehmann and Harder (1970), it was pointed out that the yellow color in sapphire was generally due to trivalent iron impurities. There were, however, some yellow sapphires that owed their color to "irradiation color centers." The authors noted that these sapphires "bleach completely within a few days even in the dark."

The actual heat-treatment process for these golden sapphires appears to be quite simple. Most of the sapphires treated are colorless stones from Sri Lanka. These sapphires are typically very clean and free from the "silk" or rutile that provides the

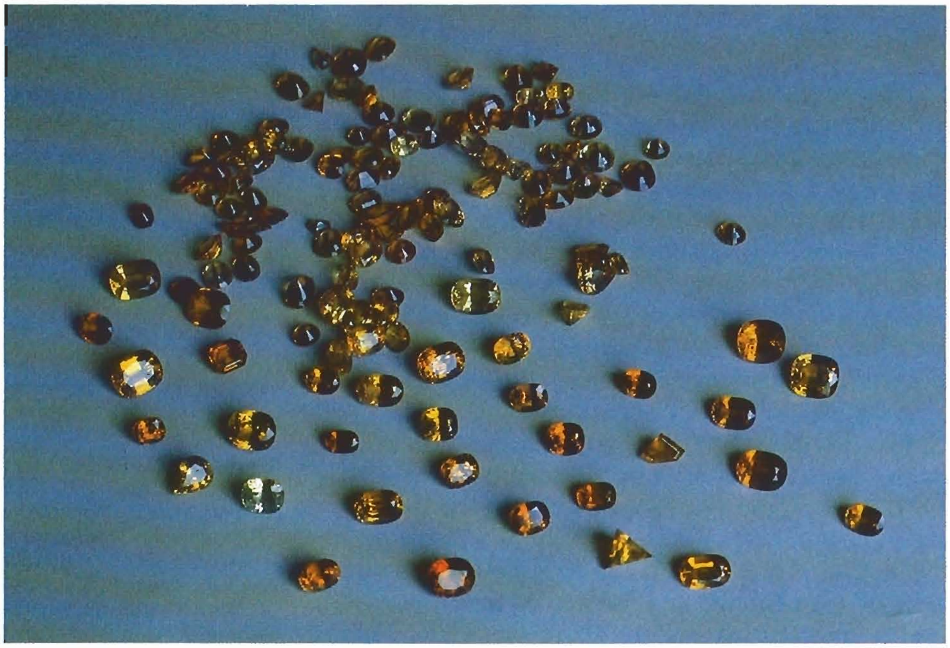


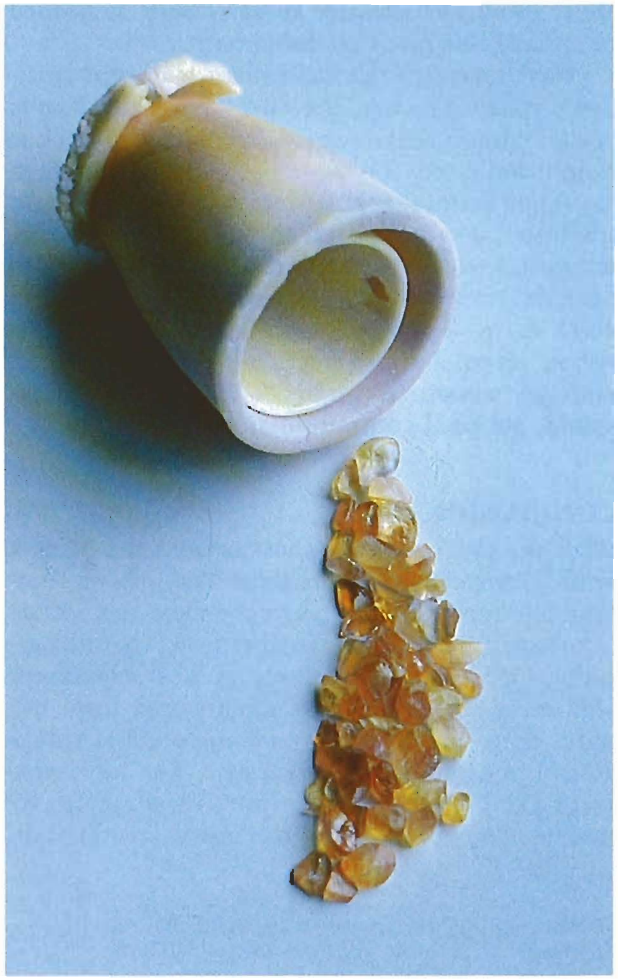
Figure 13. A parcel of faceted golden sapphires after heat treatment. The largest stones are about 10 ct.

titanium which, in conjunction with divalent iron, is responsible for a sapphire's blue color (Nassau, 1981). Any highly included or flawed portions of the rough sapphire are trimmed prior to treatment. The material is heated in an open crucible, that is, in an oxidizing environment, in an oven similar to that described by Abraham (1982) for blue sapphires. The divalent iron is converted to trivalent iron following the simple equation offered by Nassau (1981):

$$4\ \mathrm{FeO} + \mathrm{O_2} \rightarrow 2\ \mathrm{Fe_2O_3}$$

This conversion results in a yellow sapphire (Lehmann and Harder, 1970). Specifically, to produce this change, the colorless sapphires are heated for about 12 hours at 1000°C to 1700°C in two crucibles, one placed inside the other (figure 14). The corroded surface of the treated rough suggests that the temperatures are at the high end of this estimate. The variation in color is dramatic, some stones remaining colorless while others become a dark, rich golden color. The treaters interviewed were very adamant that no chemicals are used in the crucible with the sapphire. Theoretically, no chemicals are necessary for the conversion of divalent to trivalent iron. The treated rough does show signs of very localized partial melting; this is possibly due to a spattering of the borax in which the corundum-bearing crucible is packed during the heating process. (The borax would be an excellent flux to promote melting in the corundum, as it is in the diffusion treatment of this material.)

Figure 14. Heat-treated golden sapphires with the pair of crucibles used in heating.



The actual mechanism for the appearance of the golden yellow color in the sapphire is open to speculation until the extensive research required to provide a conclusive answer can be completed. According to George Rossman, of the California Institute of Technology (personal communication, 1982), trivalent iron alone will produce a pale yellow color, but cannot be called upon for the rich golden color observed in many of the treated stones seen in Chanthaburi (figure 13). Rossman suggests that perhaps we are seeing incipient exsolution of the trivalent iron as submicroscopic iron oxides in the corundum lattice. This mechanism would be very similar to the exsolution of hematite in plagioclase feldspar giving rise to the golden color of sunstone. In the case of plagioclase, the hematite may become coarse enough to result in aventurescence. This phenomenon has not been observed in sapphire, although the process is not unlike the exsolution of titanium oxides (rutile) in corundum to produce the familiar "silk" inclusions. As noted above, however, detailed research will be needed to answer this question for certain.

With regard to the identification of heat treatment in these stones, the GIA Gem Trade Lab is of the opinion that once irradiation (fade test) has been eliminated, the source of color in brownish to orangy yellow sapphire may be ascribed to heat treatment on the basis of the rare and somewhat unnatural nature of this hue. Additional clues to heat treatment are the absence of an iron line at 4500 Å in the spectroscope, subdued fluorescence, internal stress fractures, pockmarked facets, and abnormal girdles* (Robert Crowningshield, personal communication, 1982).

CONCLUSION

With the decline in production from the Mogok area of Burma, the Chanthaburi-Trat area of Thailand has become of world importance as a source of rubies and sapphires. Furthermore, the increasingly sophisticated methods of heat treatment stemming from the Chanthaburi area have not only increased the supply of fine-colored rubies and blue sapphires substantially, but have also introduced relatively large amounts of previously rare "golden" sapphire of fine color. Greater technological sophistication has also been applied to the actual mining of the corundum to increase the supply of rough to the market. Reduced military activity in the adjacent gem fields in Kampuchea (Cambodia) in recent months suggests a return to importance of this area as well, contributing to the overall gem potential of the region.

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**Editor's note: These latter two characteristics are discussed and illustrated (figures 13 and 14) in the Gem Trade Lab Notes section of this issue.*

GEMSTONES WITH ALEXANDRITE EFFECT

By E. Gübelin and K. Schmetzer

The term alexandrite effect *refers to the apparent change of color in certain minerals from blue-green or greenish violet in daylight to red or reddish violet in incandescent light. This effect was discovered in chrome-bearing chrysoberyl from the Ural Mountains as early as the beginning of the 19th century. In more recent times, it has also been observed in certain varieties of garnet, corundum, spinel, kyanite, fluorite, and monazite. It has been determined that the absorption spectrum of all alexandrite-like minerals is characterized by transmission maxima in the blue-green and red regions and by a transmission minimum in the yellow region. The color of minerals with two such regions of transmission is determined in daylight (richer in blue and green) by the position of the transmission maxima and in incandescent light (richer in red) by the ratio of transmission in the red and transmission in the blue-violet sections of the visible spectrum.*

ABOUT THE AUTHORS

Dr. Gübelin is a certified gemologist in Meggen, Switzerland, and honorary professor at the University of Stellenbosch, South Africa; Dr. Schmetzer is a research associate at the Mineralogisch-Petrographisches Institut der Universität Heidelberg, D-6900 Heidelberg, Federal Republic of Germany.

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The alexandrite effect was observed for the first time in 1830, in a chromium-bearing variety of chrysoberyl from the emerald mines on the eastern slopes of the Ural Mountains. The new gem was named by the Swedish explorer Nils Nordenskiöld in 1838 (Koksharov, 1861), in honor of then-Tsarevitch Alexander Nikolayevitch, the future Tsar Alexander II (1818–1881). The alexandrite, famous for its conspicuous change of color—green in daylight and red in incandescent light—soon enjoyed great popularity as well. This gem was appreciated not only for its curious color change, which has only very recently been explained (Carstens, 1973; Hassan et al., 1974; Gübelin, 1976 a and b; and Schmetzer et al., 1980 a and b) but also because red and green were the colors of the tsarist army; thus the alexandrite was considered by many to be the national gem of tsarist Russia.

Most of the alexandrites found on the gem market today originate from deposits in Sri Lanka and those recently discovered in Zimbabwe, Brazil, and Tanzania. The Brazilian specimens usually display only a weak change of color, while those from Tanzania and Zimbabwe demonstrate a striking alteration from dark green and blue-green to pure or violetish red. Sri Lanka has been and still is the most important producer of alexandrite. The colors seen in the Sri Lankan specimens (brownish green in daylight and olive-tinged red in incandescent light) are more subtle than those commonly observed in their Russian counterparts (blue-green and deep red), and the change of color is less pronounced. Figure 1 illustrates the color change in a fine Sri Lankan alexandrite.

White et al. (1967) introduced the term *alexandrite effect* to the literature and identified that it was not just restricted to alexandrite, although alexandrite-like sapphire has been known to exist since at least the 1950s (the American Museum of Natural History in New York placed such a sapphire on display in 1960). A few garnets

Figure 1. Color change visible in an 8.07-ct alexandrite from Sri Lanka, from natural or fluorescent light (left) to incandescent light (right). Stone courtesy of the Los Angeles County Museum of Natural History. Photo by Tino Hammid.

from the gemiferous Sri Lankan district of Ratnapura displaying a very similar change of color came onto the market in the 1960s (the senior author acquired his first specimen, 5 ct, in 1968). Subsequently, alexandrite-like garnets were found in the Umba Valley of Tanzania as well as in Bohemia, Norway, and Yakutia. They were either chrome-rich pyropes or, more commonly, vanadium and/or chrome-bearing spessartite-rich pyropes (Amthauer, 1976; Schmetzer and Ottemann, 1979).

Although well-informed gemologists have known for some time that an alexandrite effect may be produced in synthetic corundum by adding 20% chromium oxide or traces of vanadium oxide (Barks et al., 1965), natural corundum from Thailand and Colombia displaying a similar effect has only recently been described in detail (Schmetzer et al., 1980). These gems contain V_2O_3, Fe_2O_3, and TiO_2 in addition to Cr_2O_3. A few examples of natural spinel from Sri Lanka showing a change of color from bluish violet in daylight to red-violet in incandescent light have also appeared on the market. The one such crystal examined by the authors contains approximately 2% FeO as well as small amounts of Cr_2O_3 and V_2O_3 (Schmetzer and Gübelin, 1980). To complete this record, it may be mentioned that an alexandrite-like fluorite, from Cherbadung in Switzerland, was studied by H. A. Stalder (1978), an alexandrite-like kyanite from East Africa was described by Bosshart et al. (1982), and an unusual alexandrite-like monazite from North Carolina was described by Bernstein (1982).

The following discussion reviews the current knowledge on gemstones with the alexandrite effect and seeks to describe a common denominator for this unusual phenomenon. In our search for such a factor, we focused away from the question of how the eye perceives color (an important issue, but beyond the scope of this study) and concentrated on the conditions—the chemistry of the stone and how certain elements interact within a particular crystal to produce a characteristic spectrum—that produce the color the eye observes.

ALEXANDRITE

In the geochemical cycle, it is extremely uncommon that the structural component beryllium on one side and chromium as a coloring agent on the other should combine to form a crystal (Gübelin, 1976 a and b). The chromium-bearing variety of chrysoberyl ($BeAl_2O_4$) is thus a very rare gemstone. The petrology and paragenesis of alexandrite have been described by Bank and Gübelin (1976) as well as by Leithner (1980).

In alexandrite, part of the aluminum is substituted by chromium (Cr^{3+}). However, the chromium content varies within relatively broad limits depending on the occurrence. To date, the smallest trace of chromium, 0.03% Cr_2O_3, has been determined in samples from Tanzania, whereas a concentration between 0.30% and 0.73% was found in Brazilian alexandrites (Schmetzer, 1978). The chromium ions produce the typical color and color change of alexandrite, whereas chrysoberyl normally owes its range of hues to traces of iron. Since Cr^{3+} has a slightly larger ion radius (0.63 Å) than Al^{3+} (0.51 Å), it naturally prefers the more spacious of the two available aluminum lattice sites (Al_2) within the chrysoberyl structure; yet some Cr^{3+} ions are nevertheless incorporated into the second and narrower aluminum sites (Al_1). It will be shown that not only the amount of chromium in the chrysoberyl lattice, but also the distribution of the chromium ions between these two aluminum sites, as reflected in the spectrum, is responsible for the characteristic color change and especially for its intensity.

The spectrum for alexandrite (figure 2a) shows a transmission maximum at about 490 nm (i.e., in the blue to blue-green region), an absorption maximum at 570 nm (i.e., in the yellow region), and a second transmission maximum after about 600 nm in the red region and beyond in the adjacent infrared. This spectrum is primarily dependent on the presence of the Cr^{3+} ions, which occupy 65% to 80% of the Al_2 lattice sites (Solntsev et al., 1977; Matrosov et al., 1978). The presence of the Cr^{3+} ions in Al_1 sites effects the widening and eventual displacement of this absorption maximum, yet the corresponding Cr^{3+} bands remain weaker than the bands for the Cr^{3+} in Al_2 sites. The ratio of the Cr^{3+} ions in these two Al sites varies from crystal to crystal, and thus explains the variance in hue and intensity of the color change observed in different specimens from daylight to incandescent light.

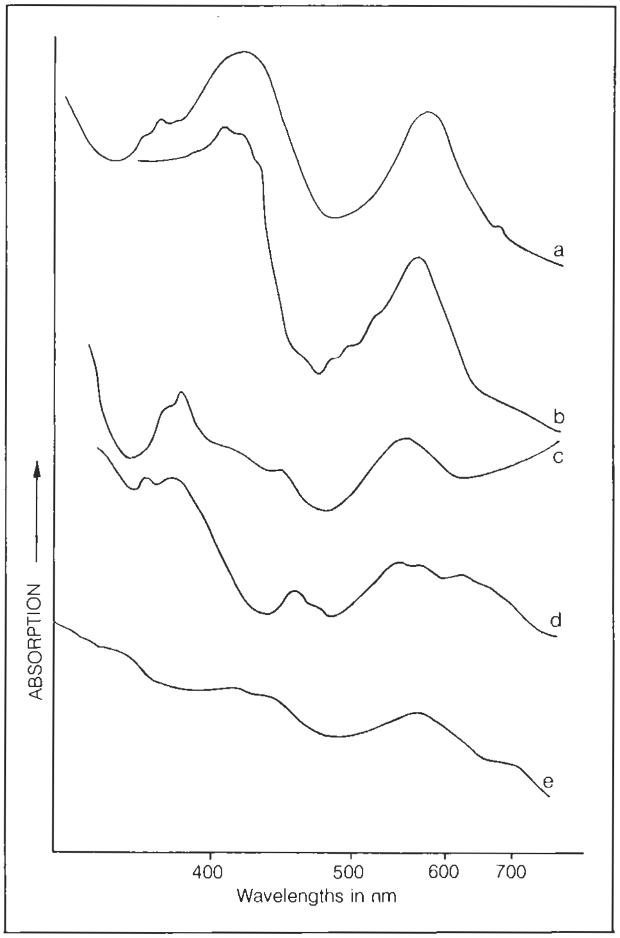
The transmission of alexandrite for visible light is high in the blue-green as well as in the red region of the spectrum. In daylight, in which the blue short-wave components predominate (figure 3), green to blue-green results. This effect is amplified by the optimal sensitivity of the human eye for green light. In incandescent light, however, in which the long-wave spectral components predominate, the human eye perceives a red hue because of the transmission in the spectral section of minimal red absorption. The iron ion does not directly contribute to the alexandrite effect, although it enhances the brownish cast of certain alexandrites from Sri Lanka.

GARNETS WITH ALEXANDRITE EFFECT

Crowningshield (1970) was the first author to mention this new type of garnet. Garnets belong to the group of neso-silicates with the general formula $X_3^{2+}Y_2^{3+}[SiO_4]_3$, which indicates that the silicate anion is combined with a divalent metal ion X and a trivalent metal ion Y. The alexandrite effect is displayed only by some pyrope garnets (Mg_3Al_2 $[SiO_4]_3$) and some mixed crystals between the end members of the isomorphous series of pyrope-spessartite garnets (spessartite: Mn_3Al_2 $[SiO_4]_3$). The color change of chromium-rich pyropes is from bluish green in daylight to wine red or reddish violet in incandescent light.

According to Yeremenko and Polkanov (1972), the alexandrite effect occurs in all pyropes that contain 4% or more Cr_2O_3. The absorption maximum of pyropes with a lower chromium content lies in the green to yellowish green region of the

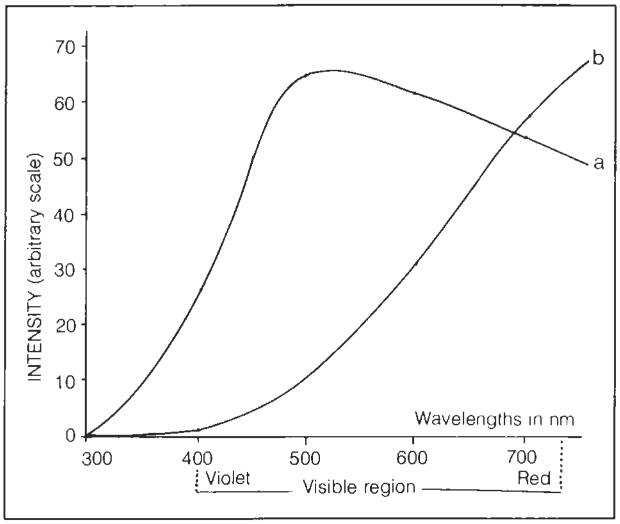
Figure 2. Absorption curves of gemstones with alexandrite effect: (a) alexandrite (from Lake Manyara, Tanzania); (b) Mn-rich pyrope (from Ratnapura, Sri Lanka); (c) corundum (in this instance, from Colombia, although similar sapphires may be found in Thailand); (d) spinel (from Ratnapura district, Sri Lanka); and (e) fluorite (from Cherbadung, Switzerland). The absorption spectra for all of these stones have transmission maxima in the red and blue-green regions and an absorption maximum in the yellow region in common.



spectrum; hence, such pyropes appear red to bluish red in both natural and incandescent light. A greater amount of inherent chromium displaces the transmission from the blue-violet to the blue-green spectral region. Consequently, such garnets transmit the red rays of incandescent light (figure 2b). These circumstances are responsible for the alexandrite effect (Amthauer, 1976; Schmetzer and Ottemann, 1979).

Spessartite-rich pyropes from Tanzania, on the other hand, in which a larger portion of Mg is replaced by Mn, require only small amounts of vanadium or chromium (or both) to evoke an alexandrite effect (Gübelin, 1968; Schmetzer et al., 1980). The absorption spectrum for these types of garnets is characterized by a sharp maximum between 560 and 576 nm. The transmission occurs, just as with alexandrite, in the blue-green and red regions of the spectrum. Considerable differences in the coloration of individual garnets may be noted, caused by the situation of the absorption minimum in the blue-green region and a maximum in the yellow region of the spectrum. The iron content of the particular crystal is primarily responsible for this condition, inasmuch as some bands of Fe^{2+} are situated between 454 and 526 nm in the domain of the blue-green absorption minimum (figure 2b). The alexandrite effect occurs in iron-rich pyropes with no spessartite molecules when they contain relatively high contents of chromium (e.g., 8% or more Cr_2O_3).

Figure 3. Spectral composition of (a) daylight (with the sun 65° above the horizon), and (b) artificial light (50 W incandescent lamp). The different-intensity maxima (for daylight in the blue-green and for artificial light in the red spectral region) are very conspicuous.



With regard to the absorption spectra for these stones, the chromium and vanadium ions behave similarly in all garnets. For instance, in Mn-rich crystals, the specific absorption is partially superimposed by Mn^{2+} bands; they appear between 408 and 422 nm. In the garnet crystal lattice, the Cr^{3+} ions (as well as the V^{3+} ions) substitute for some of the Al^{3+}, while Mn^{2+} replaces Mg^{2+}. Further details concerning the interpretation of the spectra of alexandrite-like garnets may be consulted in the articles by Amthauer (1976) and Schmetzer and Ottemann (1979). The article by Stockton (1982) illustrates some interesting color-change garnets from East Africa.

CORUNDUM WITH ALEXANDRITE EFFECT

Corundum is crystallized alumina ($\alpha-Al_2O_3$). Pure corundum is colorless; the partial replacement of Al^{3+} by one or another of the transition elements will introduce a wide variety of colors. Corundum forms a continuous isomorphous series of mixed crystals with chromium oxide, $(Al_{1-x}Cr_x)_2O_3$. Small amounts of chromium impart a red color; greater amounts impart green. Thus, a 20% Cr_2O_3 content renders corundum green in daylight and pink in incandescent light. The absorption maxima of synthetic alexandrite-like corundum lie at 415 and 568 nm. The spectrum of vanadium-bearing synthetic corundum is also conspicuous by two strong absorption maxima at 571 and 398 nm. The stones are gray-green in daylight and amethyst-like reddish violet in artificial light.

Natural corundum with alexandrite effect (figure 2c) develops transmission maxima at 633 nm (red) and 483 (blue-green). The alexandrite effect thus materializes the same as in alexandrite itself. Alexandrite-like sapphire from Thailand, which has less chromium, displays only a weak change of color; while the blue sapphire from the Umba Valley, which turns violetish red under incandescent light, possesses a greater amount of chromium and hence shows a stronger color change. This suggests that the intensity of the color change depends on the concentration of the transition-element atoms present (Schmetzer et al., 1980). Figure 4 illustrates the color change in a blue sapphire with alexandrite effect.

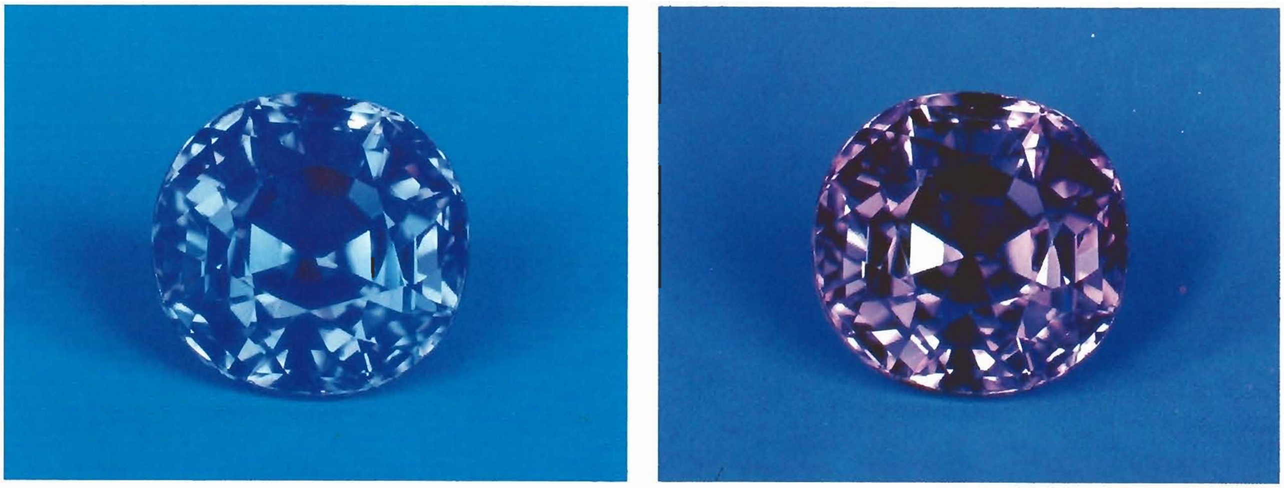


Figure 4. Color change evident in a 9.54-ct sapphire, purportedly from Sri Lanka, from natural or fluorescent light (left) to incandescent light (right). Stone courtesy of the Los Angeles County Museum of Natural History. Photo by Tino Hammid.

SPINEL WITH ALEXANDRITE EFFECT

Spinel is a combination of a divalent cation, typically magnesium in gem spinels, with alumina ($MgAl_2O_4$). Characterized by a dense cubic stacking of oxygen atoms, the tetrahedral interstices between the oxygens are filled in with bivalent metal ions (e.g., Mg^{2+}, Fe^{2+}), while trivalent ions (Cr^{3+}, V^{3+}, Al^{3+}) find their places in the octahedral coordinated lattice points.

The only alexandrite-like spinel described so far (Schmetzer and Gübelin, 1980) has a color change from violet-blue in daylight to red-violet in artificial light. This unusual spinel, which originated in Sri Lanka, contains 2.27% FeO as well as lesser concentrations of Cr_2O_3 (0.06%) and V_2O_3 (0.03%). Transmission maxima of equivalent intensities are observed at 490 and 440 nm; absorption maxima are at 571 and 633 nm (figure 2d). In contrast to the more typical blue spinel, which is rich in iron (without traces of Cr and V), the chromium and vanadium ions in the alexandrite-like variety strengthen the intensity of the absorption maximum at 571 nm, while the transmission maximum in the blue region is simultaneously weakened by the same ions. This means that the spectrum displays transmission in the blue-violet and red regions with an absorption maximum in the yellow regions, thus producing the alexandrite effect.

KYANITE WITH ALEXANDRITE EFFECT

Kyanite (Al_2SiO_5), which occurs in various shades of blue and green, has become a highly appreciated collector's gem.

In their publication, White and White (1967) claimed that titanium was solely responsible for the typical blue color of kyanite. More recently, Bosshart et al. (1982) stated that "the chromofore pairs Fe + (Ti) and Cr + Fe produce the various blue colorations of kyanites rather than titanium traces" (see Schmetzer, 1978). Among the four kyanites examined by Bosshart and his colleagues was one greenish blue specimen that turned purple under incandescent light and was found to have an exceptionally high precentage of chromium (Cr_2O_3, 0.50%) coupled with a low iron content (Fe_2O_3, 0.35%) and a very small amount of titanium (TiO_2, 0.04%).

In general, the absorption spectrum of the color-changing kyanite was similar in character to the spectra of all other minerals with an alexandrite effect examined thus far, in that the transmission maxima in the near ultraviolet (at 345 nm) and blue-green (at 488 nm) regions are combined with strong absorption in the violet (at about 410 nm) and in the green-yellow to red region (from 560 to about 650 nm). However, the decisive absorption of the α-ray, with transmission peaks at 345 and 488 nm and absorption maxima at 417 and 578 nm, is (according to Bosshart et al., 1982) governed totally by the chromium content, which imparts the α-ray with all four properties for releasing the color change. The β- and γ-rays do not directly participate in the color change, although their influence on the absorption enhances its general appearance. Thus, in this rare gem, the conditions leading to an alexandrite effect are fulfilled by the particular spectral features generated by the chromium and assisted by the iron content, in that the α-ray mainly transmits the red rays of the incandescent light, whereas the β- and γ-rays transmit the strong greenish blue rays of daylight.

FLUORITE WITH ALEXANDRITE EFFECT

The gemstones with alexandrite effect described thus far are all oxides or silicates in which coloration and color effects are caused by ubiquitous ions such as Cr^{3+} and V^{3+} as well as Fe^{2+} and Fe^{3+}. The alexandrite-like fluorite cannot be fitted into this scheme because it is a calcium fluoride, occurring in nature as violet, blue, green, yellow, orange, red, pink, and colorless crystals, depending on the incorporated ion. The coloration of various fluorites was investigated by Bill and Calas (1978).

Stalder et al. (1978) referred to alexandrite-like fluorite from Cherbadung (VS, Switzerland). The absorption spectrum for this stone is similar to that of all other minerals with an alexandrite effect identified thus far; yet in the case of fluorite the alexandrite effect is caused by a superimposition of the bands projected onto one another by the ions of rare-earth elements such as yttrium (Y^{3+}), cerium (Ce^{3+}), and samarium (Sm^{3+}). As illustrated in figure 2e, the absorption maximum in the visible sector of the spectrum is situated at 578 nm and the absorption minimum occurs at 495 nm (Schmetzer et al., 1980). The fluorite illustrated in figure 5 shows a distinct change from blue in natural light to lavender in incandescent light.

MONAZITE WITH ALEXANDRITE EFFECT

The cerium-phosphide monazite, $CePO_a$, is not usually considered a gemstone, although this mineral may be found among the oddities of some gem collections; yet it confirms that many other minerals—especially the chromium-, iron- and titanium-bearing ones—could theoretically display an alexandrite effect. According to Bernstein (1982), yellow-orange crystals of monazite from Montgomery County, North Carolina, appeared reddish orange under incandescent light and pale green under fluorescent light. These differing colors were found to be caused by the rare-earth element neodymium and the particular arrangement of narrow absorption bands centered at about 800, 745, 580, 525, and 515 nm, with a cut-off below approximately 480 nm. The close coincidence of these bands, due to Nd^{3+}, and the transmission gaps between them create absorption features that are consistent with those observed in the aforementioned gems. The eye perceives different hues in response to changes in the wavelength compositions of different light sources; the narrow absorption bands of the monazite prove to be sufficient to generate the color change.

DISCUSSION AND SUMMARY

In reducing these observations to a common denominator, we wish to emphasize that the cause of the alexandrite effect shared by all of these stones lies not in the crystal structure or in the chemistry of the coloring agents, but rather in an equivalent correspondence of the position of the absorption maxima and minima in the visible region of the spectrum. Alexandrite and the alexandrite-like varieties of garnet, corundum, spinel, kyanite, and fluorite demonstrate a strong transmission as much in the blue-green to violet as in the red region of the visible spectrum. In addition, a strong absorption occurs in the yellow region, where it culminates in a pronounced maximum. Starting with 476 nm (blue region), the absorption increases gradually until it reaches the long-wave end of the visible spectrum in the red region (Schmetzer et al., 1980). Alexandrite-like spinel presents an exception to this general rule, developing three regions of strong transmission, in the red, blue-green, and violet. Consequently, the color change in this stone is from violet-blue (not blue or green) to red-violet.

The color of each mineral depends on a superimposition of the light components of all spectral regions not absorbed by the mineral. In minerals with an alexandrite effect, the occurrence of the absorption minimum in the green, bluish green, or blue region (i.e., between 560 and 480 nm) is decisive for their color in daylight because the red component of daylight is not strong (figure 3a) and, as mentioned before, the sensitivity of the human eye is greatest for green light. On the other hand, in incandescent light, which has a weaker blue and stronger red component (figure 3b), the transmission in the red region, from about 600 nm to the end of the visible spectrum, exerts a dominant influence on the resulting color.

The intensity of the color change and the hues

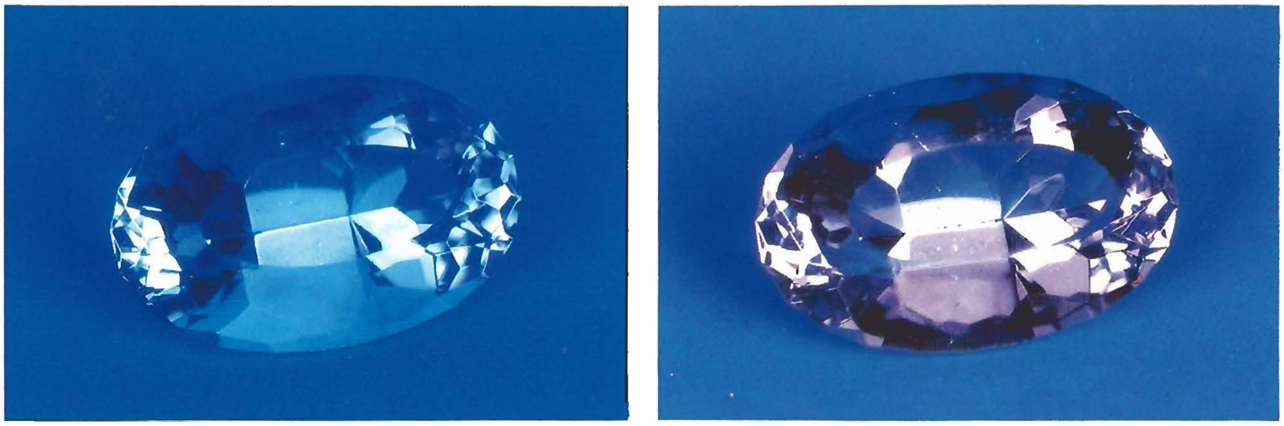


Figure 5. Color change apparent in a 28.55-ct fluorite from England, from natural or fluorescent light (left) to incandescent light (right). Photo by Tino Hammid.

observed in daylight and incandescent light in minerals with alexandrite effect depends on the particular position of the transmission and absorption regions as well as on their relative intensities. These in turn are dependent on the very complex absorption spectra, which themselves are influenced by minute traces of chromophorous ions within the individual crystal. Nature possesses an enormous repertoire of such complex occurrences. It would, therefore, hardly be astonishing if more gemstones with such a color change were to appear in the future.

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GEM-QUALITY GROSSULAR GARNETS

By D. Vincent Manson and Carol M. Stockton

***The** gemological classification and identification of gem grossular garnets is examined through the study of 105 gem-quality grossulars. These specimens were measured for refractive index, specific gravity, absorption spectrum, color, and chemical composition. From these data, the authors were able to reexamine the ranges of physical and optical properties that are characteristic of the gem species grossular. In addition, they discuss the problems encountered in defining the two gem varieties of grossular, tsavorite and hessonite.*

ABOUT THE AUTHORS

Dr. Manson is director of research and Ms. Stockton is senior research gemologist at the Gemological Institute of America, Santa Monica, CA.

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Grossular garnet occurs in a diversity of colors, including tones of orange, yellow, and green. Until recently, this garnet species encountered little popularity as a gemstone, and then only in its brownish orange variety hessonite. About 10 years ago, however, a large deposit of vivid green grossular was discovered in east Africa (Bridges, 1974). Popularization of this material followed the coining of the trade name "tsavorite" (now accepted as a variety by mineralogists), and grossular emerged as a significant gem species. More recently, another new east African garnet, tagged with the trade name "malaya" and easily confused with hessonite, has brought new attention to bear on grossular (Stockton and Manson, 1982).

Hessonite and tsavorite illustrate the inconsistency that surrounds the definition of many gem varieties. *Hessonite* is the name traditionally applied to the yellow, orange, or brown transparent variety of grossular. However, color descriptions of hessonite are varied and vague: "cinnamon-colored" and "yellow" (Dana, 1911), "yellowish and brownish red" (Deer et al. 1963), "brownish-yellow, through a brownish-orange to aurora-red" (Webster, 1975), "orange-brown" (Anderson, 1959), "light yellow to dark yellow shades" (Arbuniés-Andreu, 1975), "yellow-brown to orangy-brown" (Shipley, 1974), "orangy-yellow to orangy-brown" (Liddicoat, 1981). In addition to the lack of agreement we encountered on the precise range of hues associated with this variety, nowhere could we find mention of the saturation of color to which these various hues referred.

The original description of tsavorite as being similar in color to emerald (Bridges, 1974) is also rather vague. At what point does green grossular have sufficient depth and intensity of color to be considered tsavorite? This is much the same as the familiar question, At what stage does green beryl become emerald? The net result of this lack

Figure 1. This selection of stones used in the grossular portion of the garnet study illustrates the range of colors examined.

of agreement with regard to the colors of the gem varieties of grossular is confusion among gemologists, understandably, as to the correct applications of these varietal terms.

The final goal of our study and review of garnets (Manson and Stockton, 1981; Stockton and Manson, 1982) is to provide clear, functional definitions of all the gem species and gem varieties of the garnet group. The size of this problem required that we divide the subject into a series of descriptive papers to be followed by a concluding article that proposes a cohesive gemological classification of the garnets on the basis of the data gathered. This study of the transparent grossular garnets continues the garnet project. Inasmuch as grossular has been well documented both mineralogically and gemologically, this portion of our study serves primarily to confirm previous work on the grossulars and to supply data (such as color description) not provided in earlier reports.

DATA COLLECTION

Stones were selected for study on the basis of gem quality, transparency, and colors that are typically associated with grossular. Chemical analyses from a previous study (Stockton and Manson, 1982) confirmed the identity of stones that might visually be mistaken for some other type of garnet. The resulting collection contained 105 specimens ranging from colorless through pale to intense hues of yellow, green, and orange (figure 1). Although orange grossulars were examined as part of the paper just cited, we included them here as well in order to compare all colors of grossular. Not included in this study are the massive, translucent materials (including pink and green) that in many cases actually belong to the separate species hydrogrossular (Deer et al., 1963). There have been cases of translucent grossular reported (Bank, 1980), but this material is ornamental rather than gem quality.

Refractive index, specific gravity, spectrum, color, and chemical composition were determined for the 105 garnets selected. The instruments and methods used to obtain these data were described fully in a previous article in this journal (Manson and Stockton, 1981). The data gathered on the 105 gem garnets used in this study will be published at a later date, upon completion of the entire GIA garnet project, and are summarized below. Specific data will be provided on request to the authors.

DISCUSSION OF DATA

Physical and Optical Data. Comparison of the ranges we obtained for refractive index and specific gravity with the values quoted by three other gemological references (table 1) reveals that the ranges we found in our 105 samples are somewhat broader than one might presume on the basis of the gemological literature. A graph of the relationship between refractive index and specific gravity among our 105 specimens (figure 2) suggests that, of the nongrossular components present, andradite appears to have the strongest effect on the departure of these properties from the values for pure grossular: 1.731 (McConnell, 1964) and 3.594 (Skinner, 1956), respectively. However, the scattering of points to either side of the grossular-andradite trend suggests that other influences, such as other end-member components, are present, as one might expect (Ford, 1915; Fleischer, 1937).

Comparison of our data with references in the mineralogy literature sometimes reveals discrepancies that result from the particular nature of our samples. Gem specimens are relatively inclusion-free, transparent, single crystals, while mineralogical specimens are frequently fractured and included such that they are not transparent even as single crystals. For example, data cited by Ford (1915) resulted in a low estimate of the specific gravity of pure grossular (3.530 rather than the 3.594 found by Skinner in 1956). It is recognized now that, as stated by Deer et al. (1963, p. 81), "garnets commonly have small inclusions of quartz or other minerals which cause the composite grain to have a low specific gravity." In fact, their data reflect this bias when compared with our results.

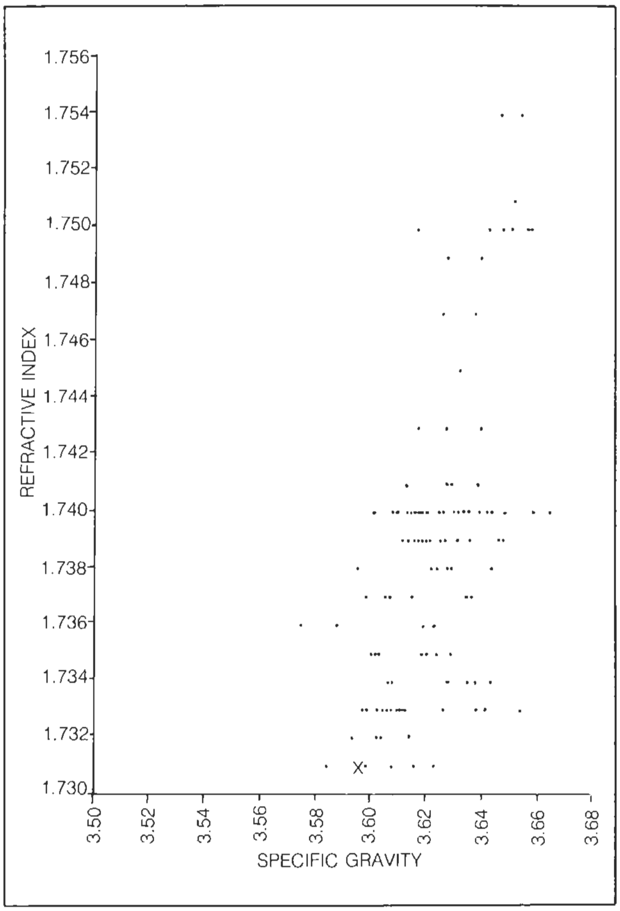
Absorption Spectra. We observed two basic shapes of spectral curves for grossular garnets on the recording spectrophotometer. Green stones exhibited two broad regions of absorption and two of transmission (figure 3). Absorption occurs from the short wavelength end of the visible region to about 460 nm and again in a broad region centered around approximately 603.5 nm and varying in width. However, these broad bands or regions of absorption can be discerned with the hand spectroscope only rarely, in some dark green stones. Transmission is centered around 525 to 550 nm in the green region, as might be expected, and in the far red around 700 to 735 nm. This is virtually identical to the spectra observed by Gübelin and Weibel (1975) and by Amthauer (1975) for similar grossulars.

The second type of spectral curve, associated with colorless, yellow, and orange stones, shows gradually increasing transmission from the short wavelength region to maximum transmission in

TABLE 1. Refractive index and specific gravity ranges for grossular garnets.

Reference	Refractive index	Specific gravity
Shipley (1974)	1.74 -1.75	3.57-3.73
Webster (1975)	1.742-1.748	approx. 3.65
Liddicoat (1981)	approx. 1.735	approx. 3.61
Manson and Stockton (present study)	1.731-1.754	3.57-3.67

Figure 2. Refractive index plotted against specific gravity for the 105 grossulars studied. The coordinate point for the ideal end member grossular is also shown (X).



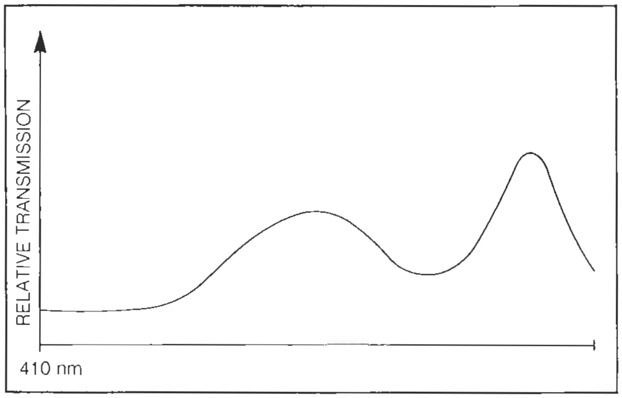


Figure 3. Representative spectral curve of a green grossular as observed with the spectrophotometer.

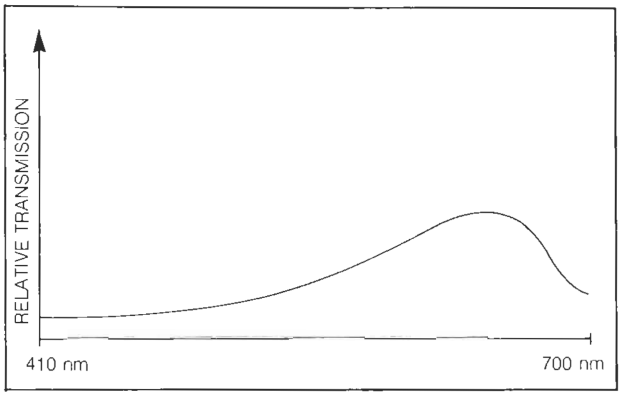


Figure 4. Representative spectral curve of a yellow-orange grossular as observed with the spectrophotometer.

the yellow-to-orange region, depending on the color of the stone, followed by a rapid decrease in transmission to the end of the long wavelength region of the visible spectrum (figure 4). Most of the stones examined showed no sharp absorption bands, but a few showed a faint band around 434 nm that is probably due to Fe^{3+} (Amthauer, 1975; Slack and Chrenko, 1971). One light orange stone also had very faint bands at 418.5, 489.5, 503.5, and 529.5 nm that to our knowledge have not been observed elsewhere in grossular. This stone, however, is the most heavily included one in our collection, and these absorption bands may be related to the inclusions that pervade the specimen. In any case, none of these bands is strong enough to be seen with the hand spectroscope, so they are purely of academic interest to most jeweler-gemologists.

Chemistry. It has long been considered that grossular is chemically continuous with andradite and uvarovite and forms a subgroup with them (Winchell and Winchell, 1951). While the amount of andradite in the 105 gems we analyzed ranged from approximately 0 to 19%, the most uvarovite we encountered was 1.5%. In fact, no single end-member component other than andradite exceeded 7% in any of the gem grossulars we analyzed (table 2). The relative quantities of grossular and andradite compared to all the remaining components can be observed in the ternary diagram of these three divisions (figure 5).

Although examples of stones containing less than 75% and more than 20% grossular have been cited (e.g., Deer et al., 1963), we personally have observed no gem-quality stones in that range. Grossular appears to be chemically less inclined to mix with other end-member components to produce large single crystals of gem quality, so grossulars of gem quality are generally very high in grossular content. The net result is that, chemically, grossular is easy to isolate and identify as a gem species.

Color and Chemistry. CIE color coordinates for the 105 grossulars were derived from ColorMaster notations (Manson and Stockton, 1981) and plotted in a chromaticity diagram (figure 6). The stones themselves were then placed on their respective coordinate points and photographed to show the complete range of colors for these gem grossulars (figure 7). This also illustrates, coincidentally, the quality of color description we have been able to obtain using the ColorMaster.

Pure grossular is colorless. Departing from this pure (and rarely seen) grossular are two distinct color trends that are evident on the chromaticity diagram (again, see figure 6). One of these proceeds through yellow-green to a pure, vivid green at one extreme, and the other proceeds through

TABLE 2. Weight percentage ranges of garnet end members calculated for the 105 grossulars studied.

Formula	End member	Weight %
$Ca_3Ti_2^{4+}(Fe^{3+},Si)_3O_{12}$	Schorlomite	0.02 - 2.14
$Ca_3Fe_2Si_3O_{12}$	Andradite	0 - 19.07
$Mn_3V_2Si_3O_{12}$		0 - 3.05
$Ca_3V_2Si_3O_{12}$	Goldmanite	0 - 6.91
$Ca_3Cr_2Si_3O_{12}$	Uvarovite	0 - 1.51
$Mg_3Cr_2Si_3O_{12}$	Knorringite	0
$Mg_3Al_2Si_3O_{12}$	Pyrope	0 - 2.19
$Mn_3Al_2Si_3O_{12}$	Spessartine	0 - 3.15
$Ca_3Al_2Si_3O_{12}$	Grossular	77.71 - 97.91
$Fe_3Al_2Si_3O_{12}$	Almandine	0 - 3.35

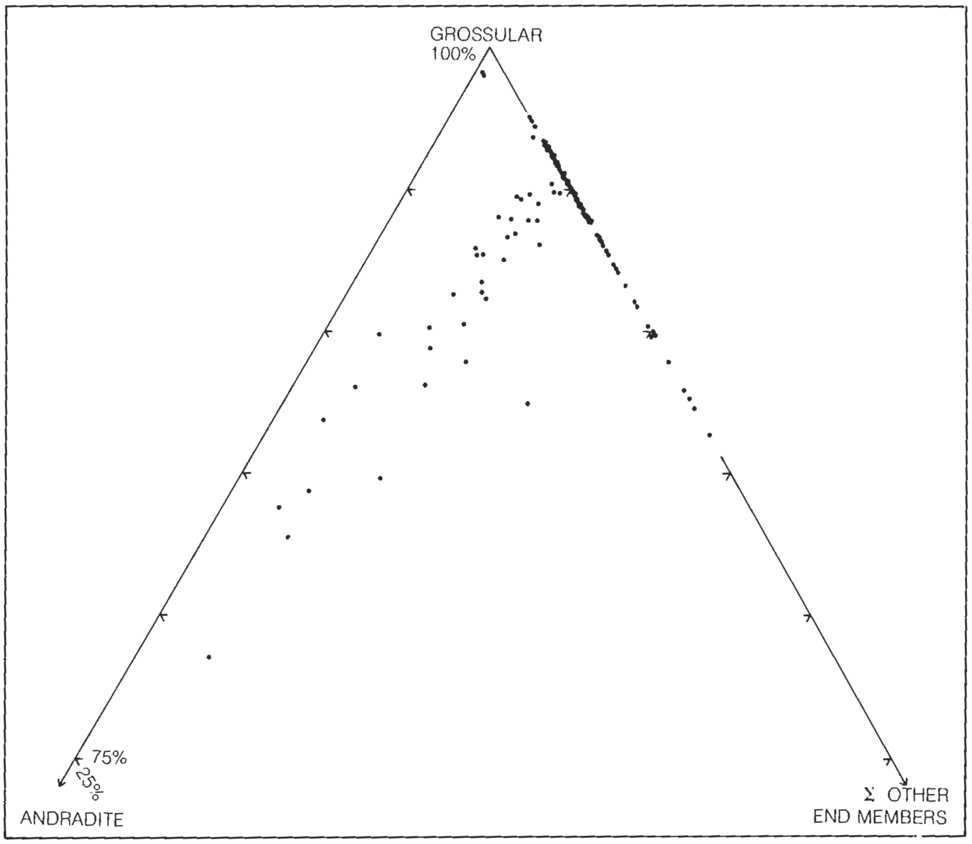
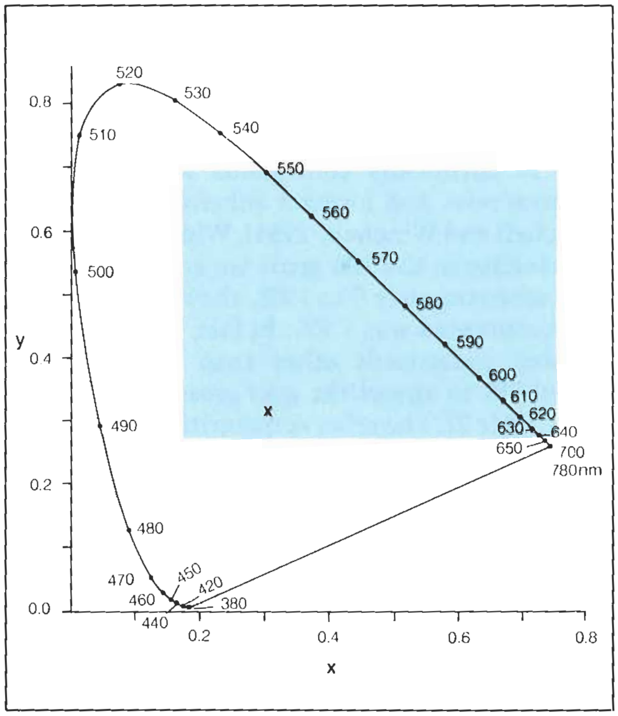


Figure 5. Points for the 105 grossulars plotted on a ternary diagram that displays the relationship between grossular, andradite, and the sum of the remaining end-member components. Grossular is clearly the dominant component among these garnets.

yellow and orange to a vivid red-orange at the other extreme. As the hue changes toward one of the extremes, the saturation increases. Each trend can be roughly represented by a curved line (figure 8). The change in color, corresponding to the changes in both hue and saturation, can then be measured as a percentage of the distance along the respective trend line.

To determine the relationships among the nine oxides present in these garnets, we used the statistical method of factor analysis as described earlier by Manson and Stockton (1981). This analysis of the oxide components for all 105 grossulars revealed the three important clusterings presented in table 3. (We used the original oxide figures from our microprobe analyses in order to avoid any bias that might have been introduced in our calculation of end members.) Factor 1 interprets as the basic grossular component, which is almost invariably accompanied by small amounts of pyrope (less than 2.20%), spessartine (less than 3.15%), and schorlomite (less than 2.15%). Factor 2 expresses the correlation between vanadium (V_2O_3) and chromium (Cr_2O_3) end-member components, and factor 3 is essentially an iron component that appears principally as Fe_2O_3, or

Figure 6. The CIE chromaticity diagram with an indication of the region reproduced in figure 7. X indicates the coordinates for colorless or neutral grey.



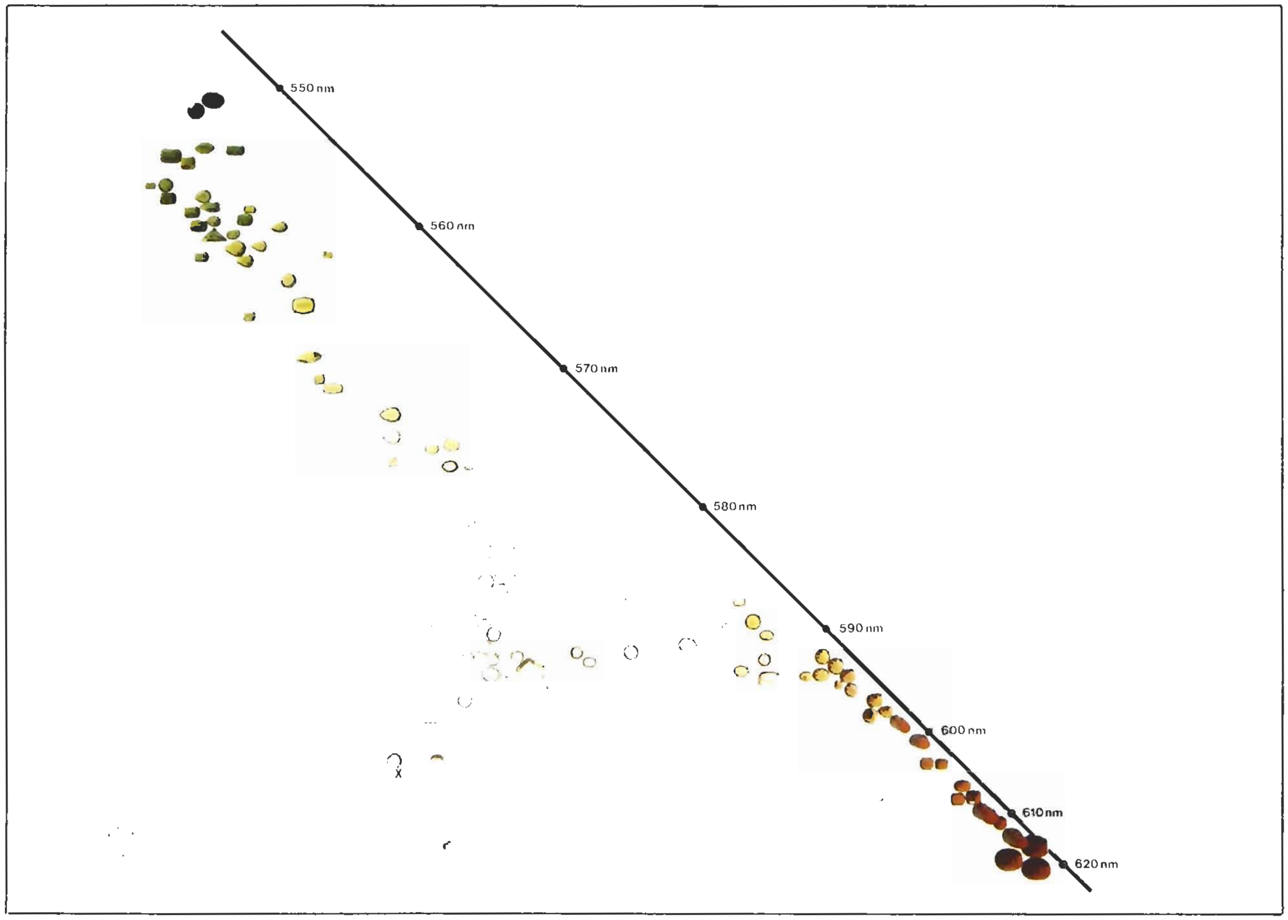


Figure 7. The green-through-orange region of the CIE chromaticity diagram with the 105 garnets positioned according to their x-y coordinates.

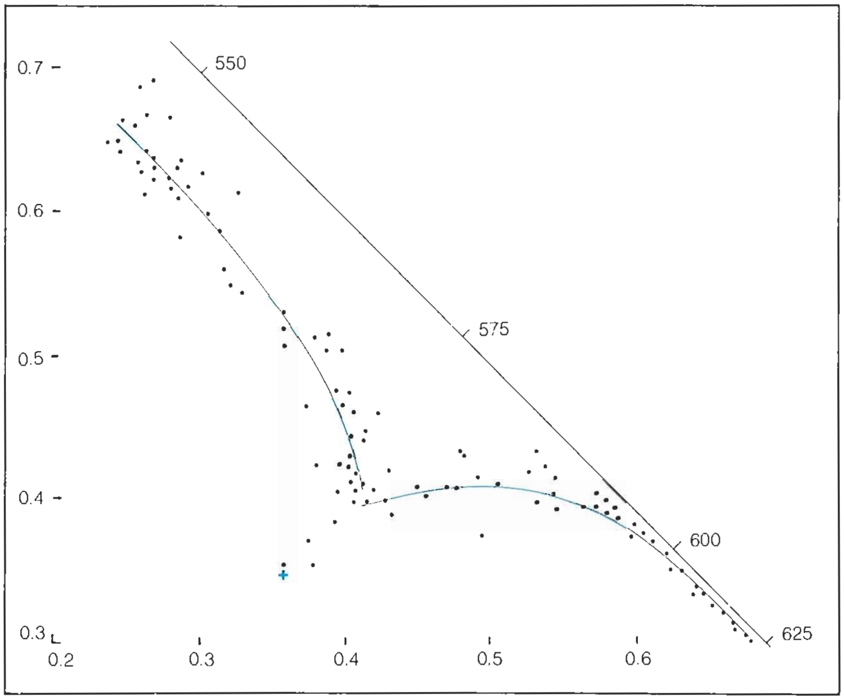


Figure 8. The green-through-orange region of the CIE chromaticity diagram with the color trend lines used to approximate changes in color of the 105 grossulars.

andradite. Factors 2 and 3 become especially significant when we compare the oxides that they represent with the two color trends in grossulars.

Specifically, the measure of color change described above can be plotted against the quantities of the color-related oxides as identified by our factor analysis. Figure 9 shows that there is a direct relationship between the amount of V_2O_3 in a stone and increasing green, but there is no correlation between V_2O_3 and yellow and orange grossulars. Cr_2O_3 (figure 10) behaves remarkably like V_2O_3, although in smaller quantities (only two stones with more than 30% green contained no chromium). This suggests that generally the V_2O_3:Cr_2O_3 ratio in green grossulars is considerably greater than 1:1 but that both vanadium and chromium are usually responsible for the green in grossular garnets. A similar relationship between V^{3+} and Cr^{3+} has been observed by Switzer (1974) and by Amthauer (1975). An exception to this relationship between vanadium, chromium, and green coloration apparently exists in grossulars that are colored principally or solely by Cr_2O_3 (Amthauer, 1976; Wight and Grice, 1982). We have not yet had the opportunity to examine any such material and so have no idea how the green of these stones compares to that of the gems in our study.

By examining how the quantities of FeO and Fe_2O_3 calculated by our end-member program behave with respect to changes in color, we can in-

TABLE 3. Factor analysis of the oxides present in the 105 garnets studied.

Oxide	Factors		
	1	2	3
SiO_2	+++		+
TiO_2	+++	−	−
Al_2O_3	+++		
V_2O_3		+++	
Cr_2O_3		+++	
MgO	+++	+	−−
CaO	+++		+
MnO	++	++	
FeO			+++

+++ *strong positive correlation*
++ *moderate positive correlation*
+ *weak positive correlation*
−− *moderate negative correlation*
− *weak negative correlation*

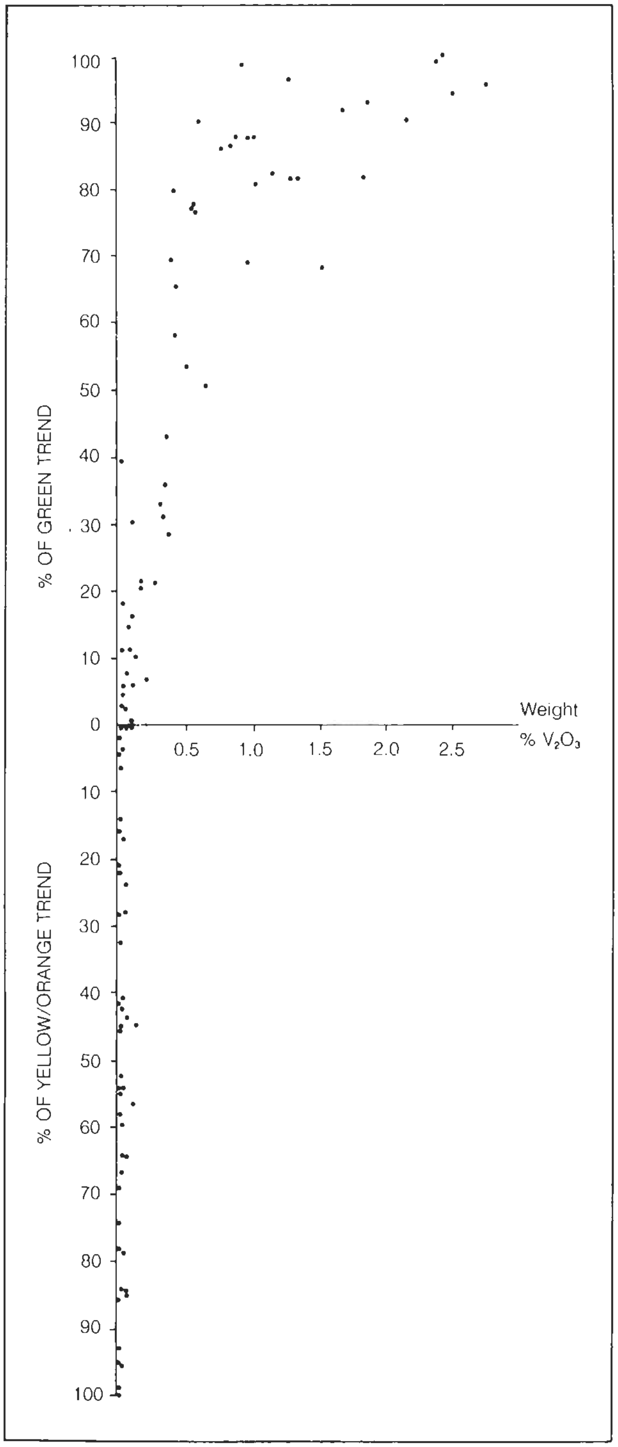


Figure 9. A comparison of the weight percentages of V_2O_3 in the 105 garnets with their respective positions along the color trend lines illustrated in figure 8. V_2O_3 shows a definite increase with respect to increasing green trend.

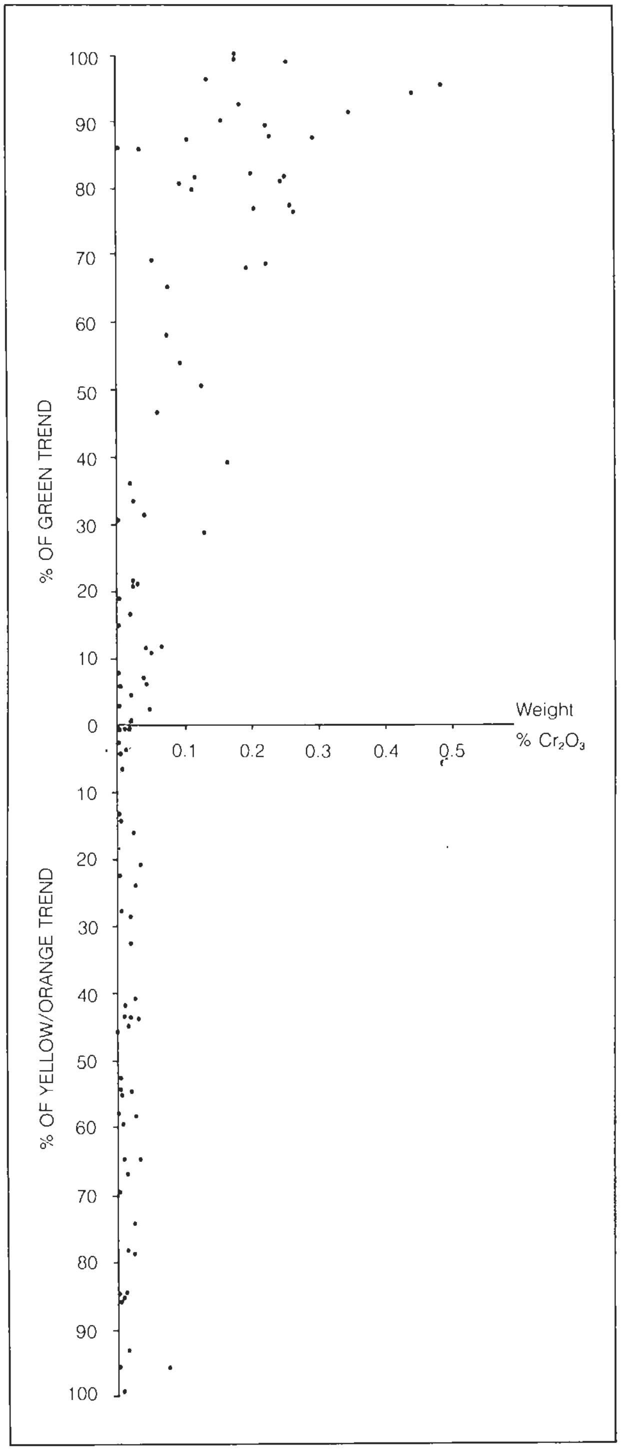


Figure 10. Weight percentage of Cr_2O_3 compared with changes along the color trend lines. Cr_2O_3 increases with the green trend here in much the same way as V_2O_3 does in figure 8. (Caution must be taken to consider the different scales along the x-axis in figures 9–12.)

fer in which valence state (Fe^{2+} or Fe^{3+})* iron is affecting color in grossulars. Figure 11 shows that the amount of Fe_2O_3 clearly increases with the change of color through yellow and orange to red-orange and decreases as green increases. While FeO is conspicuously absent from the green grossulars (figure 12), its role in the color of yellow and orange grossulars remains ambiguous. In order to resolve this question, determination of the valence states of iron in yellow and orange grossulars by means more accurate than stoichiometric calculation is required. In fact, numerous such studies have been performed on the roles of Fe^{2+} and Fe^{3+} in grossular (e.g., Amthauer, 1975; Manning, 1972 and 1973). These have supported the relationship we found between yellow and orange grossular and Fe^{3+}. A study by Manning and Tricker (1977) confirmed the role of Fe^{3+} in this context.

CONCLUSIONS

The gem species grossular presents few problems in description or identification. All of the gems we examined in this study contain more than 70% of the component $Ca_3Al_2Si_3O_{12}$, considerably more than the 50% required to assign them to a gem species. Mineralogical evidence based on non-gem-quality material has shown that there is indeed a continuous chemical series between grossular, andradite, and uvarovite, but the grossulars examined in this study suggest that there is a gap in this series with regard to gem-quality grossular garnets. Until we receive evidence to the contrary, then, we can regard gem grossulars as discrete with respect to any other gem garnet species. Gem grossulars have been observed in this study to possess refractive indices from 1.731 to 1.754 and specific gravities of 3.57 to 3.67. The hand spectroscope revealed no characteristic absorption bands for the 105 grossulars examined, in support of past observations.

Considering the effect that the application of varietal names has on the appreciation of gemstones, the precise definition of gem varieties is of some importance. The two gem varieties of grossular, hessonite and tsavorite, lack such def-

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** Fe^{2+} is the valence state of iron in FeO; Fe^{3+} is the valence state of iron in Fe_2O_3.*

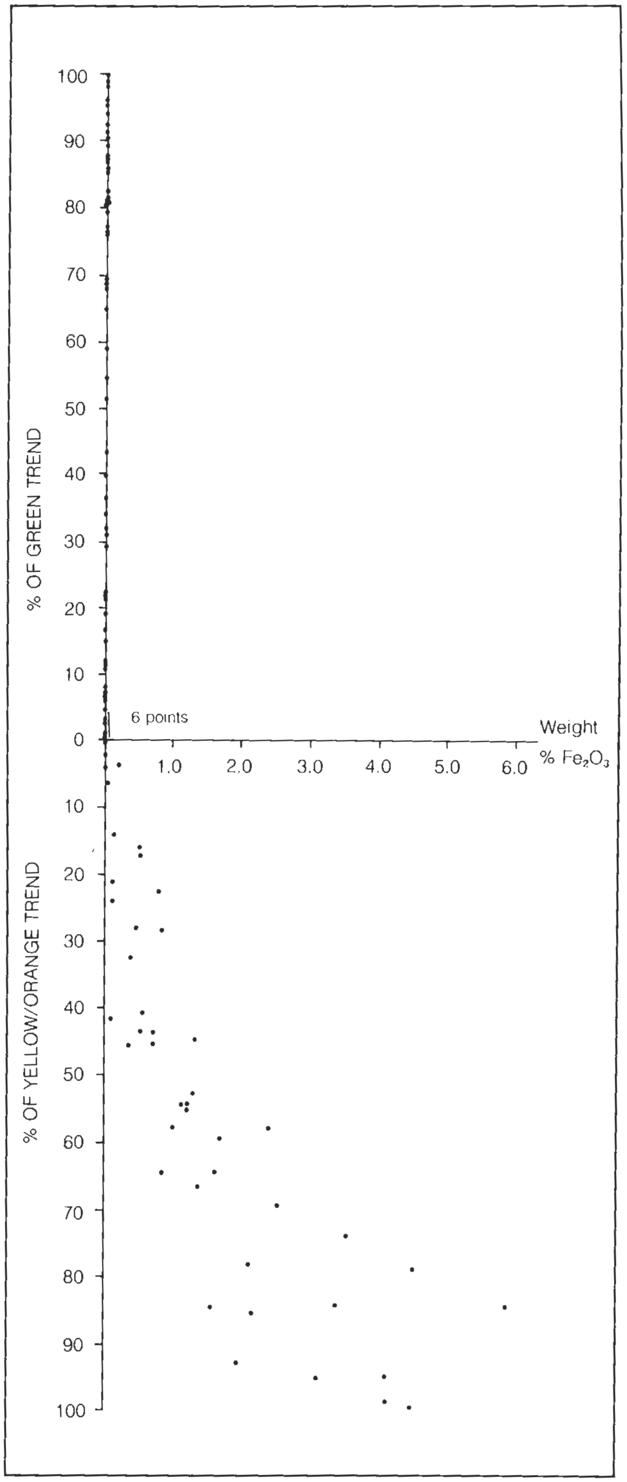

Figure 11. Weight percentage of Fe_2O_3 as determined by the end-member calculations compared to changes along the color trend lines for the 105 grossulars. Fe_2O_3 increases with the increase along the yellow/orange trend line.

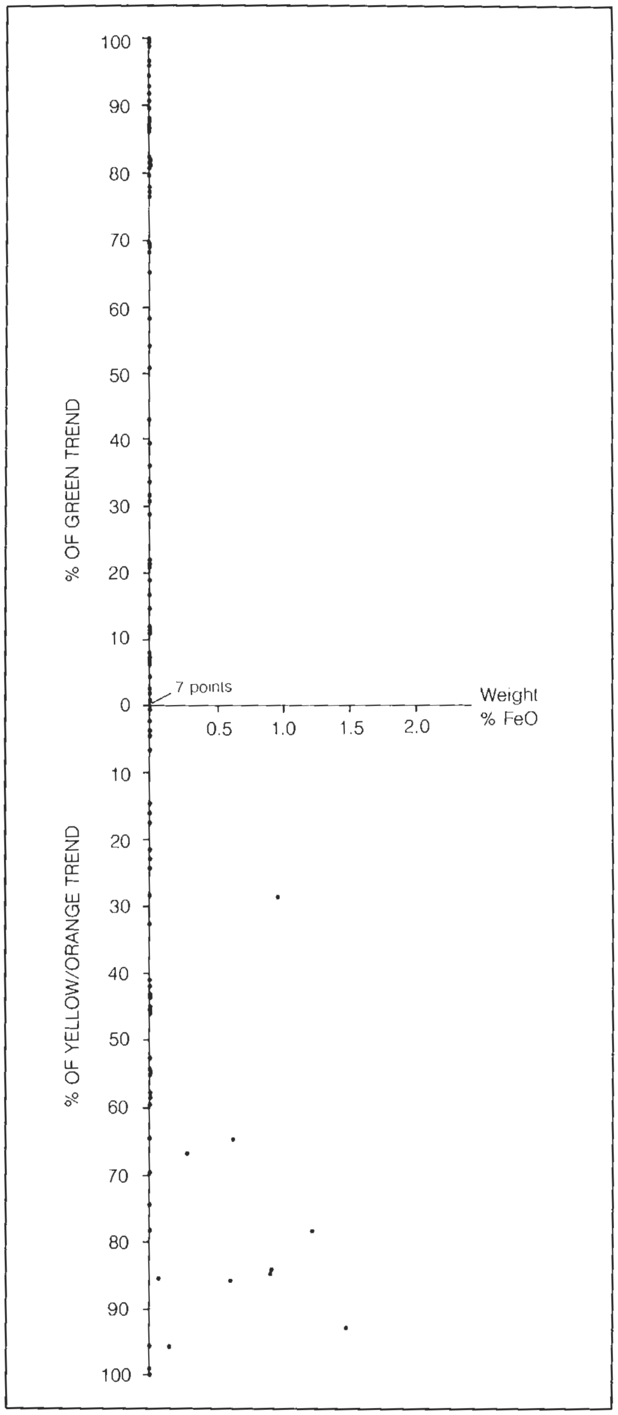

Figure 12. Weight percentage of FeO as determined by the end-member calculations compared with changes along the color trend lines. While FeO is present only in some stones located along the yellow/orange color trend line, no clear-cut correlation can be observed between changing yellow/orange color and the amount of FeO present.

inition, as do most varieties in gemology. In the case of grossular, we have been able to observe a correlation between color and certain chemical elements that strongly supports the use of varietal distinctions. However, as with red and violet garnets, including rhodolite, the causes of color are not always so readily determined. Before we can define any varieties of garnets, therefore, we must review all the variables related to the varietal classification of gem garnets in order to formulate general rules that can be applied uniformly across the group. The concluding paper of the garnet project will include our recommendations for the precise definition of the gem varieties hessonite and tsavorite.

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NOTES
· AND ·
NEW TECHNIQUES

ARTISTRY IN ROCK CRYSTAL: THE VAN PELT COLLECTION

By John Sinkankas

Harold and Erica Van Pelt of Los Angeles are known worldwide for their superb color photography of gems and minerals. A well-kept secret, however, has been their remarkable proficiency in the lapidary arts, specifically in the production in traditional styles of many important rock crystal objects, including candlesticks, vases, paperweights, and polished quartz crystals containing various mineral inclusions. Agate, amethyst, and other gemstones are also employed. For the most part, the machinery used to create these objects was designed or modified by the Van Pelts themselves and includes devices for sawing, grinding, and polishing. A step-by-step procedure for making a hollow ostrich egg, completely covered by triangular facets, is explained.

The purest form of quartz, known as rock crystal, is one of the most abundant and widely distributed of all minerals. Relatively few places, however, provide clear crystals large enough for lapidary work of the scale covered in this article; currently, Brazil is the primary source of large pieces of gem quality. This fascinating substance was used by the ancient Egyptians, Chinese, Japanese, and by many cultures around the Mediterranean. Marvelous carvings were made from it by pre-Columbian Indians of the Americas.

In later years, large crystals found in the Alps enabled Renaissance lapidaries such as the celebrated Miseroni family of Florence (late 16th century-17th century) to create outstanding works of art as urns, vases, bowls, cups, and figurines. These were often engraved with scenes and figures in shallow relief. Many were complemented by precious-metal attachments and joints on which were expended the best efforts of master enamelists and jewelers (Michel, 1960). Examples of such masterpieces can be seen in most major art museums, notably the Metropolitan Museum in New York, the Victoria and Albert in London, the Green Vaults in Dresden, and the Residenz in Munich (Strohmer, 1947; Rossi, 1954; Morassi, 1963; Menzhausen, 1968).

Because of the enormous amount of labor required to work rock crystal, fewer objects were made from it as subsidies from European royal houses gradually fell away. Despite the availability of suitable rough, only the Chinese continued to produce large carvings into modern times, although smaller objects of rock crystal—such as spheres, seals, figurines, and the like—were made by the artisans of the Urals in Russia, the famous carvers of Idar-Oberstein in Germany, and elsewhere in the Orient and in Europe.

ABOUT THE AUTHOR

Dr. Sinkankas is a retired naval officer and author of numerous books and articles on lapidary work, mineralogy, and collecting.

Figure 1. The Van Pelt quartz egg measures 5 in. (12.7 cm) high × 3 in. (7.6 cm) in diameter. The top has 176 facets, and the bottom 240. The walls of this hollow egg are 3 mm thick. Photo © 1982 Harold and Erica Van Pelt, Los Angeles, CA.

In part, the decline in carving large objects from rock crystal may be attributed to the appearance of high-quality glass, a much softer and far more easily worked material. Much of the initial shaping labor required to "rough out" a rock crystal urn, for example, is completely eliminated in glass manufacture, where the approximate shape of the finished object can be obtained directly from molten glass. Furthermore, after suitable surface treatment, such as engraving or grooving, a finished object in colorless glass is scarcely distinguishable by the casual glance from its more precious counterpart in rock crystal.

Thus it is news indeed to find a resurgence of traditional rock crystal lapidary work taking place in a modest workshop in Los Angeles by the team of professional photographers, Harold and Erica Van Pelt. Both are known worldwide for their skill in realistically and artistically portraying gems and minerals, as seen on the pages and covers of *Gems & Gemology* and many other journals and books. This article examines the origins of the Van Pelts' interest in carving and faceting gemstones, and, specifically, the techniques they use to create fine, large objects such as the hollow egg in figure 1 from rock crystal.

FROM PHOTOGRAPHERS TO LAPIDARIES

The Van Pelts' interest in minerals and gems was aroused in the late 1960s, when they were first persuaded to try their hands at photographing mineral specimens. Years of experience in the photography of art objects of all kinds, including sculptures, which are notoriously difficult to photograph well, aided their early success in depicting mineral specimens and faceted stones.

This interest in minerals led to the accumulation of specimens for themselves, and eventually the desire to create from gem materials

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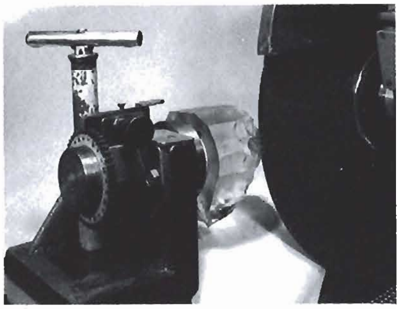

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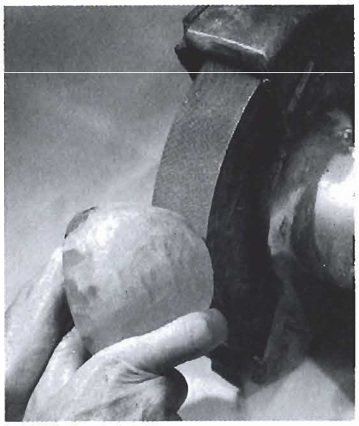

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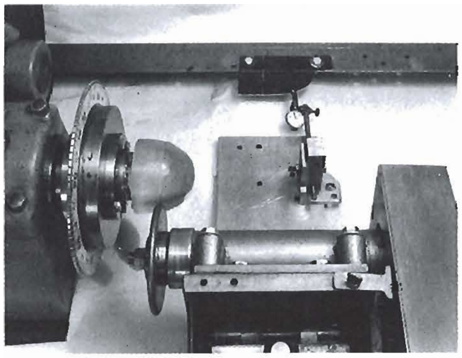

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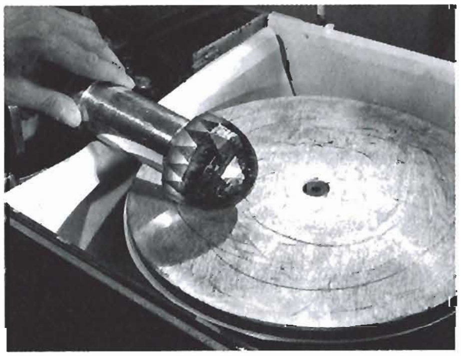

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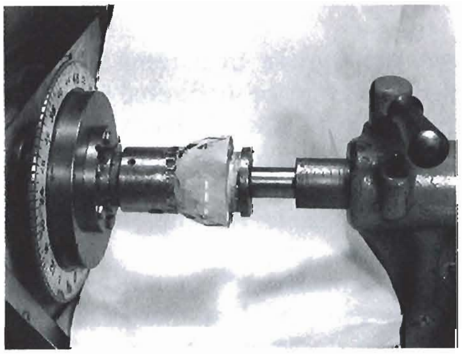

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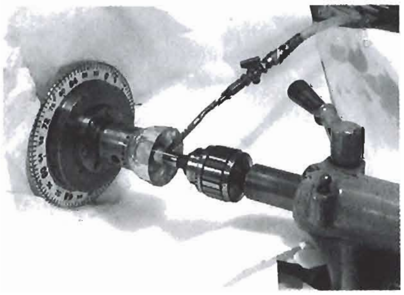

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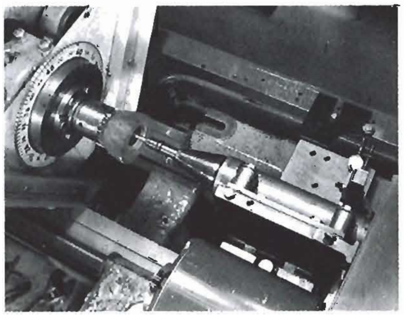

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Figure 2. The procedure used to fashion the faceted hollow quartz egg. (A) The sawed block of rock crystal with cross-section profile marked and dop attached with epoxy. Note the cardboard strips, which raise the dop enough to permit ingress of a hacksaw blade when later transfer takes place. (B) The rock crystal block is mounted in a rotatable tool for sawing off strips to achieve an approximate cylindrical profile. The index gear at left allows rotation by an equal number of degrees for each cut made by the diamond blade at right. (C) After the initial sawing, the rough profile is ground in by hand against the diamond-charged Crystalite turbine wheel shown at right. (D) Accurate profiling is accomplished using a Crystalite grinding wheel, ¼ in. × 4 in. radius (foreground), adjusted to the profile template shown in the background. (E) The marks left by the profiling operation are ground out using an 8 in. Crystalite 220-mesh diamond wheel. Great care must be taken not to overgrind. This step establishes the basic reference surface for faceting. (F) The facets are ground using a large, home-designed machine with a Crystalite 8 in., 100-mesh diamond disc. The diagrams on the wall show the positions and inclinations of the facets, which gradually decrease in size toward the tip of the egg. (G) The facets are prepolished on a wood lap, using Crystalite 15-micron diamond compound with Crystalube for lubricant. (H) The stone is turned around using the lathe to provide alignment. The old dop is on the right and the new dop is on the left. (I) The old dop has now been removed, and the first drilling with a Crystalite ¾ in. core drill is in progress (note the oil-coolant feed pipe). The narrow core is knocked out later to leave a cylindrical recess. This step is followed by two other core drillings, each of larger diameter. (J) The rough interior is now cut by the use of a suitable diamond wheel attached to the post at right, while the egg itself is slowly rotated at the left. (K) The interlocking rim recess is machined before the egg is removed from the lathe. A series of felt wheels charged with cerium oxide provide the final polish.

something that would be artistically satisfying yet different from the usual projects undertaken by beginning lapidaries. Their experience in the art world suggested a revival of the art of carving large objects from rock crystal and other hard and compact gem materials. Using *Gem Cutting* (Sinkankas, 1962) as a guide, they made or modified as necessary the machinery needed to solve the problems of rapid, safe removal of unwanted material and at the same time insure geometrical accuracy in the finished work. Among their modifications and alterations are a slab saw for blocking out rough, fitted with clamps and adjustment devices to hold the stone at preset angles; a smaller "trim saw" with a unique raising platform to regulate depth of cut; an arbor with grinding wheel attachments and special elongated shaft extensions to hold grinding, smoothing, and polishing wheels and points; a drill press for coring and hollowing; a lathe for turning round sections; a lap for flattening large plane areas; and a very large, strong, faceting head to apply facets to large objects.

One of the most intriguing rock crystal objects made by the Van Pelts is the ostrich egg in two halves shown in figure 1 and on the cover of this issue. Each of the halves is accurately faceted to provide exterior surfaces entirely covered by small, polished triangles. The smoothly rounded interior is hollowed out to very thin walls, and the halves interlock by means of machined recesses along their rims. It is truly a masterpiece of design and creativity. The closed egg is 5 in. (13 cm) tall and 3 in. (7.7 cm) wide, and the walls are about 3 mm thick. The procedure for making the egg is briefly explained below to show the lapidary problems involved and how they were solved.

FASHIONING THE HOLLOW EGG

The first step was to saw an almost flawless piece of rock crystal in half, one half for each half of the egg. One of the halves was then attached with epoxy to the dop shown in figure 2A. Three spacer strips of cardboard were used to raise the quartz slightly above the dop to allow ingress of a hacksaw blade for later removal of the dop. The dopped block was then inserted into the special device shown in figure 2B; this, in turn, was locked into the feed carriage of the slabbing saw to make the cuts shown in the photograph. After each cut, the block was rotated a like number of degrees to a new position to achieve a rough circular outline.

In the next step, the quartz block was held against a diamond-charged wheel, shown in the background of figure 2C, until the desired shape was achieved. Then, as shown in figure 2D, the block was slowly rotated in the lathe head at the left while being ground with the round-nose diamond wheel in the foreground. The in-movement of the grinding wheel was regulated by the template in the background to insure an accurate profile. Another hand-grinding operation followed to remove the excess material between the grooves, as shown in figure 2E, and to establish the final surface for faceting.

The dopped stone was next inserted into the faceting machine in figure 2F for cutting the numerous facets according to the plans seen here on the wall charts, which detail the steps, the angles between them, and the peripheral arrangement of the facets. After cutting, the facets were polished on the wood lap shown in figure 2G. The stone was now ready for turn-around and hollowing.

Figure 2H shows the redopping procedure, in which the lathe itself was used as an accurate axial alignment tool. The new dop at the left is a tube of metal which was bonded to the stone with epoxy. The tube has teeth cut into its edge which allows the epoxy solvent better access when the dop must be removed from the stone. Alternate teeth are covered with tape to prevent direct and possibly damaging contact of tube and stone. The first dop, on the right, was removed and the egg-half positioned for the initial hollowing operation, as shown in figure 2I. Here a hollow diamond-charged drill was used to cut a core to suitable depth, with care being taken to insure that the cut was not made too deep. The slender core was then knocked out and a large core drill substituted to remove further material; the process was subsequently repeated once more using a still larger core drill.

The roughly hollowed recess was then ground smooth with a diamond wheel set off-center as shown in figure 2J, again using an internal template, visible here in the background on the right. This template helps the cutter maintain uniform thickness and parallelism of the curved walls. Because of the limited availability of grinding wheels that could accommodate the gradually changing curvature of the inside, it was necessary to hand-finish the interior as shown in figure 2K. For this step, a resilient drum, covered by diamond-coated cloth, was brought into play. Other drums of different shapes were used to methodically smooth the interior and were followed by polishing wheels made of felt and charged with a slurry of cerium oxide. Note also in figure 2K that the interlocking rim previously mentioned has been machined in place; it was later smoothed and then fitted with a metal, gold-plated rim cemented in place with epoxy resin.

If all of this seems difficult and tedious, be assured that it is. As each thin-walled creation neared completion, the mechanical problems were further burdened by the constant dread that one slip would ruin the work and nullify hours and hours of labor. A decided advantage of hand-holding the object during the last stages of smoothing and polishing is that build-up of excessive and possibly damaging heat can be detected and counteracted quickly.

SOME NOTES ON OTHER VAN PELT PIECES

A few words of explanation are in order in connection with other objects made by the Van Pelts, such as those shown in figures 3 and 4. As a matter of convenience and safety, it is often better to make vases and urns from several sections of quartz, with the faceted or fluted sections mated by peg-and-socket joints machined into the pieces themselves and finally cemented with colorless epoxy. Joints of this kind may be covered with gold bands as shown in the slender vases of figure 3, where the separate segments have been individually faceted. On the other hand, the goblet shown in figure 4 has had its smoothly curved flutes cut into the rock crystal by hand. For the most part, the Van Pelts now do their own metalwork, gem setting, and plating. Other objects made by the Van Pelts include spoons fashioned from colorful Uruguyan agate, a series of paperweights

Figure 3. Rock crystal vases measuring 10½ in. (26.6 cm) high × 3 in. (7.6 cm) in diameter at the top and 3½ in. (8.8 cm) in diameter at the base. Each vase has six sides and 96 facets. The tops of the covers are made of pink tourmaline and green tourmaline, respectively. Photo © 1982 Harold and Erica Van Pelt, Los Angeles, CA.

Figure 4. Rock crystal vase measuring 4½ in. (11.4 cm) high × 3¼ in. (8 cm) in diameter. There are 24 flutes on the body and the base. The natural quartz crystal in the background, from Arkansas, is representative of the material used for fine pieces such as this. Photo © 1982 Harold and Erica Van Pelt, Los Angeles, CA.

made from rock crystal, agate and petrified wood, also pill boxes and other types of small containers.

While the production of these objects is a severe test of patience and skill, the Van Pelts are emphatic in pointing out that the greatest initial difficulty is in finding suitable rough. Large masses of rock crystal and some other gem materials are available, to be sure, but careful examination usually shows that most are unsatisfactory, containing either too many flaws in critical areas, or, far worse, fractures that could lead to disintegration before a piece is finished. The scarcity of large rough insures that few rock crystal masterpieces will ever be made. The Van Pelt creations, none of which has ever been sold, are unique in today's lapidary community.

Editor's Note: The hollow quartz egg is currently on display at the GIA headquarters in Santa Monica, California. The vases shown here will, together with other pieces fashioned by the Van Pelts, be on display at the Tucson Gem and Mineral Show, February 10–13, 1983.

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GEM-QUALITY FRIEDELITE FROM THE KALAHARI MANGANESE FIELD NEAR KURUMAN, SOUTH AFRICA

By Herbert S. Pienaar

Gem-quality friedelite was discovered by chance during shaft-sinking operations in a new, deep manganese mine near Kuruman. This article reports on the general geology and mineralization of the friedelite, speculates on the age and origin of the deposit, and describes the gemological properties of this material.

The comparatively rare mineral friedelite was first reported in 1876 by Bertrand. This occurrence was in the manganese mine at Adervielle, in the Vallée du Luron of the Hautes Pyrénées, France. The mineral was named in honor of Charles Friedel, the French chemist and mineralogist.

Since then, friedelite has been recorded as occurring sporadically in other manganese silicate deposits worldwide, including the Hartig mine near Pajsberg, Sweden (Lindström, 1891); the Sjö mine near Örebro, Sweden (Ingelström, 1891); the mines near Veitsch, Austria (Hoffmann and Slavik, 1909); the Buckwheat mine and Parker shaft, Franklin Furnace, Sussex County, New Jersey (Palache, 1910); the Taylor mine, Franklin Furnace, and the mines at Sterling Hill, Sussex County, New Jersey (Palache, 1935); the Fe-Mn deposits at Dshumart and Kamya, Central Kazahkstan, U.S.S.R. (Kuyapova, 1960); and the deposits of the Atasui region of Central Kazahkstan (Kuyapova, 1968).

It appears that only the occurrences at Franklin Furnace and Sterling Hill have produced gem-quality friedelite (Sinkankas, 1959; Sinkankas, 1962; Arem, 1977; Webster, 1978). The suitability of this comparatively rare mineral for gem cutting has been mentioned by Sinkankas (1968), Vargas (1969), and Vargas (1979).

In November 1980, a little more than 100 years after its original discovery, a new occurrence of gem-quality friedelite was discovered, at the Kalahari manganese field in the Republic of South Africa. A brief description of the mineralization of this rare gem material and the circumstances that led to its discovery is presented here.

MINERALIZATION

The friedelite was found during shaft-sinking operations at the Middelplaats mine in the Kalahari manganese field, near Kuruman, northern Cape Province, Republic of South Africa (figure 1). It is associated with the lower manganese ore zone indicated in figure 2. The ore itself is a fine-grained mudstone into which the ore mineral, braunite, is incorporated in a highly disseminated state (Middelplaats Manganese Ltd., 1981).

Koekemoer, a mineral dealer, relying on information supplied by the miners who removed the friedelite from the shaft, originally placed the occurrence in the upper portion of the 25-m-thick ore zone at a depth of about 395 m below the surface and a distance of about 75 m from the main shaft (personal communication, 1981). Subsequent follow-up investigations by Zaayman, the resident mine geologist, placed the friedelite locality at the base of the lower ore body near the old ventilation shaft. Unfortunately, the precise underground position could not be determined, inasmuch as that portion of the mine, once it was worked out, had been converted into maintenance workshops and all the rock faces covered by "shotcrete," a cement aggregate applied at high pressure. Nevertheless, small fragments of friedelite were subsequently found in this vicinity (Zaayman, personal communication, 1982).

On the basis of information received from the miners, it is estimated that originally two to three tons of low-grade manganese ore were collected, from which about 100 kg of friedelite (then thought to be a variety of rhodochrosite) and gan-

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ABOUT THE AUTHOR

Mr. Pienaar is lecturer in gemology at the De Beers Laboratory, University of Stellenbosch, Republic of South Africa.

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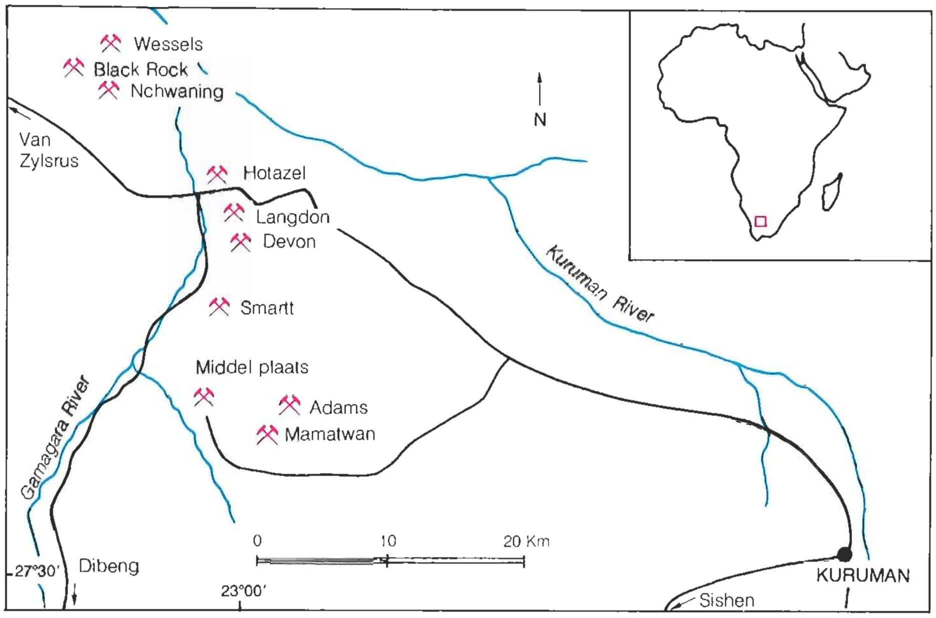
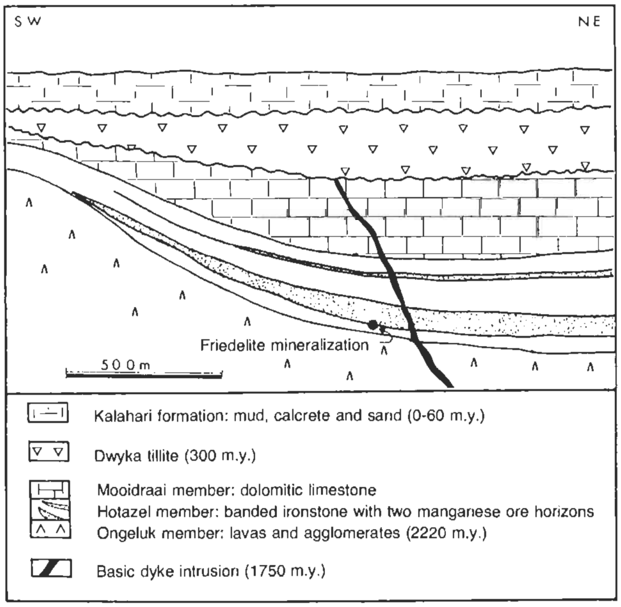


Figure 1. Locality map of mines in the Kalahari manganese field, Republic of South Africa.

gue were later separated. According to the miners, the friedelite occurred in three discrete, near-horizontal veins within the low-grade manganiferous ironstone. As seen in large hand specimens, two of these "veins" have a thickness of about 10 mm and contain the pure cryptocrystalline friedelite; the third is about 35 mm thick and is criss-crossed by veinlets of carbonate-rich minerals, which give it a composite, matrix-like appearance.

Figure 2. Generalized section through the Middelplaats manganese mine, modified after Middelplaats Manganese Ltd. Report (1981). Vertical scale exaggerated.



The friedelite mineralization tends to follow the general bedding of the sediments, with a slight cross-cutting relationship in places. Consequently, the origin of the friedelite occurrence is not clear. It could be metasomatic and associated with the nearby 1750-m.y.-old basic dykes, or it could be the metamorphic product of a discrete layer within the original banded ironstone formation. It is, however, definitely younger than the 2220-m.y.-old Ongeluk volcanic rocks onto which the banded ironstone formation was deposited.

GENERAL GEMOLOGICAL DESCRIPTION

Two forms of gem-quality friedelite have been found. The one is evenly colored and translucent, and has a rose red to carmine red appearance (figure 3). The other form is also predominantly rose red to carmine red, but it is streaked by pink and white veinlets of rhodochrosite and other carbonate minerals. It is referred to here as matrix friedelite (figure 4).

Ideally, the chemical composition of friedelite is $Mn_8Si_6O_{15}(OH,Cl)_{10}$. However, according to the accompanying electron probe analysis by D. H. Cornell of the Department of Geology, University of Stellenbosch, the friedelite from this occurrence has some of the manganese replaced isomorphously by iron and magnesium (table 1).

Thus far, no discrete crystals have been found in this locality. All the material examined was cryptocrystalline and optically anisotropic; it produced a typical aggregate reaction when exam-

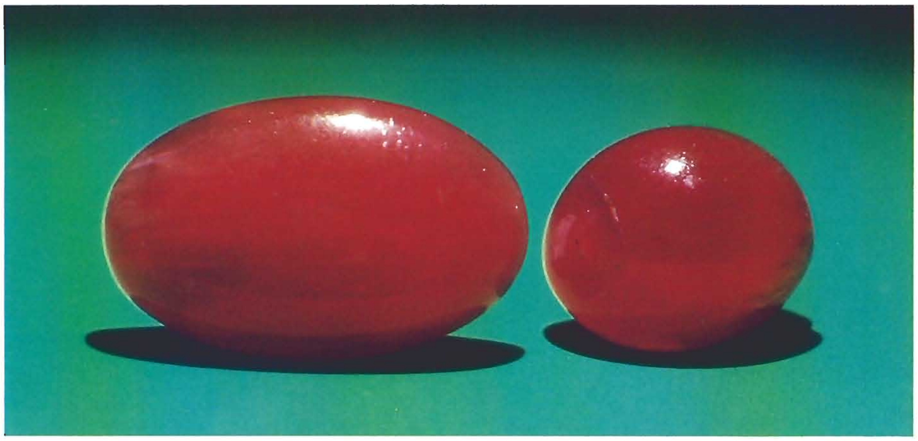


Figure 3. Cryptocrystalline friedelite cabochons, 16 × 10.1 mm (5.42 ct) and 10.4 × 8.8 mm (3.83 ct). Photo by Tino Hammid.

ined under crossed polarizing filters. However, the X-ray diffraction powder pattern for this material agrees well with that published by Frondel and Bauer (1953) for friedelite and which they placed in the trigonal crystallographic system.

Refractive index determinations using immersion techniques gave values of $\omega = 1.657$ and $\epsilon = 1.630$. However, measurements made on a standard gemological refractometer result in a general single value of 1.64. Moreover, some gems do display "form birefringence" (Webster, 1978, p. 189) and show two distinct shadow edges, which can be separated in the usual way by a polarizing filter. The "form birefringence" values determined on 10 examples with flat facets varied from 0.005 to 0.020, usually symmetrically placed around the mean value of 1.64.

An examination of oriented petrographic thin sections revealed that the friedelite crystallites are spindle-shaped, with their long axes more-or-less coinciding with the crystallographic c-axis. The vein-like infill is such that the spindles tend to be oriented preferentially at right angles to the plane of the bedding of the rock in which the friedelite occurs. Refractive index measurements made on polished sections oriented first parallel and then perpendicular to the plane containing the "vein" gave values of 1.64 and 1.63–1.65 respectively.

The luster on freshly broken surfaces is waxy to dull. On polished surfaces, however, it is vitreous. Polished cabochons are translucent to semitranslucent.

None of the samples of friedelite examined displayed fluorescence when exposed to long-wave ultraviolet (365 nm), short-wave ultraviolet (254 nm), or X-rays.

On the hand spectroscope, the absorption spectrum shows a clear absorption band from 535 to 595 nm, with a general absorption from 400 to 480 nm. This absorption pattern is persistent and was observed in all specimens tested. Furthermore, as may be concluded from its absorption spectrum, friedelite has a vivid red appearance when observed through a Chelsea dichroic filter.

Other physical properties include hardness, which falls between 4½ and 5 on the Mohs scale; relative density for the pure material, which is 3.066 ± 0.003, with a slight increase up to 3.11 for matrix samples; fracture, which is even to semigranular; structure, which is massive; and toughness, which may be regarded as fair to good.

Although most of the examples of massive friedelite examined were free of any characteristic inclusions, some did show small white blebs of carbonate mineralization.

DISCUSSION

Friedelite, schallerite, and pyrosmalite form a group of minerals collectively referred to as the pyrosmalite group, with the general formula $(Mn,Fe)_8Si_6O_{15}(OH,Cl)_{10}$. Although these minerals are known to occur at times as single crystals, it is mainly the massive forms of friedelite that have been used for gem cutting.

Palache (1935) mentions a number of color varieties of friedelite occurring in the Franklin and Sterling Hill areas. These include the compact forms tinted brownish red, through the flesh-colored shades, to a "lively pink." By comparison, the friedelite from Middelplaats displays very little color variation and its reddish appearance is its main attraction. The Kazahkstan cryptocrystalline forms of friedelite described by Kuyapova in 1960 are reddish brown or a light somewhat greenish brown.

The cause of the color cannot be explained with any certainty. In broad terms, it may be as-

Figure 4. Matrix friedelite cabochon (28 × 14 mm).

sumed that friedelite is an idiochromatic mineral with compositional manganese as the principal colorant. Since the ferroan-friedelite described by Kuyapova (1968) is dark brown with an iron content of about 10% (reported as an oxide), and the pink friedelite described by Palache (1935) has a low iron content (±0.7% oxide), the lightness or darkness of the tonal quality of the reddish color could very well be associated with the amount of iron that has isomorphously replaced the manganese. It should be pointed out, however, that the pink friedelite is also described as being a low-chlorine friedelite and its unusual pink color could also be associated with the low chlorine content (±0.25%) reported by Palache in 1935.

The comparative rarity of friedelite is emphasized if one considers that this occurrence is the first to be reported in the Kalahari manganese field (which extends for about 500 km^2; see figure 2), that manganese ore has been mined in a number of mines during the past 25 years, that the present discovery is limited to the originally recovered 100 kg of friedelite and gangue, that the geologist at Middelplaats mine had great difficulty in relocating the mineralization and could only find tiny fragments of friedelite, that the method of underground mining at depths of 250 m and more is highly mechanized thereby minimizing in-situ discoveries, and that the friedelite mineralization did not occur in the present ore horizons.

To date, friedelite has been encountered as a gem only rarely, while neither schallerite nor pyrosmalite has ever been recorded as such. It is quite possible that these minerals do exist as gems, but because of their similarity in appearance and durability to reddish brown varieties of bowenite serpentine, they were misidentified as such. They do, however, display slightly higher values for their physical and optical properties.

TABLE 1. Electron microprobe analysis (in wt. %) of friedelite from the Kalahari manganese field.

SiO_2	35.82
Al_2O_3	0.06
MgO	1.43
FeO	1.29
MnO	52.33
CaO	—
TiO_2	—
K_2O	—
Na_2O	0.04
Cl	3.59
	94.56
O−Cl	− 0.81
	93.75
H_2O^+ (by difference)	6.25

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TOURMALINE AS AN INCLUSION IN ZAMBIAN EMERALDS

By John I. Koivula

This article reports the identification of tourmaline crystals as inclusions in emeralds from Zambia, in south-central Africa. To understand the paragenesis responsible for this unusual association, the geology of the area is reviewed. The gemological properties of these emeralds are also noted.

To date, a variety of interesting mineral inclusions have been reported in the emeralds from the deposits at Miku-Kafubu, in Zambia (Sinkankas, 1981). These include the micas biotite and phlogopite, rutile, and apatite. Recently, the author had the opportunity to study three rough emeralds and one faceted stone from this locality with inclusions that appeared to be tourmaline, a mineral that has been reported as inclusions in emeralds from the Urals in the Soviet Union and from the Habachtal mine in Austria (Sinkankas, 1981; Gübelin, 1974) but has not previously been noted as occurring in Zambian emeralds.

If the inclusions the author observed are in fact tourmaline, then a new paragenetic relationship could be established and a new species added to the list of known inclusions in Zambian emeralds. To this end, the geology of the area is reviewed and the inclusions themselves described in detail. Also, the gemological properties of these stones are compared to those previously reported for Zambian emeralds.

GENERAL GEOLOGY OF THE ZAMBIAN EMERALD AREA

The main emerald-producing area in Zambia comprises two deposits, Miku and Kafubu, which lie within a few kilometers of each other. This emerald field is located in the Kitwe district of northern Zambia, approximately 32 km southwest of Kitwe and 40 km west-northwest of Luanshya, near the entrance of the Miku River into the Kafubu River (Bank, 1974). Both Miku and Kafubu produce excellent, gem-quality emeralds; some crystals weigh well over 100 ct.

The two deposits are geologically similar. The emeralds are found in biotite-phlogopite schists in which dark brown to black tourmaline also occurs. Other rocks intimately associated with the emerald- and tourmaline-bearing mica schists are talc-magnetite schists and quartz-amphibolite-chlorite schists with secondary quartz veining (Bank, 1974; Sinkankas, 1981). It is thought that the chromium necessary to provide the trace-elemental coloration of the emerald was derived from magnetite in the talc-magnetite schists, as the magnetite in these rocks has been shown to contain a small percentage of chromium (Bank, 1974).

TOURMALINE AS AN INCLUSION

Because tourmaline is found throughout the schist host rock in direct association with the emeralds, it is not surprising to find tourmaline crystals as inclusions in the emeralds. The inclusions observed in the four specimens studied by the author are prismatic and, as is typical of tourmalines, striated parallel to the c-axis (see figure 1). They are transparent dark orangy brown in a strong transmitted light or on very thin edges, but generally they appear black and opaque. They occur up to 10 mm in length and 2 mm in diameter. Many are easily seen with the naked eye.

Surrounding the tourmalines are numerous tiny, whitish-appearing tension fractures that extend into the host emerald. Some of these, as illustrated in figure 1, are decorated with brownish

ABOUT THE AUTHOR

Mr. Koivula is the senior staff gemologist in the Gem Identification Department of the Gem Trade Laboratory, Inc., Santa Monica, California.

Acknowledgments: The author would like to express his sincere thanks to Julius Petsch for donating the emeralds with tourmaline inclusions for this study, and to Peter Keller for arranging the donation. A special thanks goes to Chuck Fryer for the X-ray diffraction work, to Roger Kuchek for his assistance in obtaining the ColorMaster notations, to Stephen Hofer for his consultation on the absorption spectra, and to William Kerr for faceting the large stone used in this study.

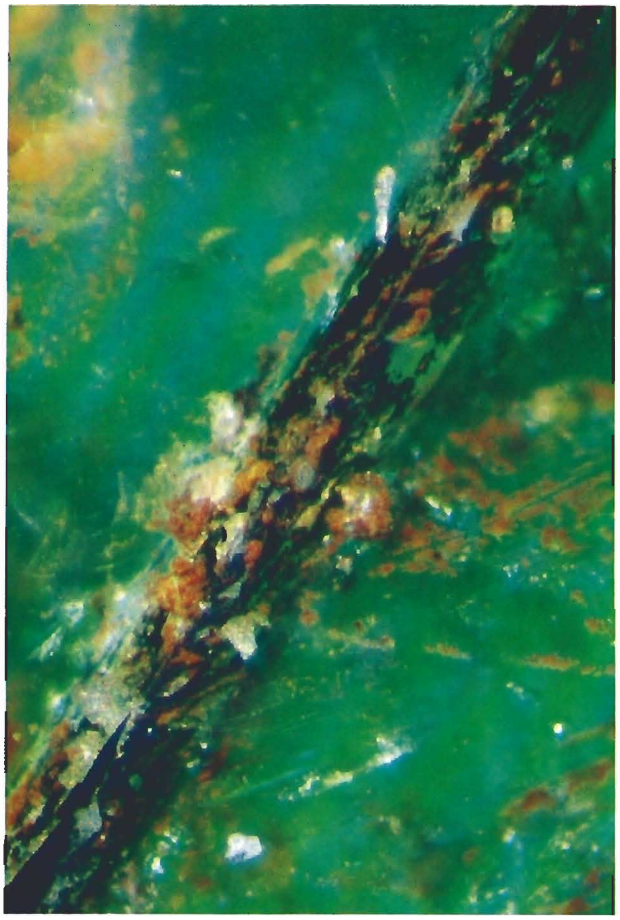

Figure 1. A black-appearing crystal of dravite tourmaline in a Zambian emerald is decorated by numerous small tension fractures, some of which are stained by limonite. This photomicrograph was taken using a combination of low-intensity transmitted light and oblique illumination, magnified 20×.

orange limonite. In cross section, as in figure 2, the tourmalines display typical trigonal or triangular outlines. No crystallographically dictated alignment was noted between the tourmaline inclusions and their host.

Noted gemologist Chuck Fryer scraped one of the inclusions that reached the surface and obtained enough powder for X-ray diffraction analysis. The inclusion was found to correspond to tourmaline in the schorl-dravite series, schorl having the chemical composition $Na(Fe,Mn)_3Al_6B_3Si_6O_{27}(OH,F)_4$ and dravite, $NaMg_3Al_6B_3Si_6O_{27}(OH,F)_4$. The diffraction pattern obtained matched dravite more closely than schorl, but a detailed chemical analysis would be necessary to conclusively place these tourmalines in their proper position in the schorl-dravite series.

Figure 2. Cross-sectional view of one of the dravite tourmaline inclusions breaking the surface of a rough crystal of Zambian emerald. Oblique illumination, magnified 50×.

GEMOLOGICAL PROPERTIES

One faceted and three rough emeralds were examined. The faceted stone was an emerald cut that weighed 0.91 ct, and the largest rough crystal section weighed 3.48 ct. The emeralds varied in color from a bluish green of medium intensity to a dark, intense bluish green.

Using the GEM ColorMaster, the color of the 0.91-ct faceted stone was dialed in as 00 red, 43 green, and 22 blue using the E modifier. This reading calculated as 0.230 x, 0.586 y, and 5.72 z for the coordinates on the CIE color chart, giving a very slight bluish green by CIE standards.

Refractive index and optic character were determined using a Duplex II refractometer and a sodium vapor light source. Refractive indices of $\epsilon = 1.581$ and $\omega = 1.588$ were noted, which gives an optic character and sign of uniaxial negative and a birefringence of 0.007.

The emeralds were studied for their visible light absorption characteristics using a Beck wavelength prism spectroscope and the GEM spectroscope unit. In the direction of the ordinary ray, parallel to the c-axis, sharp absorption lines could be seen at approximately 479 nm, 610 nm, 638 nm, and 670 nm, with a single, somewhat thicker band at approximately 682 nm.

A general absorption band was also noted between 580 nm and 610 nm. At 90° from the c-axis, only four distinct absorption lines were observed: 638 nm, 650 nm, 670 nm, and 690 nm. All of the absorption points in these emeralds can be correlated to known chromium absorption peaks (Sinkankas, 1981).

The emeralds showed no reaction to long-wave or short-wave ultraviolet radiation, or to X-radiation.

The specific gravity was hydrostatically determined for two of the emerald specimens. One specimen, devoid of tourmaline and containing only a small number of mica platelets, showed an average specific gravity reading of 2.71. The second specimen, shot through with numerous tourmaline crystals as well as with mica and other assorted inclusions, revealed a specific gravity of 2.82. This higher S.G. could be due in part to the presence of the schorl-dravite tourmaline, which has a specific gravity (3.03–3.25) that is much higher than that of emerald. The gemological properties obtained by the author for refractive index and specific gravity (on the less included stone) were in close agreement with those published by Bank (1974) for emeralds from Miku, Zambia.

CONCLUSION

Although tourmaline has been reported as inclusions in emeralds from the Ural Mountains in the Soviet Union and from the Habachtal emerald mine in Austria, this is the first report of such inclusions in African emeralds. Since emerald has not yet been found included in Zambian tourmalines, it can be inferred that the emeralds may be geologically younger than the tourmalines.

In reviewing the suite of inclusions now known to occur in Zambian emeralds, we find striking similarities to inclusions in emeralds from other schist-type deposits. In fact, the emeralds from the mica schist in Habachtal, Austria (Gübelin, 1956, 1974), are known to play host to all of the minerals so far found as inclusions in Zambian emeralds. Such comparable parageneses support the view that schist-type emeralds all undergo similar stages of genesis.

Editor's note: An attractive example of a faceted Zambian emerald is illustrated in the Gem Trade Lab Notes section of this issue.

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SECOND ANNUAL GEMS & GEMOLOGY MOST VALUABLE ARTICLE AWARD

This issue marks the end of the 1982 volume year of *Gems & Gemology.* Once again, we are asking you—our readers—to select the three articles that you found most interesting and potentially useful. By participating in this ballot, you not only help us acknowledge the time and effort that these authors have contributed to expanding the gemological literature, but you also give us a better idea of your needs and interests.

Your ballot is located on the insert card inside this issue. Please choose three articles from 1982 and mark them in order of numerical preference: (1) first, (2) second, (3) third. Be sure to mark *only three articles for the entire year.* Additional comments concerning the journal are welcome in the space provided. After voting, simply detach the postcard ballot and drop it in the mail (postage pre-paid if mailed in the U.S.). Ballots must be received by March 15, 1983 to be included in the final tally.

The winning articles will be announced in the Spring 1983 issue of *Gems & Gemology,* with cash awards of $500, $300, and $100, respectively, given to the authors of the three most valuable articles.

Your participation is important to the vitality of the journal. So please take just a few minutes now to let us know how you feel, and help honor the authors whose work has educated and enlightened gemological readers around the world.

Richard Liddicoat

Gem Trade LAB NOTES

EDITOR
Chuck Fryer
GIA, Santa Monica

CONTRIBUTING EDITORS
Robert Crowningshield
Gem Trade Laboratory, New York
Karin N. Hurwit
Gem Trade Laboratory, Santa Monica
Robert E. Kane
Gem Trade Laboratory, Los Angeles

DIAMOND

"Chameleon" Diamond

Perhaps the most striking color change of a diamond is in the so-called chameleon. These diamonds were discussed, but not illustrated, in the Winter 1981 issue of *Gems & Gemology.* It was noted at that time that these stones glow red while hot from being on the wheel, then on cooling appear to be fancy yellow before changing on exposure to light to the dull yellow or gray-green usually associated with chameleon diamonds.

Figure 1 shows a particularly attractive dark yellow-green emerald-cut diamond seen recently in the New York lab. The stone displayed strong yellow fluorescence and phosphorescence. Also observed were a weak pair of absorption lines at approximately 4155 Å and 4190 Å in the spectroscope. Figure 2 shows the same stone while it is still warm from an alcohol flame. In this phase, it would be considered a fancy, intense orange-yellow. Unfortunately, few future owners will ever see this color, as the diamond returned in seconds to its "normal" green as soon as it was exposed to light.

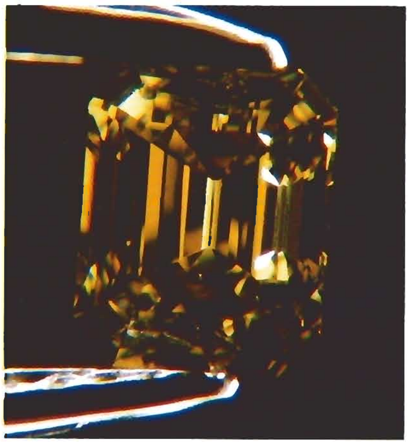

Figure 1. Normal color of this 2.5-ct "chameleon" diamond.

Figure 2. The stone shown in figure 1 after heating and before exposure to light.

Crusader Diamond

What's new in diamond cutting? In New York, we had the opportunity to examine a seven-sided modified brilliant resembling a crusader's shield, complete with a white cross engraved on the table (figure 3). It appeared at first that the table was originally mechanically "frosted," then repolished with four shallow facets designed to leave the cross as shown. However, the mechanical etch marks are at right angles to the two cross members, which suggests that the "frosting" may have been done later.

Figure 3. Shield-shaped diamond with cross on the table. Magnified 10×.

Diamond Oddities

Only rarely have we seen needle-like inclusions in diamonds, and even more rarely have we seen them in patches resembling those found in natural corundum. Figure 4 shows two long rows of needles as viewed through the crown of a round brilliant that came into the New York lab. When viewed from the pavilion, the needles take on a more scattered appearance, with brilliantly reflected spots along some of them.

A naturally yellow fancy diamond that also came into the New York laboratory for a complete quality analysis was puzzling to the graders because of what appeared to be the blackish outlines of all the

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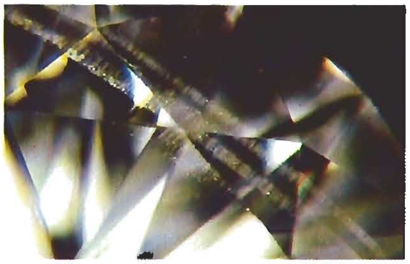


Figure 4. Needle-like inclusions in diamond. Magnified 30×.

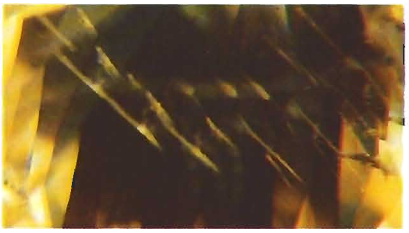


Figure 5. Unusual facet-edge appearance in yellow diamond. Magnified 20×.

Figure 7. Natural 6-ct emerald from Zambia.

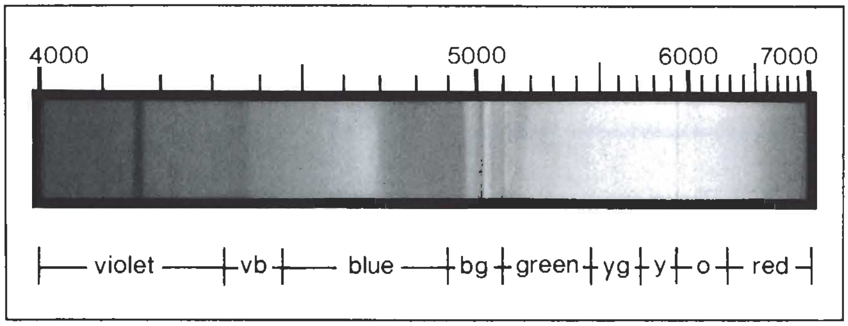
pavilion facets (figure 5). The best explanation we had for the appearance was that the pavilion had been lightly burned. With the dark yellow as contrast, the nonburned areas appeared blackish. It was odd that the effect was confined to the pavilion; one possible explanation is that the stone had been lightly burned all over and repolished only on the crown.

Unusual Absorption Spectrum

The spectroscope is invaluable in determining the origin of color in most colored diamonds. This determination is usually routine, and we see new or unexpected absorption spectra only infrequently. Recently, however, a bright yellow marquise-shaped diamond weighing approximately 1.38 ct was sent to the Los Angeles laboratory. This stone exhibited an absorption spectrum almost identical to that described for bright yellow diamonds of natural color on page 210 of the 11th edition of the *Handbook of Gem Identification*, by Richard T. Liddicoat, Jr. Upon careful examination of the spectrum, however, a very faint line was noted at 5920 Å, which proved that the stone had been treated (see figure 6). Even when the diamond was cooled with an aerosol refrigerant gas, which often aids greatly in observing absorption spectra, the 5920 Å line was difficult to see.

This stone exemplifies the fact that care must be taken when examining the absorption spectra of diamonds. If a stone like this one were hastily examined, a gemologist might miss the very faint 5920 Å line and therefore misinterpret the spectrum as being that of a natural yellow diamond. Note also that the long-wave ultraviolet fluorescence was a strong yellow, rather than the expected yellow-green.

Figure 6. Absorption spectrum of treated bright yellow diamond.



EMERALD

Figure 7 illustrates a nearly flawless 6-ct Zambian emerald that recently came into the New York lab. When examined with a hand spectroscope, the stone showed a distinct line at 4270 Å. This absorption line has heretofore been reported as being present in some natural emeralds of unknown origin (Kane, *Gems & Gemology*, Winter 1980-81) and in some Pakistan stones (Gübelin, *Gems & Gemology,* Fall 1982), as well as in iron-rich Gilson synthetic emeralds. The identifying features of this Zambian stone are its nearly inert reaction to ultraviolet radiation and its high refractive indices (1.585–1.592). Other stones from the same lot, but with inclusions, had similar properties.

PARISITE

A client submitted two earthy-looking hexagonal crystal fragments to the New York laboratory with the comment that they were very rare gems. The crystals resembled brown corundum with a highly developed basal parting, or cleavage. We accepted them for identification only after determining that one had a natural face that appeared to be smooth and lustrous enough to allow a refractive index reading.

The test for refractive index was inconclusive, though the stone appeared to be strongly birefringent, with readings of approximately 1.67–1.77. This suggested the possibility that the material might be a carbonate. The hardness was approximately 4½ on the Mohs scale. Specific gravity was 4.18. When we observed the crystals with a hand spectroscope, we were amazed to see many bands of the spectrum that would be associated with a rare-earth element.

One of the many possibilities we considered on the basis of these properties was siderite, an iron carbonate, but our samples of siderite are semitransparent, greenish yellow-brown cleavages, with a different absorption spectrum (figure 8) and refractive indices of approximately 1.63 to above the scale (actually, 1.873).

Before we were able to complete our tests, however, our client returned for her stones and told us they were parisite crystals that she had collected herself at the Muzo mine in Colombia. She said she just wanted to know if we could recognize a "gem" when we see one. With a hardness of only 4½, basal cleavage, and a nondescript color and appearance, parisite seems a poor candidate for adding to the list of gemstones, though her crystals (one weighed in excess of 5 ct) are indeed rare.

Gemologists are acquainted with parisite (named for J. I. Paris, first lessee of the Muzo mine after Colombia gained its independence in 1819) as a yellowish, blade-like inclusion in Muzo emeralds. In fact, their presence in an emerald is considered proof that the stone came from the Muzo mine. Parisite is a fluocarbonate of the cerium metals (cerium, lanthanum, and the pair praseodymium and neodymium [usually called didymium]) that are collectively known as rare-earth elements. It is, therefore, not surprising to see that parisite has a rare-earth spectrum. Robert Webster mentions seeing an emerald with a rare-earth spectrum that was later found to be due to the numerous parisite inclusions in the stone. Note, however, that the spectrum shown here in figure 9 is somewhat different from the one shown in the Spring 1973 issue of *Gems & Gemology,* which was of a lighter-colored parisite inclusion in emerald.

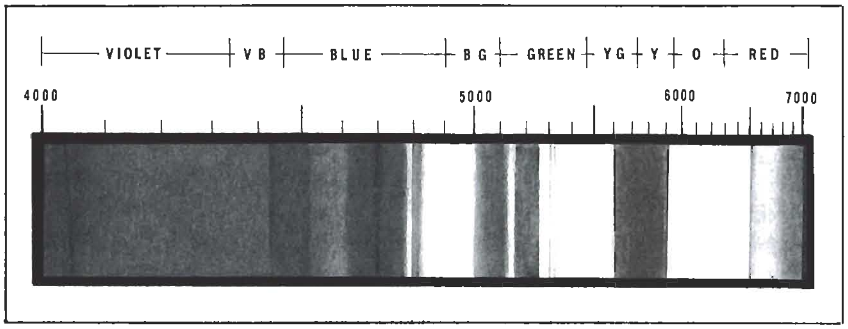
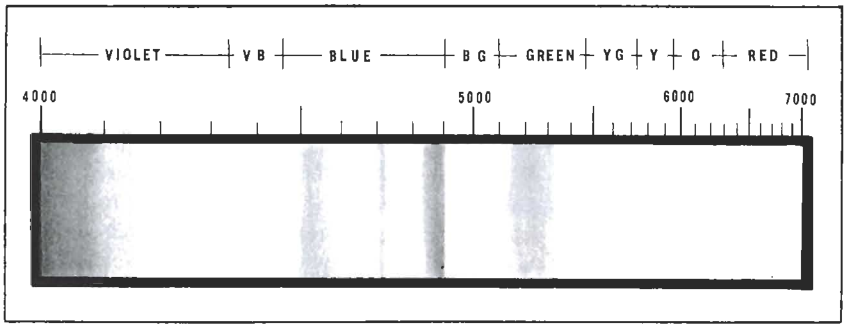


Figure 8. Absorption spectrum for siderite.

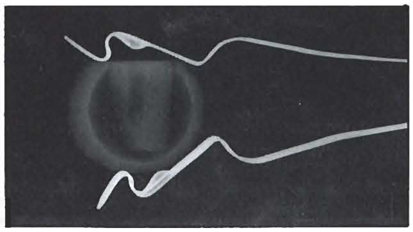
Figure 9. Absorption spectrum for parisite.



PEARLS, Plugged Natural Blister

Since preparing the entry on cultured ¾ blister pearls for the Spring 1982 issue of *Gems & Gemology,*

Figure 10. X-ray showing plug in a blister pearl. Actual size.



we at the New York lab have been more conscious of blister pearls than before. The X-radiograph of a large "pearl" in figure 10 shows that it is actually a natural blister pearl that has been plugged. The plug provides the material for the drill hole and the peg used to secure the pearl to its mounting.

Star QUARTZ

The 11.77-ct translucent, white, asteriated, oval double cabochon shown in figure 11 was recently brought to the Los Angeles laboratory for identification. When the stone was examined in a polariscope, a "bulls-eye" uniaxial interference figure was obtained, thus proving it to be quartz.

The phenomenon of asterism in quartz was discussed in some detail in the Winter 1981 issue of *Gems & Gemology*, on page 230. The unusual feature about this stone, reportedly from Sri Lanka, was the fact that the rutile needles that evoked the asterism were relatively large, and were even visible to the unaided eye. When examined with the microscope, the rutile needles were strikingly enhanced by interference colors that changed as the stone was moved (see figure 12). The iridescence produced by the interference of light with the rutile needles was easily visible to the unaided eye as the stone was rotated under a single light source.

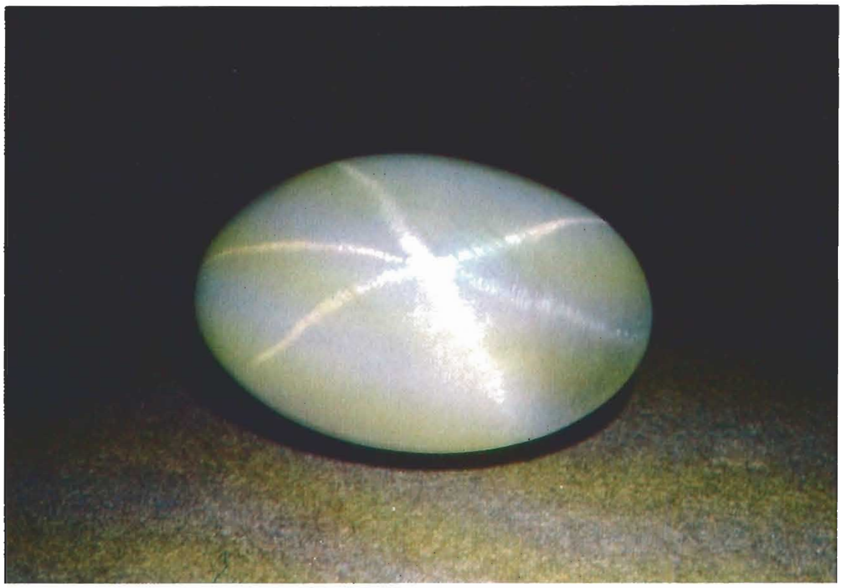


Figure 11. Star quartz, 11.77 ct.

Figure 12. Rutile needles in the star quartz cabochon shown in figure 12. Magnified 30×.

SAPPHIRE, Heat Treated

A natural sapphire of unusual color came into the New York lab for identification. The brilliant orange-yellow seemed unnatural, and the lack of fluorescence and absence of an iron line in the absorption spectrum strongly suggested a heat-treated stone. The clincher, however, was an unpolished burned area near the multiplane girdle (figure 13).

Figure 14 shows yet another example of incomplete repolishing of a heat-treated orangy yellow natural sapphire. It came from a lot of six stones, all of which clearly owed their color to heat treatment.

One yellow sapphire from another lot of four stones recently seen in New York faded appreciably after exposure to south daylight for a day or so. Normally, we would assume that the color was due to irradiation and not to heat, but we recently heard that certain heat-treated yellow natural sapphires may fade (*Gems & Gemology*, Spring 1982, pp. 47 and 48). This has not yet been confirmed.

Figure 13. The unpolished burn area near the girdle of this yellow sapphire reveals heat treatment.

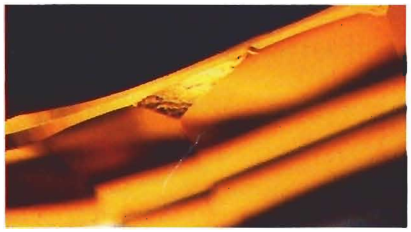


Figure 14. Partly polished facet of a yellow heat-treated sapphire. Magnified 10×.

SPINEL AND SAPPHIRE, Colored by Cobalt (?)

One of the most unusual coincidences to occur in the New York

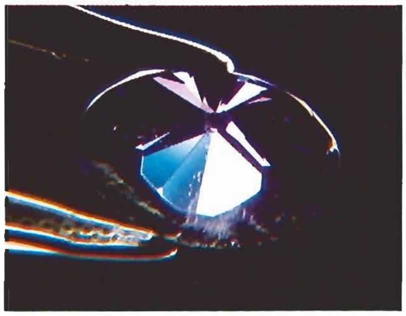


Figure 15. Red flashes in a dark blue spinel, 2.56 ct. Magnified 10×.

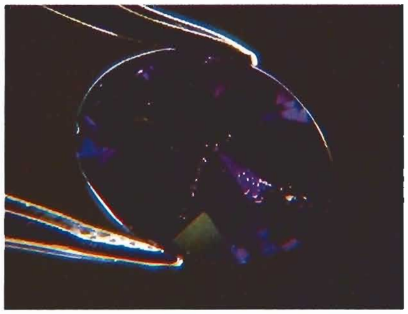


Figure 16. Rain-like inclusion in the spinel shown in figure 15. Magnified 10×.

laboratory in recent years was the receipt in one week of identification requests for two natural-appearing blue gemstones that seemed to be colored by cobalt. All gemologists have been taught that cobalt-colored blue stones do not occur in nature. It was therefore a distinct surprise to test a dark blue oval stone that exhibited red flashes (figure 15) similar to those seen in synthetic blue spinel. The presence of included crystals and fingerprint inclusions suggested natural origin. However, the unnatural-appearing "rain" inclusions (figure 16), normally associated with flux-grown materials, puzzled us. The refractive index of 1.715 was normal for natural spinel. The stone appeared red under the color filter. In addition to the cobalt spectrum associated with synthetic spinel, the absorption spectrum showed a weak iron line at approximately 4500 Å (figure 17).

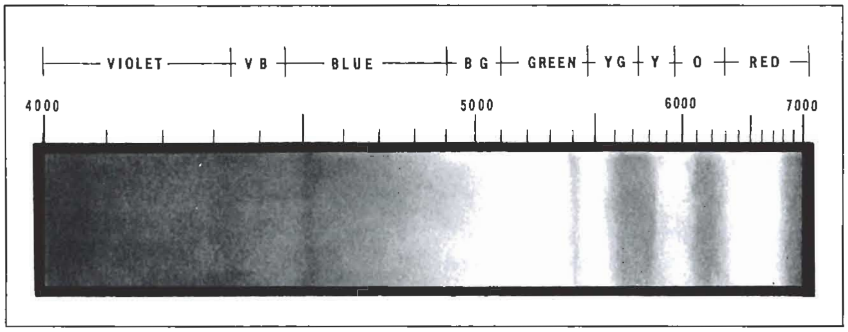
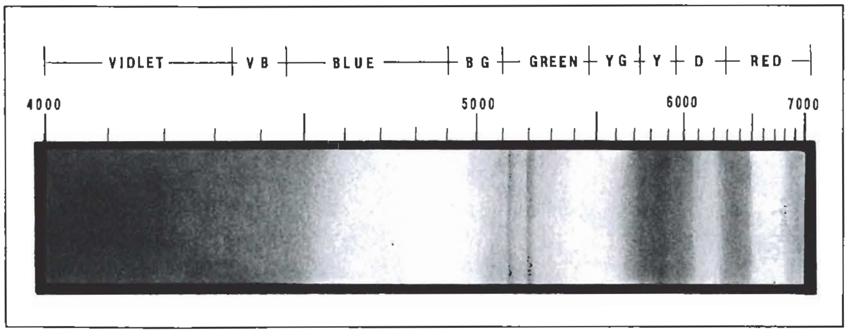


Figure 17. Cobalt-like absorption spectrum in spinel.

Figure 18. Unusual spectrum observed in a sapphire.



A search of the literature turned up only one report of stones that fit this description. In an article in the July 1977 issue of the *Journal of Gemmology*, R. Keith Mitchell describes three such spinels with these characteristics. In view of advances in the flux growth of synthetic crystals and in the heat diffusion of surface color in corundum, it would be hasty to conclude that these "new" blue spinels are in truth natural. The stone we had in the laboratory, with both crystals and "rain-like" (flux?) inclusions, is suspicious. However, the only flux-grown cobalt-colored blue synthetic spinels we have seen, which were kindly furnished by Dr. Kurt Nassau, had no inclusions and the surfaces of the octahedra were crazed, which suggests difficulty in manufacturing. There was really no comparison to be made other than color, red flashes, refractive index, and color filter reaction. We did not detect iron in the absorption spectrum of the flux-grown synthetic spinels provided by Dr. Nassau.

Later that same week another client asked if we could identify a purple-blue stone in an Edwardian ring while his customer waited. This stone was clearly an unusual, but natural, purple-blue sapphire. The stone appeared red under the color filter and showed red flashes under a direct incandescent light. The absorption spectrum (figure 18) was unlike any we had seen before in natural sapphire. It resembles the absorption spectrum of cobalt-colored synthetic blue spinel; the only differences are that the two long-wave bands toward the red end are approximately 200 Å higher in the spectrum of this sapphire, and the shorter wave-length band toward the blue end becomes two bands offset 200 Å toward the shorter wave-length end of the spectrum.

The fact that surface diffusion of titanium and iron as well as chromium has been successfully used to impart a "synthetic" color to natural corundum makes it a matter of conjecture as to the possibility that cobalt could be used for the same purpose. Possibly, cobalt may diffuse much more readily than the other elements so that more than just surface coloration would be the result. We must emphasize, however, that we have not encountered any report of such cobalt diffusion, so this is merely conjecture at this time.

Star SPINEL

The New York lab also received for identification a very "clean" gray-purple six-ray star spinel (figure 19). The asterism was exceptionally sharp but showed the alternating six- and four-ray stars expected of asteriated spinel in different orientations (figure 20).

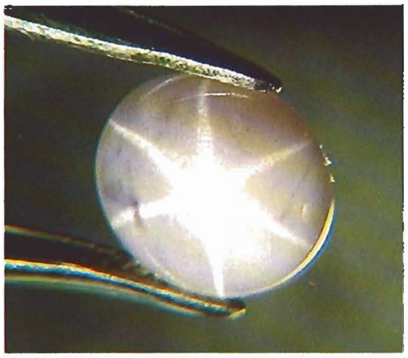


Figure 19. A 1.83-ct star spinel showing six rays.

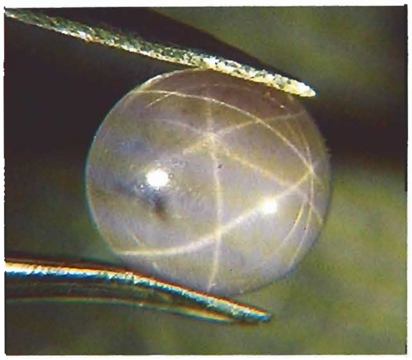


Figure 20. Four- and six-ray stars visible in the star spinel shown in figure 19.

UNCLASSIFIED ODDITIES

The Gem Trade Laboratory in Santa Monica was recently asked to issue identification reports on two rather interesting man-made items. The first was a singly refractive, transparent, green, rectangular piece of rough material that had one of the most intricate internal patterns we have yet encountered. The pattern, as can be seen in figure 21, showed the isometric nature of the host. The refractive index was 1.39, and the specific gravity was approximately 2.64. The material, which showed perfect cleavage in two directions, fluoresced a very strong yellow to long-wave ultraviolet radiation and a strong greenish yellow to short-wave ultraviolet radiation. X-ray diffraction proved the material to be lithium fluoride, a slightly water-soluble chemical compound. There is no known natural counterpart.

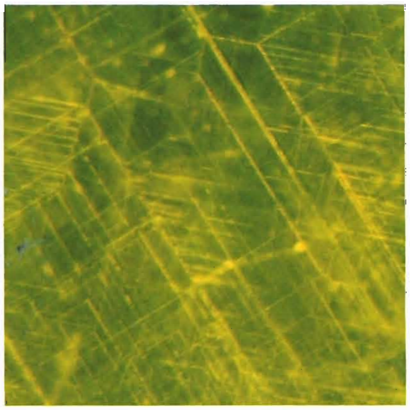


Figure 21. Isometric inclusion pattern seen in lithium fluoride. Magnified 25×.

The second item was a singly refractive, transparent, purplish blue, triangular piece of rough material that had no distinctive internal patterning. X-ray diffraction and chemical analysis by the electron microprobe proved the material to be potassium chloride, a highly water-soluble substance. Because of the poor surface on the material, only a hazy refractive index was seen at approximately 1.49. There was no reaction to ultraviolet radiation. Potassium chloride does occur in nature as the mineral sylvite.

ACKNOWLEDGMENTS

Andrew Quinlan from New York supplied figures 1, 2, 3, 4, 5, 13, 14, 15, 16, 19, and 20. Peter Johnston drew the absorption spectrum in figure 6. Shane McClure provided figure 11. Figure 7 was supplied by Tino Hammid. John Koivula is responsible for figure 21. Bob Crowningshield prepared figures 8, 9, 10, 17, and 18. Bob Kane took the photo in figure 12.

Editorial Forum

DEBATE OVER LARGEST KNOWN FACETED TAAFFEITE CONTINUES

I notice that you marked the statement "WORLD'S LARGEST TAAFFEITE?" (Gem Trade Lab Notes, Spring 1982, p. 49) with a question mark, and I appreciated your caution in this matter. Of the five taaffeites in my private collection, the largest weighs 11.24 ct. It is pink, has a faceted oval cut, and contains a yellowish brown inclusion of monazite. Even this taaffeite is not the largest in the world, as the largest known to me weighs 13.22 ct. It is flawless and has a pleasing mauve color. It is cut oval and faceted. This very rare and beautiful collector's item is in the possession of Mr. R. Fonseka in Colombo, Sri Lanka.

E. Gübelin
Meggen, Switzerland.

JEWELRY SUITE MARKINGS

Regarding the markings you show and describe on the pink topaz, peridot, and seed pearl parure shown on page 121 of the Summer 1982 *Gems & Gemology,* I may be of some assistance. The owl marking you described applies to gold items which are being imported into France for which earlier French provenance cannot be absolutely guaranteed, or items which were proved to come from countries other than those which had been French colonies. In order for a jewellery item to be resold in France legally, it had to be marked with this control mark. The swan marking you have photographed is the corresponding control mark for items made of or partially made of silver. These two markings were in use from July 1, 1893, until 1970. It is therefore possible that the suite was imported into France anytime from 1893 to 1970.

There would also appear to be a good possibility that some of the stone settings are actually made of silver and that this has been obscured by the later plating process.

The mark with the letters and umbrella is in all probability either an original maker's mark or the mark of the firm which had the pieces for resale and therefore had the control marks put on. Of the two possibilities, the more likely would be that this is the later retailer's or importer's mark. The box shape and the fact that it is an applied plate lead me to believe that it was a French firm. The double struck marking of the ram appears to be the gold guarantee mark of Paris 1819-1838, as per the *Book of Old Silver* by Seymour B. Wyler, page 336.

By the design and style, it is certainly possible that the jewellery was made in France, 1819-1838, purchased by someone who moved out of the country, and many years later brought back into France for resale.

For further reference on international precious metals markings, I would suggest *Poincons d'or et de Platine* and *Poincons d'Argent* by Tardy, 21 Rue des Boulangers, Paris, S.E., which contain textual explanations of various French import and export marks as well as international guarantee marks.

Debra Fraleigh, G.G.
Fraleigh Jewellers & Gemmologists
Toronto, Ontario, Canada

GEMOLOGICAL ABSTRACTS

Dona M. Dirlam, Editor

COLORED STONES AND ORGANIC MATERIALS

The colors of sillimanite. G. R. Rossman, E. S. Grew, W. A. Dollase, *American Mineralogist,* Vol. 67, No. 7-8, 1982, pp. 749-761.

Sillimanite, Al_2SiO_5, occasionally seen as a faceted gemstone, is a common mineral constituent of aluminum-rich rocks in metamorphic environments. While normally colorless, sillimanite is also known in three colored varieties: yellow, brown, and, rarely, blue. As in various other gem minerals (e.g., corundum) that are colorless when free of impurities, these three colors in sillimanite are due to the presence of small amounts of trace elements such as iron, chromium, and titanium which substitute for aluminum. Crystal-structure analysis has established that aluminum occurs in both six-fold (octahedral) and four-fold (tetrahedral) coordination with oxygen in sillimanite. The purpose of this investigation was to relate the observed colors and optical absorption spectra for sillimanites from a number of localities with the pattern of trace-element substitution for aluminum in these different crystallographic sites.

The authors conclude the article with a discussion of the relationship between the cooling history of a sillimanite crystal in an igneous or metamorphic rock and the distribution and oxidation state of trace elements, such as iron substituting for aluminum, in the crystal structure. *JES*

Cultured pearl experiment puts mussel in TN economy. L. M. Henderson, *Southern Jeweler,* Vol. 58, No. 3, 1982, pp. 32-34.

Within the next few years, John Latendresse plans to

This section is designed to provide as complete a record as possible 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.

make the biggest splash on the cultured pearl scene since the first importation to America of cultured pearls from Japan. His goal is to be the owner of the first productive cultured pearl farm in the United States. Latendresse, who has been in the pearl business for some 29 years, briefly discusses how his soon-to-be-producing pearl farms in Tennessee will help the local community's ailing economy.

By offering American cultured pearls to jewelers in this country, he also expects to make inroads into the fluorishing Japanese import market of freshwater cultured pearls. *GAR*

Monazite from North Carolina having the alexandrite effect. R. Bernstein, *American Mineralogist,* Vol. 67, No. 3–4, 1982, pp. 356–359.

"Alexandrite effect," the property of a crystalline material to change its apparent color when viewed under different lighting conditions, is commonly associated with alexandrite, a chromium-bearing chrysoberyl that appears green in sunlight or fluorescent light and red in incandescent or candle light. Other minerals known to display this effect are chromium- and vanadium-bearing corundum and garnet, yttrium-bearing fluorite, and spinel and diaspore.

In this article, Bernstein describes the first documented occurrence of such behavior in monazite (Ce,La,Nd,Th) (P_4), a common accessory constituent of igneous rocks but a rather unusual gemstone. The material examined in this study consists of a few small (1 mm or less) euhedral crystals from a mineralized quartz vein in the Uwharrie National Forest, near Badin, Montgomery County, North Carolina. These crystals appear yellow-orange in daylight, reddish orange in incandescent light, and light green in fluorescent light, but they do not fluoresce to short-wave or long-wave ultraviolet radiation nor are they pleochroic. Quantitative microprobe analysis revealed the presence of various rare-earth elements (cerium, lanthanum, neodymium, samarium, praseodymium, gadolinium, yttrium), but not elements such as iron, thorium and uranium, which are common constituents of monazite. Bernstein suggests that the pastel colors caused by such rare-earth elements should be present in most monazite specimens but are usually masked by the normal dark color of this mineral, which results from the presence of iron and from the thorium- and uranium-induced radiation damage to the crystal structure.

This article demonstrates that color change under different lighting conditions is probably a more common optical phenomenon than was once believed. Potentially, these color changes may be observed in a range of gem materials that contain rare-earth or transition elements. One might suppose, therefore, that with a knowledge of the relative absorption spectra of these elements in different crystal-structure environments, it would be possible to predict the occurrence of the "alexandrite effect" in various minerals. *JES*

Nature of color centers and EPR of a manganese-activated beryl. V. P. Solntsev, E. I. Kharchenko, A. S. Lebedev, V. A. Klyakhin, and A. G. Il'in, *Journal of Applied Spectroscopy,* Vol. 34, No. 1, 1981, pp. 111-115.

In attempting to understand the causes of color and other optical absorption phenomena in gem materials, a scientist may use any of a number of spectroscopic techniques for examining absorption bands (energy transitions) over different portions of the electromagnetic spectrum. The technique employed by these investigators in their study of red and pink beryl is that of electron paramagnetic resonance (or EPR, also known as electron spin resonance, ESR) spectroscopy. The method involves the measurement of absorption bands (and corresponding energies) in the microwave region of the spectrum (wavelength = 0.1 mm to 30 cm). These particular bands arise in the spectra of certain atoms, such as those of the transition metals, that do not have each of the valence orbitals, or energy levels, filled by two electrons. In those orbitals that contain unpaired electrons, the electrons can undergo a transition between energy levels by the absorption of microwave radiation.

As is the case with a number of gem minerals, the range of colors exhibited by beryl is caused by the presence of trace amounts of different transition metals. It has been recognized for some time that the pink of morganite and the rose red of bixbite are due to the presence of manganese. However, there has been some uncertainty regarding both the valence state of manganese and the site it occupies in the beryl crystal structure. On the basis of their data, these investigators believe that the rose color in beryl is due to Mn^{+3} substituting for Al^{+3}.

This article provides a good discussion of the causes of color in pink and red beryls. However, since manganese can exist in several valence states in beryl specimens, and additional transition metals can also be present, one should expect slight variations in absorption spectra between different specimens. The article also illustrates the continuing problem of accounting for the various absorption bands in the complicated spectra of most gem materials. *JES*

A U.S. review: chrysoberyl. M. I. Jacobson, *Rocks and Minerals,* Vol. 57, No. 2, 1982, pp. 49–57.

Although chrysoberyl has been found in minor amounts in only a handful of localities in the United States, the author hopes that a review of the mineral, its geologic associations, and known localities might contribute to the discovery of other occurrences.

Jacobson begins with a discussion of the varieties of chrysoberyl and the mineralogy of this species. He includes a map of the U.S. with the reported pegmatite localities plotted, of which 10 districts are known to have produced chrysoberyl.

In the detailed description of the historical occurrences of chrysoberyl, Jacobson presents such information as exact locations, types of crystals found, associated minerals, dates of discovery, and names of discoverers. The first discovery of chrysoberyl in the U.S. was in 1810 at Haddam, Connecticut, where 3-in. crystals were found in a pegmatite vein in gneiss. Building projects have since made this site inaccessible. In 1892, individual twinned crystals of green chrysoberyl up to 0.55 in. long were found in a quartz matrix in an excavation at 88th and Amsterdam Streets in New York City. This one find, however, was never repeated at that site. Other states in which chrysoberyl has occurred include Maine, New Hampshire, Colorado, South Dakota, Arizona, and Nevada.

The author concludes with a discussion of museums that have chrysoberyl collections and a list of 40 references. *SFM*

Zur Erkennung diffusionsbehandelter Korunde (Recognizing diffusion-treated corundum). H. A. Hänni, *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 31, No. 2, pp. 49-57.

In a discussion of heat-treated corundum, Dr. Hänni describes the diffusion heat-treatment process. He nicely illustrates typical inclusions in, and distinguishing characteristics of, some blue Sri Lankan sapphires after heat diffusion treatment.

In this process, small quantities of trace impurities, titanium oxide (TiO_2) and/or iron oxide (Fe_2O_3), are actually added to the surface of the stones and then the stones are heated to temperatures of at least 1700°C. The treatment produces a thin layer at the surface, with a depth of approximately 2 mm.

Characteristic inclusions and surface features enable the identification of sapphires in which some foreign material has been added by diffusion treatment. With immersion in methylene iodide, the following characteristics may be seen: strongly colored facet junctions, differences in color from one facet to another as a result of unequal repolishing, and possibly a colorless girdle area due to excessive repolishing. With the unaided eye, a dark rim around the girdle of the stone may be seen, as well as a "color hole" in the center of the stone and color concentration in surface pits and cracks. *BJT*

DIAMONDS

The Australian wild card is now DeBeers' ace in the hole, part I. DeBeers and the Australian diamond connection, part II. E. Farrell, *Goldsmith,* Vol. 161, 1982: No. 2, pp. 39-50; No. 3, pp. 57-61.

There has been much speculation in the diamond industry about the new Australian diamond mine at Argyle. Who will market the output? What effect will this new deposit have on the world market? Eileen Farrell attempts to answer these and other frequently asked questions in two consecutive articles.

It now seems that some sort of agreement will be reached between the Ashton Joint Venture, the developers of the mine, and DeBeers's Central Selling Organization. DeBeers will most likely distribute the majority of the diamonds, as they must to perpetuate their dominance of the market, but they will make several unprecedented concessions for this privilege. The Australians are firm in wanting a local cutting industry and in marketing part of the gem and near-gem production themselves.

The Argyle pipe is expected to yield approximately 35% of the world diamond production in quantity, but only about 4% by value, because of the low overall quality of the diamonds and their small size. If the valuations of the initial samples are correct, and there has been some disagreement about these figures, the market should not be upset by this new influx of diamonds.

Ms. Farrell's articles, which make interesting reading, are well researched. *FLG*

Diamond collecting in northern Colorado. D. S. Collins, *Mineralogical Record,* Vol. 13, No. 4, 1982, pp. 205-208.

The occurrence of diamonds in kimberlite is usually associated with the classic areas of diamond production in Africa, but similar occurrences are known. Within the United States, for instance, the diamond locality near Murfreesboro, Arkansas, has been recognized since the early 1900s. This article describes a recent discovery of diamonds in the northern Front Range of the Wyoming-Colorado border, between Laramie and Fort Collins.

As in other areas, the diamonds at this locality occur in kimberlite, a type of olivine- and pyroxene-rich ultramafic igneous rock known as peridotite. Within this particular area of the Front Range, some 90 separate kimberlite bodies have been identified in Precambrian granitic rocks. The kimberlite pipes were emplaced along several major fault zones. Fission-track dating of zircons recovered from the kimberlite gave an average value of 377 million years, which indicates a Devonian age for these diamond-bearing pipes.

Since 1975, a small number of diamonds have been found in the weathered kimberlite at this locality. These stones average approximately 1 mm in diameter; the largest recorded diamond is a distorted octahedron weighing 0.06 ct. Some of these stones are of gem quality. They may occur as crude crystals, or as rounded or broken fragments, white or pale yellow in color.

The future prospect for diamond recovery from this area is not known at present. The author considers the area to be a potentially rich find on the basis of unpublished estimates of the diamond concentrations in this kimberlite. However, he gives no indication of plans for future development or geologic study beyond that associated with scientific research. *JES*

The ever-rising tide of Russian diamonds. R. V. Huddlestone, *PreciouStones Newsletter*, Vol. 5, No. 6, 1982, pp. 34-39.

The Siberian diamond production is perhaps the single most influentual factor in today's nonregulated distribution of diamonds. Huddlestone offers an optimistic view of the effect of these stones on the world market. He begins with an historical account of the prediction and eventual discovery of kimberlite pipes in the Siberian platform, the most notable being the Mir pipe in 1955. Today, over 450 pipes have been located.

Mining in Siberia produced problems that had not been encountered in other localities. Temperature variations of 120° from a low of −70°F required ingenious solutions for mining techniques, equipment, and people. In fact, in 1972 bonuses were paid to the estimated 60,000 workers on the basis of how far north they worked.

Huddlestone then turns to the issue of diamond production figures and marketing practices. Noting the difficulty of obtaining accurate statistics from the Soviet Union, he reports the generally accepted figures of 10.5 million carats, or about 25% of the world's annual production, of which 20% are gem quality. In 1972, Russia modified its contract with DeBeers and now markets some of its own stones.

Acknowledging that the actions of the Russian government are dictated by the country's need for foreign currency, Huddlestone argues that the Soviet Union has marketed its stones in such an orderly fashion that "the ever rising tide of Russian diamonds should not, therefore, be viewed with such apprehension." *MWP*

Famous diamonds of the world (XII): the Colenso diamond. I. Balfour, *Indiaqua*, Vol. 31, No. 1, 1982, pp. 133–137.

The story behind the Colenso diamond is as unique as the 133.14-ct pale yellow octahedron itself. The controversy begins with its discovery and continues to the question of where it is today. Exactly when and where the stone was found is not known, although production statistics suggest that it came from the DeBeers mine. An 1896 magazine account reported that it was found in the pocket of a dead miner who had been buried in the collapse of an open-pit mine.

From South Africa the Colenso went to England and was purchased by John Ruskin, writer and social critic, who donated it to the British Museum (Natural History) in 1887. He attached two stipulations: (1) it could never be cut, because uncut jewels were "twenty times more interesting"; and (2) it must be exhibited with a description naming it the Colenso diamond after his friend John Williams Colenso. Colenso, a noted mathematician and first Anglican Bishop of Natal, had been embroiled in controversy which included his excommunication for his enlightened views on African customs and reinterpretation of theological matters.

Balfour concludes with an account of the theft of the Colenso from the museum in April 1965. Not only has the octahedron never been recovered, but one wonders if it has remained intact. *MWP*

On isotopic fractionation of carbon in the solid-state synthesis of diamond (in Russian). I. N. Ivanovskaja, S. F. Maxov, L. E. Šterenberg, A. R. Musin, and V. P. Filonenko, *Geochemistry*, Vol. 9, 1980, pp. 1415–1417.

The principle of fractionation, the tendency for the number of particles in different atoms of the same material to vary as the material crystallizes, was used by researchers at the Institute of High-Pressure Physics in Moscow to help resolve the question of what kind of carbon serves as the source for different types of diamond. By measuring this isotopic number in diamonds they synthesized under controlled conditions, the authors hoped to discover what forms of carbon produce natural diamonds.

Other scientists had already determined that very little fractionation occurs as diamond is created from mixtures of melted materials, while crystals synthesized from a gas tend toward heavier carbon. The writers thus chose to concentrate on fractionation that occurs while diamond is produced in the solid state: from unmelted materials under extremely high temperature and pressure. The results would then give an idea how natural diamond formed under conditions of impact metamorphosis, the most interesting examples being those diamonds found in meteor craters from Arizona to Popigai in the USSR.

The authors restricted their study to solid-state synthesis under both high static pressures and lower pressures with a special catalyst. Different types of carbonaceous materials and carbon, including natural and synthetic graphite, were placed in a high-temperature chamber along with bismuth and certain platinum alloys. Changes in the structure of bismuth at known pressures tell the researchers what pressures have been reached, while the platinum materials, which melt only with extreme heat, indicate the temperatures attained.

Intense heat and pressure produced small crystals that, when cleaned by acid and checked with X-rays, proved to be diamond. The crystals were then placed in a special chamber with oxygen and burned. The relative number of particles in the carbon atoms were then easily measured by a spectrometer reading of the resulting carbon dioxide.

The ratios of different isotopes of carbon present demonstrated the absence of any fractionation in either method of synthesis. The authors concluded that, assuming diamond crystallizes in nature as it does in the lab, the wide variations in the number of atomic particles with natural diamond must be caused by a wide range in the source materials, rather than by fractionation. The presence of a certain by-product (lonsdaleite) with the synthetic diamonds further allowed the writers to postulate that the source of carbon for the meteorite diamonds, which appear with the same material, must have been graphite rather than coal.

Numerous references in both English and Russian, as well as general discussions of the latest synthesis techniques and descriptions of the experiments, make this article one of the most informative of recent Soviet papers. Similar investigations should prove invaluable if and when it becomes necessary for gemologists to develop methods of separating synthetic and natural gem-quality diamonds. *MPR*

New type of diamond-bearing rock—garnet pyroxenite. A. I. Ponomarenko, Z. V. Spetsius, N. V. Sobolev, *Doklady Akademii Nauk SSSR,* Vol. 251, No. 2, 1980, pp. 438–441.

While studying plutonic xenoliths from the Udachnaya kimberlite pipe in the USSR, the authors discovered two occurrences of a hitherto unknown diamond-bearing rock of extremely unusual composition.

The most common types of diamond-bearing parent rocks previously known were bimineralic eclogites associated with kyanite and corundum, and diamond-bearing ultramafics such as garnet-ilmenite peridotite and garnet peridotite without ilmenite. Samples of this new material are highly irregular in chemical composition and growth features, suggesting to the authors that the pressure and temperature of crystallization vary from previously published data. The authors present data on the chemical composition of the minerals found in the diamond-bearing pyroxenite along with calculations of garnet and pyroxene end members. The authors conclude that the minerals in this high-aluminum, low-chromium ultramafic rock formed under conditions of high pressure in the deepest zones of the upper mantle at depths of about 260 to 270 km. *SCH*

Russians train cutters early. V. Yegorov, *Diamond News and S. A. Jeweller,* Vol. 45, No. 5, 1982, p. 53.

In a rare article on the Russian diamond industry, Viktor Yegorov, director of a vocational school for diamond cutting in the Soviet Union, describes the one-year program, which is both theoretical and practical. Crystallography, origin, and physical and optical properties comprise the theory, which also includes the study of aesthetics. The students' first cutting attempts are made on real diamonds. Yegorov points out that "their processing losses are only five percent higher than those of experienced workers." Perfect eyesight is required; it is only later that "special sight" (the ability to plan the cutting of a rough crystal) is recognized in the top graduates. The final exam includes the complete working of a crystal, giving it all 57 facets. *MWP*

GEM LOCALITIES

An occurrence of gem-quality elbaite from Glenbuchat, Aberdeenshire, Scotland. B. Jackson, *Journal of Gemmology,* Vol. 18, No. 2, 1982, pp. 121–125.

This brief article describes the first reported occurrence of gem-quality elbaite tourmaline in Scotland. The locality is near the town of Glenbuchat in Aberdeenshire, where a sequence of metamorphic schists has been intruded by pegmatite and aplite dikes of granitic composition. In this area, only one pegmatite has so far produced gem tourmaline.

Elbaite crystals up to several centimeters in length (average 1 cm) have been found in limited quantity associated with lepidolite, muscovite, and quartz within the inner zone of the pegmatite. These crystals exhibit a range of colors and are usually of gem quality. Some of the larger crystals, however, have central cores which contain abundant fractures and cavities, or are partly replaced by muscovite.

The author presents some mineralogic data on both the schorl and the elbaite from this locality. Partial chemical analyses obtained with an electron microprobe are consistent with other published data on tourmaline. Refractive index and specific gravity also agree with published data.

To date, there is no indication that faceted stones have been cut from this elbaite. Further investigation will be necessary to determine the nature, extent, and gem-producing potential of these pegmatites. *JES*

The Virgem da Lapa pegmatites. J. P. Cassedanne and J. Lowell, *Mineralogical Record,* Vol. 13, No. 1, 1982, pp. 19–28.

Cassedanne and Lowell call the Virgem da Lapa district "one of the finest localities in the world for well-crystallized minerals." The pegmatite area is characterized by an abundance of gem minerals, including tourmaline, topaz, and beryl.

Located in northeastern Minas Gerais, Brazil, the Virgem da Lapa pegmatites consist of three production centers: Limoerio, Xanda, and Toca da Onca. The physiography, geology, and mineralogy of the district are given together with a geologic sketch map and a map of the Xanda mine. Three color and numerous black-and-white photographs of crystal specimens are also included, as the authors discuss 18 of the minerals that occur here. Cassedanne and Lowell conclude that although the most accessible pockets have been exploited and commercial mining is hindered by the expense, this area has great potential for future production. *JPG*

INSTRUMENTS AND TECHNIQUES

Colour it accurate. P. Read, *Canadian Jeweller,* Vol. 103, No. 4, 1982, pp. 19–20.

In his column, "Practical Gemmology," Peter Read reports on Okuda's new Diamond Color Checker model DC-530A. He prefaces his discussion with a brief history of diamond color-grading devices, including the Shipley Colorimeter and the more recent Eickhorst Diamond-photometer.

The new Okuda instrument claims to be able to grade with repeatable accuracy all diamonds in the yellow range as well as brown and fluorescent stones. The DC-530A features an integrating sphere which collects the light reflected from the gem and effectively channels the signal through a set of red and blue filters and then into two photometers. The light signal reaching the photodetectors is fed into an electronic device which computes the ratio and derives a color grade value that is measured on a meter calibrated directly to GIA color grades D thru L. "Manual" control knobs enable the operator to calibrate according to existing master stones which may be of high color or low color in a given stone. Two additional controls provide for corrections involving diamonds over one carat and serve to compensate for the shank color of mounted stones.

Using six diamond and five cubic zirconia masters, Read found the instrument to be accurate within one-fourth of a grade on yellow diamonds in the J range and within one-half of a grade on diamonds in the D color range, but off by at least two grades on CZ. Certain precautions are necessary: notably, the diamond must be cleaned before testing, and the test platform on which the stone rests must be dust free. Read also suggests checking the instrument's calibration frequently.

Because data were not available on the DC-530A's ability to grade fluorescent and brown stones, Mr. Read intends to address this question at a later date. *SCH*

A contribution to the separability of natural and synthetic emeralds. H. A. Hänni, *Journal of Gemmology,* Vol. 18, No. 2, 1982, pp. 138–144.

Reviewing the various methods of distinguishing natural and synthetic emeralds, Dr. Hänni reminds us that physical constants such as refractive index, birefringence, and specific gravity may overlap and thus provide inconclusive results. The author then discusses the differences in the theoretical chemical composition of beryl, Gilson synthetic emerald, and Sandawana natural emerald, noting that the Gilson product is actually closer to the theoretical formula while the Sandawana stone contains significant amounts of Na_2O and MgO with minor amounts of FeO, MnO, and Cr_2O_3.

To determine whether this variation in chemical composition might be useful in separating natural and synthetic emeralds, Dr. Hänni tested 45 stones of different origin and manufacture on the electron microprobe and plotted the weight percent of Cr_2O_3, FeO, MgO, and Na_2O in each. He concludes that a concentration of Na_2O and MgO greater than 1.0% is characteristic of natural emeralds, although he does note that in Colombian emeralds this can drop below 1%. New synthetic products and a greater number of natural stones will have to be tested to determine the usefulness of this technique. *SCH*

The purification of bromoform. C. Washington, *Journal of Gemmology,* Vol. 18, No. 1, 1982, pp. 6–8.

Washington describes a simple technique for purifying bromoform. Contaminated or discolored bromoform used as a heavy liquid for specific gravity determinations may be purified by placing a stoppered flask of the contaminated solution in a bucket of ice-water slurry. Bromoform will crystallize out at 8°C (its freezing point) within a couple of hours and when remelted will have approximately 98% purity and a density close to 2.85. Best results are obtained by inserting a thermometer into the bromoform to determine when the 8°C level has been reached; further cooling may allow other impurities such as benzene (f.p., 5.5°C) and methylene iodide (f.p., 6.1°C) to crystallize out as well. *ERL*

JEWELRY ARTS

Cellini, Fabergé and me. T. Hoving, *Connoisseur,* Vol. 210, No. 842, 1982, pp. 82–91.

"Me" is Jean Schlumberger, the 75-year-old creator of "splendid baubles": a peridot-studded cucumber-shaped golden box, a foot-high clock of gold and lapis lazuli that resembles a turban, a 100-ct Kashmir sapphire–centered golden flower, bestrewn with emeralds and diamonds, growing out of a clay flower pot. Schlumberger is not exaggerating when he likens himself to the other two great jewelers of the Western world, as the 20 astonishingly beautiful color photographs reveal.

This article gives us a rare glimpse of riches both material and spiritual in this brief account of Schlumberger's life and art. "My goal was—and is—happiness," he says, and "I try to make everything look as if it were growing." Elsewhere, he speaks of a desire to "elevate . . . an art . . . which ought to be called something more than 'charming, elegant, ravishing, and chic,' " a desire it is plain he has fulfilled. *FS*

Photography for metalsmiths. Part one: What's wrong with this picture? L. F. Brown, *Metalsmith,* Vol. 1, No. 4, 1981, pp. 48–54.

Drawing from his experiences in metalsmithing and jewelry design and as a professional darkroom technician and photographer, Leslie Brown has created a minicourse to help struggling metalsmiths produce technically accurate photographs of small metallic objects. As the first in a series, this article focuses on the basic question: What are the characteristics of a quality photograph and how does one attain them? Brown discusses what film to use, how to operate the camera's meter, and what other equipment is necessary. Although each of the subjects is covered well in relatively simple language, a useful appendix has been thoughtfully provided for readers not familiar with photography terminology. *Mike Havstad*

Pre-Columbian art of Costa Rica. B. Braun, *Museum,* Vol. 2, No. 6, 1982, pp. 51–55.

The art exhibition "Between Continents/Between Seas: Pre-Columbian Art of Costa Rica," which is touring the U.S. in 1982 and 1983, is cohesively thematic in its examples of sculpture and jewelry that uniquely represent the archaeological history of the cultures and regions inhabited by pre-Columbian civilizations.

Unlike the dominant civilizations from Mesoamerica in the north and from the northern Andes in the south, no one great state or civilization seemed to establish itself in Costa Rica. The article indicates, rather, that the spare environment resulted in chiefdom-like cultures, occupying three main regions: Guanacaste-Nicoya in the north, the Central Highland-Atlantic Watershed in the east, and Diquís in the southwest.

Indicative of the priorities of the chiefdom society are objects recovered from the grave sites of high-ranking officials. Frequently, these were "three-legged metates (or grinding stones), elegant jade pendants known as axe gods, and hardstone clubs called maceheads." Such objects symbolized the importance of land, its acquisition, defense, and labor, all of which were related to power. These relics, which offer an interesting and beautiful view of early Costa Rican history, span a period from 500 B.C. to 1550 A.D. The exhibition shows a progression of archaeological finds that differ not only in meaning but also in content, as gold replaces stone and jade. *Joyce Law*

RETAILING

Cartier—two centuries of records. *18 Karati Internazional,* Vol. 12, No. 57, 1982, pp. 70–79.

In a brief history of La Maison Cartier, the author highlights the generations involved in the firm's management since the 1800s. The integration of colored stones with fashionable gold enameling was created and popularized by Louis François Cartier, a skilled craftsman who became popular with visiting aristocracy during the 1867 Paris Exhibition. Although Louis was ruined by the revolution in 1870, his son Alfred restored and strengthened the business.

In 1898, Alfred and his sons established the present headquarters in Paris and opened a house in London. In 1908, they opened the third Maison Cartier in New York. Alfred's oldest son Louis proved the creative genius of the family, and was responsible for reviving the clock-making tradition.

World War II brought the death of Louis and a new management to the house. Robert Hocq was primarily responsible for putting the empire back together and continuing the old tradition. Hocq, together with his daughter Nathalie, has increased sales of expensive jewelry while giving a new emphasis to medium-priced pieces.

This historical overview of Maison Cartier, with 27 photographs of Cartier people as well as jewelery, leaves the reader asking for more. Unfortunately, it is not supplemented with references or a bibliography. *ERH*

Employee screening. Part I, the promise and perils of polygraph. M. E. Thomas, *Goldsmith,* Vol. 161, No. 6, 1982, pp. 52–68.

In the first of a series about employee screening processes, Ms. Thomas's critical examination of polygraph testing demystifies the pretest and test procedures and enumerates polygraph limitations. The author questions the validity and consistency of polygraph findings and their use in predicting future employee behavior. Opinions from academicians, the Civil Liberties Union, and jewelry trade employers and employees are presented.

Acknowledging increased polygraph use in the jewelry industry for preemployment screening and for theft and loss situations, Thomas provides employers with guidelines for selecting a competent examiner and for evaluating the results. Consideration must be given to state law limiting and/or licensing the use of polygraph tests. Employers are cautioned that the polygraph may protect those who steal and can still pass the exam, and that there are possible legal repercussions of requiring polygraph testing for employment.

The author witnessed an actual polygraph testing session which revealed techniques used to elicit admission of wrongdoing from a respondent during the pretest interview. The most respected private polygraphers concur that 90%–95% of adverse reports given to employers are based on such admissions. Extremely important in the testing is the subject's belief that the "lie-detector" system works and that the polygraph room should be regarded as a confessional. *ALS*

SYNTHETICS AND SIMULANTS

Growth of modified cat's-eye gemstones ($MgTiO_3$ solid solutions) by the floating zone method (in Japanese). I. Shindo, *Journal of the Gemmological Society of Japan,* Vol. 7, No. 1, 1980, pp. 3–8.

Shindo, from the National Institute for Research in Organic Materials, gives a preliminary report on a new man-made cat's-eye material. The compound $MgTiO_3$

was selected because, unlike other magnesium-titanium compounds, heating of this compound produces chatoyancy. In the experiment, $MgTiO_3$ crystals were floated through zones in a halogen lamp image furnace. The author contrasts this new method with that used for YAG, GGG, etc., where the material to be crystallized is placed in a crucible, liquefied, and then cooled slowly. Here, the solidification is unpredictable because of the difficulty of maintaining an atmosphere. On a graph, Shindo illustrates what can occur in this process.

In the floating zone method, two shafts are used—the material rod positioned on the top and the seed rod on the bottom. Placed within a quartz tube, these rods are rotated in opposite directions. In the central region is the fluid stage, which is contained by surface tension only. A diagram illustrates the positioning of a halogen lamp external to the quartz tube, all of which is enveloped by a mirrored furnace. Light and heat from the lamp are focused on the area where crystal solidification occurs. Necessary in this operation are a lens and a screen used to direct heat to the central part of the quartz tube. The shafts rotate at 30 rpm with growth measured at 2 mm/hr. When the crystals reach 50 mm, which takes about 24 hours, the power is turned off and the solution is cooled rapidly. A photograph of a boule and an explanatory diagram accompany this description of the process.

The experiment was repeated several times, with resulting boules ranging from 8 to 100 mm. Annealing the boules at 1300°C for 24 hours in an oxygen atmosphere induced transparency and a lighter color. Pictured are three boules in which the chatoyancy extends approximately 2–4 cm. X-ray analysis revealed that growth occurred mostly along the 1010 axis and chatoyancy along the 0001 plane. A cabochon is also pictured. *ALS*

MISCELLANEOUS

Characteristics of crystal growth in nature as seen from the morphology of mineral crystals. I. Sunagawa, *Bulletin de Minéralogie,* Vol. 104, 1981, pp. 81–87.

Even a cursory examination of the natural crystals of zircon, topaz, beryl, quartz, and other gemstones quickly demonstrates that some minerals display a wide diversity of crystal forms, or habits. This variation in the geometrical shape of crystals is, in part, a result of mineral formation taking place over a range of physical and chemical conditions in different geologic environments in the earth's crust. In this review article, the author discusses some of the factors that influence the morphology of natural crystals and, in so doing, provides a helpful introduction to the modern ideas on crystal growth.

Sunagawa begins by stating that the essential feature of natural crystallization is that crystal growth occurs from a 'solution,' in contrast to the growth of crystals in the laboratory, which may be accomplished by melt, vapor, or solid-state crystallization, as well. In solution growth, important factors affecting crystallization include temperature, the composition of the solution and the crystallizing solid, the nature of the solid-solution interface, the degree of supersaturation of the dissolved phase in the solution, and additional thermodynamic considerations.

Because of the great differences in conditions of crystal growth in nature versus those in the laboratory, the overall morphologies of crystals formed in these two environments are dissimilar. Sunagawa concludes his article with a brief discussion of some of these contrasting features and their causes. *JES*

The mineralogy of pegmatites. G. E. Brown, Jr., *American Mineralogist,* Vol. 67, Nos. 1 and 2, 1982, pp. 180–189.

This article presents a selection of abstracts of papers presented at a conference on pegmatites held in conjunction with the 1981 Tucson Gem and Mineral Show. This conference, sponsored jointly by the Mineralogical Society of America and Friends of Mineralogy, brought together mineralogists and pegmatite experts from the U.S. and several foreign countries. Of the 23 papers presented during this two-day meeting, 17 consisted of descriptions of various pegmatite localities, while the remaining 6 covered more general topics on pegmatite features and genesis. Five of these were of a review nature and only the titles are included in this summary.

Localities described included Llano County, Texas; Marathon County, Wisconsin; San Diego County, California; Cleveland County, North Carolina; Dixon County, New Mexico; several localities in Colorado; Maricopa County, Arizona; Grafton County, New Hampshire; Oxford County, Maine; the Black Hills, South Dakota; and, in more general terms, the Soviet Union, Brazil, Canada, and Namibia. Additional presentations were given on experimental crystallization studies of pegmatite genesis, light stable isotope geochemistry of pegmatities, the origin of color in pegmatite minerals, the phosphate mineralogy of pegmatites, and the role of aqueous vapor in the crystallization history of a pegmatite magma. The abstracts presented at this meeting not only reflect the current level of knowledge of pegmatites, but also demonstrate the type of research work undertaken to better understand these fascinating igneous rocks. *JES*

BOOK REVIEWS

Michael Ross, Editor

BRAZIL: PARADISE OF GEMSTONES

*By Jules Roger Sauer, 136 pp., illus., published by J. R. Sauer, Rio de Janeiro, Brazil, 1982. US$20.00**

Given the importance of Brazil's extraordinary gem wealth in the international marketplace, it is surprising that until now no one book addressing the subject was available to the gemologist. *Brazil: Paradise of Gemstones* is an excellent beginning to the filling of this void. While the book does not go into great detail on each of the various gem species found in Brazil, it does give the reader an adequate introduction. In addition, the book is beautifully illustrated with superb photographs by Harold and Erica Van Pelt.

The text is divided by gem species. For each species, the author gives a brief gemological description, including its possible color range, the derivation of its name, the causes of its color, and the like. Following this gemological background, Sauer goes on to describe the major Brazilian deposits in which the material has been found, along with a brief history. This history may include detail on recent discoveries, such as the 1977 find of unprecedentedly large and fine rubellite crystals near Conselheiro Peña in Minas Gerais. The only distraction to the book, a minor one, is that the table of contents is in the rear; essentially doubling as a brief index.

Brazil: Paradise of Gemstones will be an important introduction to the casual reader, and delightful reading for the gemologist, particularly as a reference for gem localities.

PETER C. KELLER
Director of Education, GIA

THE JEWELLERY BOOK

By Susan St. Maur and Norbert Streep, 198 pp., illus., published by St. Martins Press, New York, NY, 1981. US$9.95

Over 35,000 book titles were published in the United States last year. One would think that publishers would devote capital and energy to books of substance and veracity rather than fluff written by people posing as experts. Given the difficulty some authors have in getting their work published, it is surprising to discover how easily pure drivel finds its way between hard covers.

The English, with their flair for understatement, have always been able to get away with printing comedy under the guise of serious material. The *Jewellery Book* is to the gem industry approximately what Mrs. Malaprop was to the educational system of Great Britain.

The Jewellery Book was supposedly written for the British layperson to give him a better idea of the types of jewelry and a reason to buy jewelry. It is fiction laced with enough facts to fool the layman . . . but for an authentic gemologist, it is fairly good comedy. Not Richard Brindsley Sheridan, you understand; more like Woody Allen's surprising, off-the-wall humor.

Because I am not a gemologist, I could read it much the same way a layman would. As a writer and former jeweler, however, I am appalled at the amount of misinformation. The book was written with two viewpoints (one from each author??) that do not always coincide. On page 29, the authors discuss the "misconception . . . that the name on the box is as important as the piece of jewellry (sic) itself." This would have been their chance to stress the value of a firm's reputation for quality. Instead they state, ". . . trendy names, and the equally trendy prices they charge, are a luxury few of us can afford." Then, on page 57, after discussing the relative merits of buying from larger or smaller stores, they say, ". . . jewellery prices don't vary much from small shop to big shop." Perhaps the English market is different, but most "trendy" stores in the United States are also larger firms, so the two statements appear to conflict. Additionally, the early part of this book seems to support the purchase of quality over nonquality, but chapter 9 is titled "Never Mind the Quality, Feel the Shine."

Some of the more humorous quotes are as follows:

On diamond cutting: "The last stage in diamond cutting (and in the cutting of precious stones, too) is the actual cutting of the facets on the stone," "First, the apprentice will be allowed to do a little harmless polishing. . . ."

On gemstones: "Many natural stones—those which are dug out of the ground—are crystallised. What this means is that they start off as a piece of wood, or other reasonably solid object, and as time goes on get gradually churned down into the depths of the earth until they become fossils. But gemstones have gone a stage further than a fossil; crystallisation is the next process that occurs through intense heat and great pressure. . . . to think that the beautiful stone started life as a rotten chip of wood. . . ."

". . . coral reefs have been fished out of existence all over the world. . . ." "Many people become very worried when they feel they might have been sold a citrine rather than a topaz, or vice versa; but even though the stones are two different things, their values are not dissimilar. . . . either stone will represent the same sort of investment."

Cat's eye and tiger's eye ". . . have roughly the same value." "If you can still see the lines or stripes distinctly marked whichever way you turn the ring, it's a tiger's eye." "Semi-precious stones, especially the less expensive varieties like citrine and cat's eye, are not worth copying as the real thing doesn't actually cost that much more."

Now I am NOT a gemologist, but one of the authors claims to be. If I can see the absurdity of the above, why couldn't they? (One of my gemological colleagues said the information would rate a 35 on a GG exam.) Any jeweler-gemologist should

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**This book is available for purchase at the GIA Bookstore, 1735 Stewart Street, Santa Monica, CA 90404.*

be able to explain gemology to a customer better than this book does.

If you need a laugh, or a good cry over the state of publishing these days, spend $9.95 on this book. You'd be better off, however, taking in a good movie and loading up on popcorn.

H. DAVID MORROW
Retail Jewelry Store Management Course Supervisor, GIA

Editor's note: The credit page of The Jewellery Book *states that Mr. Streep "qualified as a gemologist with the Gemological Institute of America." GIA's education records reveal no such qualification.*

BEYOND THE GLITTER

*By Gerald L. Wykoff, 203 pp., illus., published by Adamas, Washington, DC, 1982. US$17.95**

In *Beyond the Glitter,* Gerald Wykoff attempts to pack "Everything you need to know to buy, sell, care for, and wear gems and jewelry wisely" into 200 pages. "You" means consumers. "Everything" includes history and lore, care, treatments, identification, metals testing, diamond and colored stone grading, and investments.

Mr. Wykoff's tone is generally candid and informal, but many of his statements create an image of the consumer and jeweler as adversaries. The chapter on gem care is thorough and sound, although it contains some information that seems more suited to retail jewelry store employees than to consumers. The chapter on investments is straightforward, and Mr. Wykoff makes some positive statements about treatments and synthetics.

Unfortunately, the book has many weaknesses. Some are related to editing and production; for example, the labels for the facet diagrams on page 36 are scrambled, and many of the photographs are blurred. There are also weaknesses in Mr. Wykoff's gemology. These include references to bubbles in diamonds and silk in rubies intersecting at 140° angles. Picky stuff maybe—the kind people lose points for on the Diploma examination—but they are typical of the types of mistakes in information and interpretation that eventually lead Mr. Wykoff to recommend transparent, faceted rhodochrosite as a jewelry stone alternative to ruby.

The book's weakest aspect, however, is the choice of information presented. In the chapter on metals, Mr. Wykoff details a technique for using nitric acid to test metal content. In his discussion of cutting evaluation, one of the first features Mr. Wykoff tells us to look for is the alignment of upper and lower girdle facets. The fancy-shape section includes the statement: "The point facets should only be about 3° shallower than the adjacent facets. . . ." And in the last chapter we are advised to prepare clarity diagrams of our gems to provide positive identification in case we should ever have to entrust them to a jeweler.

Now, metals testing, cutting evaluation, and plotting all have an admitted place in a comprehensive discussion of gems and jewelry. But presenting specialized techniques, like GIA's visual proportion grading system, is only going to give consumers a false sense of security—or worse. No matter how many cautions you include, it is still dangerous to recommend that people go out and buy nitric acid to test their jewelry. It is unrealistic to expect people with no training in the use of magnifiers to critically evaluate facet alignment or to distinguish between a 34° and a 31° facet angle. And my experience as a Diamond instructor almost makes me chuckle at the thought of clarity plots prepared by people with zero training, experience, or background—except that I know that some jeweler is going to be confronted with one of these plots, along with an accusation of stone switching.

Considering Mr. Wykoff's apparent attitude toward retail jewelers, his factual inaccuracies, and his choice of material, I would say that this book which proposes to take consumers "beyond the glitter" might actually get them *into* trouble.

MICHAEL ROSS
Course Revision Supervisor, GIA

OTHER BOOKS RECEIVED IN 1982

Exploring the Earth and the Cosmos, *Issac Asimov. Crown, 1982; 352 pp., no illustrations; US$13.95.* Nothing about gemology, but reading this exuberant book about the expansion of human knowledge and experience will make you sit back and marvel at the species to which you belong.

Gem and Jewellery Year Book 1982, *ed. V. Kala. Gem & Jewellery Information Centre of India (A-95, Journal House, Janta Colony, Jaipur 302004, India); 854 pp; some black-and-white photographs, line drawings, and maps; US$26.00 (airmail), or US$18.00* (seamail).* The eighth edition of the compendium includes information about the Indian gem and jewelry trade, gemological instruments and lapidary equipment and suppliers, Indian customs regulations, the international gem trade, foreign representatives in India and Indian representatives abroad, gem and jewelry organizations, and taxation. It also includes a directory of Indian suppliers.

Jewellery Today, *Canadian Jewellers Association and Canadian Jewellers Institute, 1982; 359 pp.; 5 color photographs, many black-and-white photographs, some line drawings; US$24.95.** The new text for CJI's jewelry retailing course covers precious metals, diamonds, colored stones, synthetics and imitations, pearls, jewelry manufacturing, rings, chains, flatware, holloware, ceramics, china, glassware, clocks, appraising, merchandising, inventory control, advertising, insurance, and selling. Appendixes give information about CJA and CJI, Canadian precious metals marking regulations, and British hallmarks.

A Pictorial Guide to Fossils, *Gerard R. Case. Van Nostrand Reinhold, 1982; 515 pp; US$29.95.*

GEM NEWS

Stephanie Dillon, *Editor*

MINERALOGISTS ADOPT GEMOLOGICAL CONCERNS

The quadrennial meeting of the International Mineralogical Association took place in Varna, Bulgaria, this past September. A highlight of the meeting was the formation of a new Commission on Gem Materials, with Professor Hermann Bank selected as its leader. Representing 30 member nations, the commission will seek to achieve international accord on gemological nomenclature, to promote gemological research among mineralogists, and to encourage the exchange of information among scholars and laboratory personnel concerning synthetics and treatments.

DIAMOND SOURCE ASSUMPTION ASSAILED

The Third International Kimberlite Conference was also held in September, in Clermont-Farrand, France. The substance of the four-day meeting consisted of reports on geological studies of kimberlites from around the world. Papers presented by two groups of scientists concerning host rock of the West Australian occurrences, particularly Argyle Pipe AK-1, were of universal interest. These reported that the host material is not kimberlite, as scientists have assumed the source of all diamonds to be. Instead, it is composed of two rock types, kimberlitoid and lamprophyre.

EXHIBITS

Smithsonian Institution/Freer Gallery of Art—12th Street and Jefferson Drive, S.W., Washington, DC 20560. Telephone: (202) 357-2627. "Chinese Art of the Warring States Period: Change and Continuity, 480-222 B.C." is a selection of 151 examples of jade ornaments, lacquerware, bronze vessels, fittings, and other metalwork inlaid with intricate gold and silver designs. These are associated both with warfare and with the industrial sophistication and improved transportation systems that were developed during this turbulent era. Opened October 1 and continues through February 15, 1983.

Smithsonian Institution/Cooper-Hewitt Museum—2 East 91st Street, New York, NY 10028. Telephone: (212) 860-6898. "Fabergé: Jeweler to Royalty" consists of over 200 works by Peter Carl Fabergé, which are on loan from British collections, including that of Queen Elizabeth II. As part of the "Britain Salutes New York" celebration of 1983, this exhibit marks the first showing of the pieces in the United States. Presented March 22 through July 10, 1983.

ANNOUNCEMENTS

The Tucson Gem & Mineral Society's 29th Annual Show will be held February 10-13 at the Tucson Community Center, 260 South Church Avenue, Tucson, Arizona. The featured mineral will be cerussite. Educational programs and displays will bring together gem and mineral materials from all over the world. Special displays will include sculptured quartz, agate cameo bowls from Idar-Oberstein, an exhibit of a famous Colorado mining district, minerals from Mibladen, Morocco, and a 667-ct emerald crystal from the Muzo mine. The *Mineralogical Record* will hold silent auctions during the show, as well as its regular auction of the 50 best contributions on February 12. A joint symposium of Friends of Mineralogy and the Mineralogical Society of America will be held in conjunction with the show February 13 and 14. Further information is available from the Tucson Gem & Mineral Show Committee, P.O. Box 42543, Tucson, AZ 85733. Please visit the GIA/*Gems & Gemology* booth while you're there!

The American Gem Trade Association Fair and Conclave will be held February 5-10 at the Doubletree Hotel, 445 South Alvernon Way, Tucson, AZ 85711. "Put a little color in your life" is the theme of the association's second annual show, featuring natural, colored gemstones. There will be seminars, social events, and a business meeting of the association. Further information may be obtained by contacting Chairwoman Maureen Jones at (213) 990-2411, or Manager Don Elwood at (213) 703-8671.

The Accredited Gemologists Association will hold an educational seminar February 10 and 11 at Palo Verde Plaza Holiday Inn, 4550 South Palo Verde Boulevard, Tucson, Arizona. Speakers will address the association on such issues as color grading, appraisals, gemological instruments, and synthetic stones. Further information may be obtained from Joseph W. Tenhagen, President, Accredited Gemologists Association, 36 N.E. First Street, Suite 419, Miami, FL 33132. Telephone: (305) 372-0872.

The Israel Precious Stones & Diamonds Exchange, together with the **Israel Emerald Cutters Association,** will host the International Precious Stones Congress, April 11-16, 1983, in Tel-Aviv, Israel. The program will include lectures, professional sessions, and panel discussions concerning gem mining, cutting, marketing, and other gemological issues. There will be exhibits of professional publications and contemporary instrumentation, as well as lapidary tours. The congress will be held at the Tel-Aviv Hilton. Information may be obtained from the Congress Committee, Israel Precious Stones & Diamonds Exchange, 1 Jabotinsky Street, Ramat-Gan 52520, Israel. Telephone: (03) 256112. Telex: 341667 ATT PR STONES. "Israel Jewelry Week" will be celebrated concurrently, from April 11-14, by over 100 exhibitors of jewelry at the Laromme Hotel in Jerusalem.

Stamps honoring four gems of the Smithsonian collection may be issued as a block in 1984. Mrs. Lillian Turner, chairman of the stamp committee for the American Federation of Mineralogical Societies, suggests that those who wish to promote the issuance send requests to: Postmaster, 475 L'Enfant Plaza, S.W., Washington, DC 20260.

Gems & Gemology welcomes news of exhibits and events of a gemological nature. Please contact Stephanie Dillon, Gemological Institute of America, 1660 Stewart St., Santa Monica, CA 90404. Telephone: (213) 829-2991.

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Index to Volume 18

Numbers 1-4 1982

SUBJECT INDEX

This index gives the first author (in parentheses) and *first page* of the article or Gem Trade Lab Notes (GTLN) section in which the indexed subject occurs. The reader is referred to the author index for the full title and the coauthors, where appropriate, of the articles cited.

AUTHOR INDEX

This index lists, in alphabetical order, the names of authors of all articles that appeared in the four issues of Volume 18 of *Gems & Gemology*. Full citation is provided under the first author only, with reference made from joint authors.

Indexes prepared by Dona Dirlam