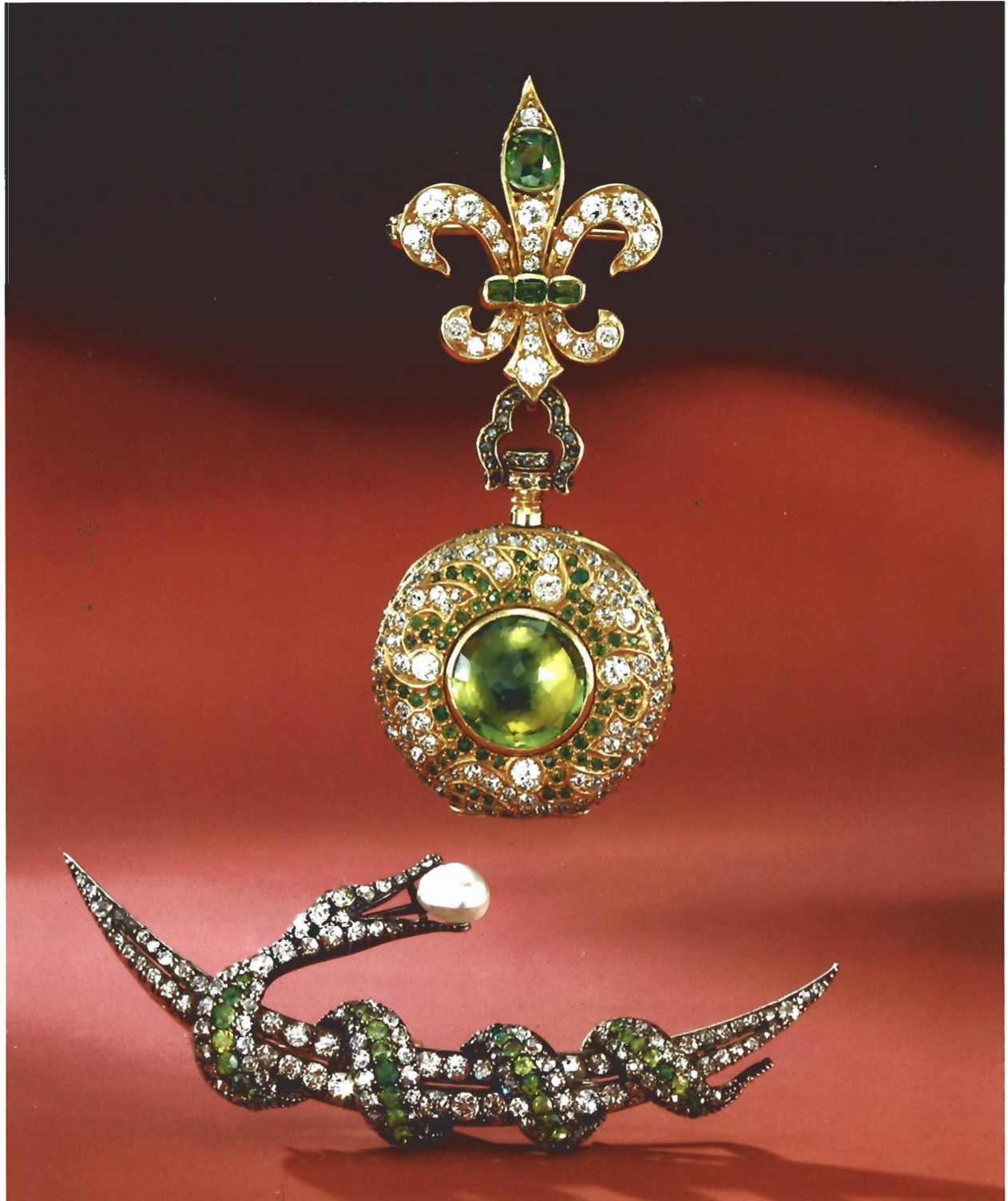


Gems & Gemology

VOLUME XXI

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Gems & Gemology

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ABOUT THE COVER: Historically, garnets have been used in a variety of fine jewelry pieces. Demantoid garnets were particularly popular around the turn of the century, as illustrated by the approximately 3-in. (7.5 cm) combination chatelaine/watch and similarly sized brooch shown here. In recent years, however, the introduction of new types of garnets from a variety of localities has created identification problems for the gemologist. The article by Carol M. Stockton and D. Vincent Manson in this issue presents the results of a five-year study of the various types of gem-quality garnets, and proposes a new classification system. Jewelry courtesy of Ebert-Richter, Los Angeles, CA, and G. R. Hansen, St. Louis, MO. Photograph © 1985 Harold and Erica Van Pelt—Photographers, Los Angeles, CA.

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Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in the Spring 1985 issue of the journal, or contact the editor for a copy. Letters on articles published in *Gems & Gemology* and other relevant matters are also welcome.

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Why You Need to Know

In the early 1930s, Robert Shipley was shocked to learn that a number of jewelers in Los Angeles had been buying zircons represented as diamonds; they simply lacked the knowledge to tell one stone from the other. On the basis of this and similar experiences in the trade, Shipley started the educational program that grew into the Gemological Institute of America that we know today. Fifty-five years later, however, while thousands of jewelers and gem buyers have been educated by GIA and other respected programs, the technology and ingenuity of deception have also advanced radically. Although much has been done to tackle the problem of deception, it continues to plague the gem industry worldwide; today, more than ever, you need to know.

In the process of publishing the article on gemstones from Afghanistan that leads off this issue, we approached some dealers who had recently returned from the Pakistan trading area to see if they would lend us Afghan gems for photography. One respected dealer offered us a beautiful 3-ct ruby that he had purchased personally from an Afghan miner. Imagine our surprise—and his—when a cursory study under the microscope revealed curved striae, a telltale sign of a synthetic stone. But the shock was probably no less in this case than in that of the dealer who purchased a fine "emerald" crystal on Bogotá's famed Avenida Jiménez, only to learn later that it was actually a colorless beryl that had been hollowed out and filled with a green plastic. Or the dealer who purchased several colored diamonds from a trusted supplier, only to learn from the laboratory that most of the stones had been irradiated.

At one time, dealers felt a certain security in buying "from the source" or from a "respected supplier." But these suppliers may themselves be victims, for today many of the sources have become as sophisticated in deception as the materials they sell. Other examples abound. One colleague actually plucked a "ruby" crystal from the miner's gem basket in Burma; only later did he learn that he had purchased a Verneuil synthetic. A Brazilian dealer of fine amethyst, who had purchased tens of thousands of carats from a respected supplier for many years, found on submitting one 5,000-ct parcel to the laboratory that 90% of the stones were glass. This same dealer received a shipment of crystals that had all of the characteristics of having been hammered from the geode; they were indeed "hammered," but hammered crystals of synthetic amethyst.

In today's sophisticated climate, the only true security that the gem buyer—whether dealer at the source or retailer buying from wholesaler—has is his or her knowledge of gems, of the various synthetics, simulants, and treatments available and how to identify them. To this end, we cannot emphasize enough with our readers the importance of keeping up-to-date with new developments in the gem trade. Attend lectures on new materials and techniques, read the professional gemological literature, maintain the skills you've learned as a gemologist and constantly hone them.

Most importantly, if you don't know, admit it. Either go to someone (e.g., a laboratory) who does, or wait until you can otherwise verify the identification. If it sounds too good to be true, it probably is. But you can only determine that if you *know*.

Alice S. Keller, Editor

A STATUS REPORT ON GEMSTONES FROM AFGHANISTAN

By Gary W. Bowersox

Although Afghanistan has historically been well known for its lapis lazuli deposits, significant amounts of fine emerald, tourmaline, kunzite, and some rubies are now emerging from that embattled nation. Emeralds come primarily from the Panjshir Valley, northeast of Kabul. Large amounts of green, blue, and pink tourmaline, as well as considerable quantities of kunzite and some aquamarine, have been taken from the pegmatites of the Nuristan region, east of Panjshir. Smaller quantities of fine ruby have been found in the Sorobi region, between Jalalabad and Kabul. The occurrence, mining, and distribution of these gem materials are summarized, as are their gemological properties. Lesser amounts of garnet, amethyst, spinel, and morganite have also been located. The prospects for future production of emeralds and pegmatite gems, in particular, are excellent.

ABOUT THE AUTHOR

Mr. Bowersox is president of Gem Industries, Inc., in Honolulu, Hawaii; he has been buying and cutting Afghan gem materials for over 12 years.

Acknowledgments: The author particularly wishes to thank the following people for providing information used in this article: Aisha Rind, Badshah, Maula Mohammad Bieg, Haji Gulam Haider, Haji Mohamuddin, Fazal Uddin, and V. Prokofiev. Dr. James Shigley and John Koivula, of the GIA Research Department, contributed information to the sections on geology and gemological properties.

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Although the political situation in Afghanistan continues to be very unstable, Afghan miners remove many thousands of carats of fine gems each year from that country. In addition to the historically famous deposits of lapis lazuli, significant quantities of emerald, tourmaline, and kunzite, among other gem materials, have emerged from the Hindu Kush region of Afghanistan within the last few years. Small amounts of fine ruby are also being mined. Most of these gem materials are of very high quality (figure 1). While much has been written about the lapis lazuli from Sar-e-Sang (e.g., Wyart et al., 1981), relatively little has been published about these other gems. To help fill some of the gaps in our knowledge of this area, this article presents a current status report on several Afghan gem materials—emerald, tourmaline, kunzite, and ruby—including the locations of the mines, mining methods, gemological properties, and some production figures.

THE HINDU KUSH GEM-PRODUCING AREAS

The mines that have recently produced gem material are for the most part in the northeastern portion of the country, north and east of Kabul, the capital of Afghanistan (figure 2). Emeralds have been found primarily in the Panjshir Valley.* Pegmatite gems—tourmaline, kunzite, and aquamarine—have been found in the Nuristan region, crossing the provinces of Laghman and Konar. Rubies have been found in the southern portion of the Sorobi district, in Kabul Province.

The topography of the region is dominated by the towering Hindu Kush mountain range (figure 3). These mountains form the western end of the Himalayas, which stretch eastward across northern Pakistan and India. The Hindu Kush range is one of the most rugged areas of the world, with mountains reaching up to 6,000 m (19,500 ft.) separated by narrow, steep river valleys. The road network



Figure 1. The 13.66-ct blue tourmaline in this pendant exemplifies the fine quality of gem material currently being produced from Afghanistan. Pendant courtesy of Norma Morein. Photo © Harold & Erica Van Pelt.

is limited, and many areas in this part of Afghanistan are inaccessible except by foot. This, combined with a climate that ranges from extremely cold winters to hot, dry summers, contributes to the inhospitability of the region.

Despite their remoteness, both the Hindu Kush range and the adjacent Karakoram range in neighboring Pakistan have been the sites of spectacular finds of gemstones during the last 15 years.

**Note in figure 2 that Panjshir Valley has been placed in Kapisa Province, on the basis of the Rand-McNally (1982) and other recent maps used as references to develop this one. However, many geologic sources refer to Panjshir Valley as being in Parvan Province. Note also that the spellings for Afghan place names used in this article are those adopted by Rand-McNally (1982). We have chosen this source for the sake of consistency, although these names, too, often vary greatly from one reference to another.*

In addition to earlier descriptions of Panjshir emeralds (Neilson and Gannon, 1977) and of pegmatite gemstones from Nuristan (Bariand and Poulten, 1978), important discoveries of tourmaline, beryl, corundum, and other gemstones have been made in Pakistan in the Gilgit area (Kazni et al., 1985), in the Swat and Hunza valleys northeast of Peshawar (Gübelin, 1982), and in Kashmir (Atkinson and Kothavala, 1983). These areas of Afghanistan and Pakistan are located in one of the most geologically dynamic regions of the world—at the juncture along which the Indo-Pakistan and Asian crustal plates collided to give rise to the Himalayas. The geology of this region is quite complex, and it has been investigated in detail only recently (for further information, see Weipert et al., 1970; Lapparent, 1972; Fuchs et al., 1974; and Wolfart and Wittekindt, 1980). These

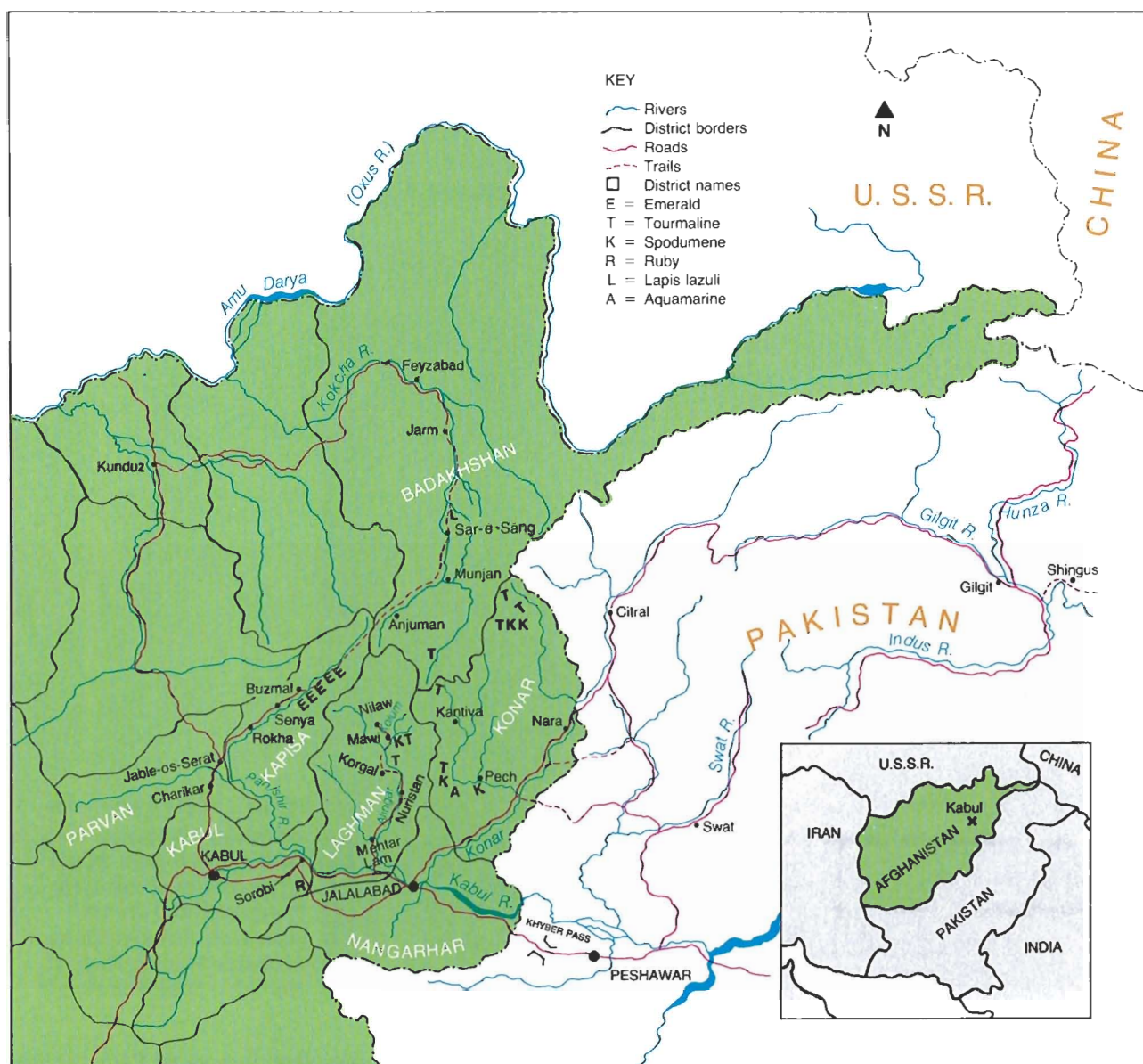


Figure 2. The northeastern provinces of Afghanistan—bordered by the USSR, China, and Pakistan (see inset)—encompass one of the most important gem-producing regions in the world today. Some of the principal localities for emerald, tourmaline, spodumene (kunzite), ruby, lapis lazuli, and aquamarine are labeled E, T, K, R, L, and A, respectively, on the map.

investigations indicate that the Hindu Kush area represents the western end of a succession of important gem-producing regions that stretch all along the Himalayas through Afghanistan, Pakistan, India, Nepal, and into Burma. Rossovskiy and Konovalenko (1976) have suggested that these separate regions are in fact part of a much larger "South Asian" gem pegmatite belt whose formation can be linked to the sequence of orogenic events that resulted in the formation of the Himalaya range.

Although gem beryl was found during the ar-

cheological excavation of an ancient Greek city in northwestern Badakhshan, organized mining of beryl, tourmaline, kunzite, and ruby in Afghanistan dates only from the early 1970s (Dunn, 1974; Bariand and Poullen, 1978). Ostensibly the mines are under government jurisdiction, but most active mining and selling is done by independent miners, usually local tribesmen. Because of the volatility of the current political situation in Afghanistan, the gem-mining areas around Kabul and Jalalabad are virtually inaccessible to foreign gem buyers. Once mined, the uncut crystals of



Figure 3. The formidable Hindu Kush mountains provide a harsh environment for gem mining, and many remote gem localities are inaccessible except by many miles of travel by foot. The Hindu Kush range forms the western end of the Himalayas and stretches from central Afghanistan to the northern tip of Pakistan. The severe climate in these mountain regions further restricts gem mining. Photo © Mike Zens.

emerald, tourmaline, spodumene, etc., are smuggled across the border into Pakistan, primarily into tribal Agency areas such as Bajaur (surrounding Peshawar), where most of the trade in Afghan gems is conducted. To enter Afghanistan, or even to travel along the frontier Agency areas of northern Pakistan, one must have special permission from both the government and the local tribal leaders. Such passes are nearly impossible to obtain, and even then there is no guarantee of safety.

This report describes some of the gem materials currently originating in Afghanistan. It is based largely on the author's many years of experience dealing with Afghan gemstones, his previous travels within the country to purchase gemstones,

and his recent (September 1985) discussions in Pakistan with several prominent Afghan miners.

THE PANJSHIR EMERALDS

Several thousand carats of fine-quality emeralds, some of which are very similar in color and quality to those from the famous Muzo mine of Colombia, have emerged from Afghanistan in recent years (figure 4). The emerald-mining area of the Panjshir Valley is located approximately 110 (air) km (70 mi.) northeast of Kabul (again, see figure 2). The Panjshir River, a tributary of the Kabul River, bisects a portion of the Hindu Kush mountain range. The emerald-mining district lies along the southern slopes of the Hindu Kush, south of the Panjshir



Figure 4. The 1.28-ct emerald in this lady's ring is typical of the dark green material found in the Panjshir Valley mines. Stone courtesy of Gem Industries, Inc. Photo © Tino Hammid.

River. It currently encompasses six active mines—Darkhenj, Mikenj, Butak, Buzmal, Bakhi, and Darun (Neilson and Gannon, 1977).

Access, Geology, and Mining. Although travel in this area is extremely dangerous at the present time, access to Panjshir from Kabul is fairly straightforward. Travel north by field vehicle 58 km to Charikar. From Charikar, travel 14 km north to Jable-os-Seraj, then 35 km northeast along the north side of the Panjshir River to Rokha, then another 29 km to Senya, and—for the last 19 km—by a poor dirt road to where it ends at the village of Buzmal (Neilson and Gannon, 1977). The Panjshir Valley is densely populated. The emeralds occur at an elevation of 3,000–4,000 m, requiring that the miners walk several hours up the rough slopes (30°–40° angle) as there are no horse or mule trails.

The Panjshir emerald locality has been actively mined only during the last 10 years, with the greatest activity since the early 1980s, although the deposit reportedly was found by Russian geol-

ogists in 1970 (Bariand and Poullen, 1978). Within this district, the emeralds occur along small replacement or fracture-filling veins. According to Neilson and Gannon (1977), the veins cut through host rocks consisting of metamorphosed limestones, calcareous slates, phyllites, and micaceous schists of Silurian-Devonian age (400 million years). The veins themselves consist mainly of quartz and albite, and are apparently related in origin to a local igneous intrusive rock described as a quartz-feldspar porphyry. When followed in an exposure, these veins vary in thickness up to 15 cm. Emerald mineralization along and within the veins is distributed sporadically, but is often associated with pyrite, which the miners use as an indication of the emerald. The emerald is believed to be of hydrothermal origin, and apparently resulted from a chemical reaction between solutions traveling along the veins and the enclosing host rocks. According to Mr. Haji Mohamuddin, one of the discoverers of the Buzmal mine, approximately 1,000 workers are mining emeralds throughout the valley; 100 men regularly work Buzmal.

Dynamite is used first to identify where in the host rock the emerald crystals are most likely to be found. The bombings that frequently occur in this area occasionally perform the same function. Using picks and shovels, the miners dig in pits as shallow as one meter and as deep as several meters to extract the individual crystals or specimens. In spite of the extreme weather conditions, the mines are worked virtually all year, the political situation permitting.

Figure 5. This parcel of 87 Afghan emeralds weighs a total of 140.9 ct and displays the range of colors found in the Panjshir material. Stones courtesy of Gem Industries, Inc. Photo by G. W. Bowersox.



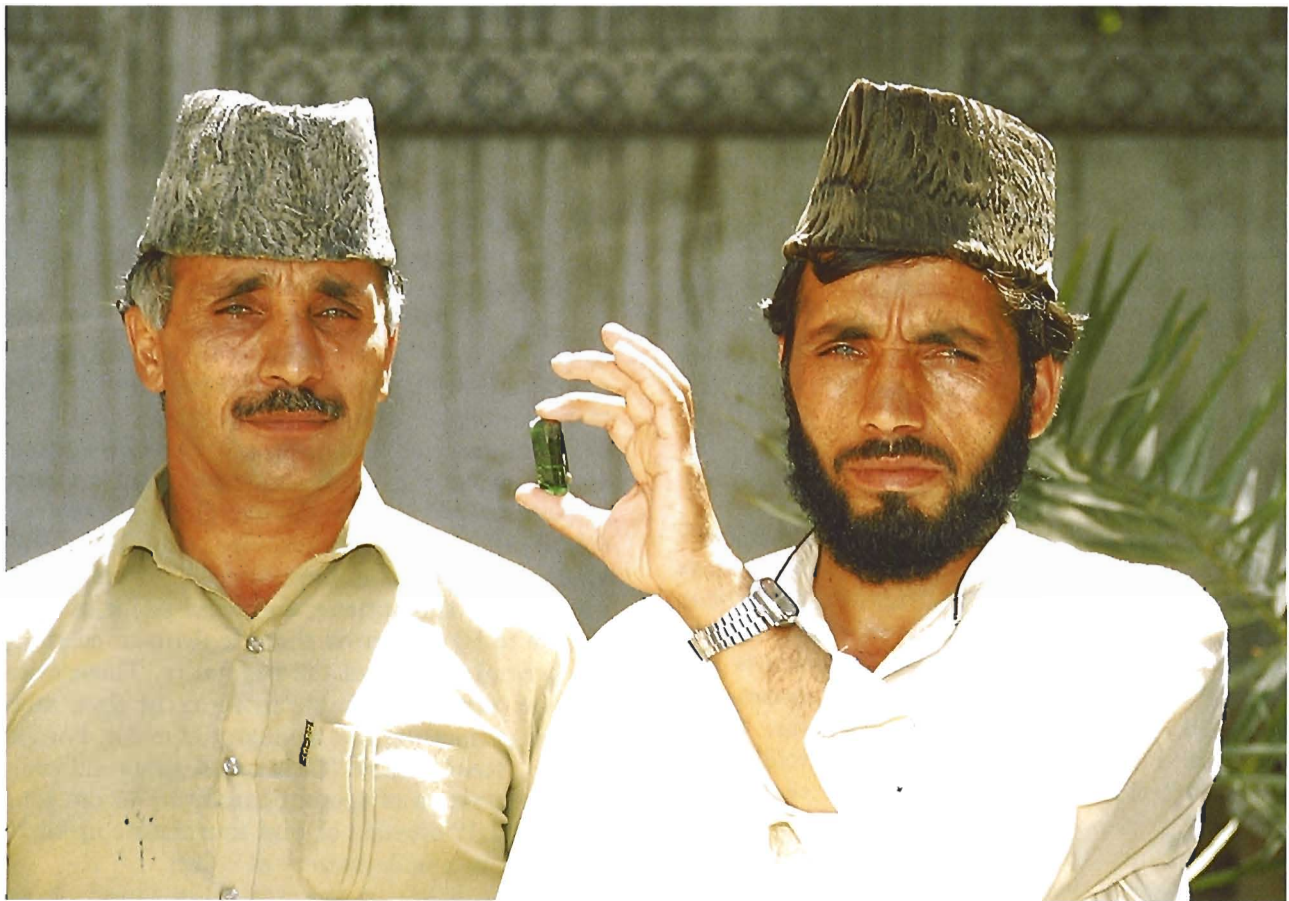


Figure 6. Hâji Mohamuddin (left) and Fazal Uddin (right), owners of the Buzmal emerald mine, display the largest specimen (190.5 ct) from a 374.5-ct parcel of 10 Buzmal emerald crystals that they brought from the Panjshir Valley to Pakistan. Photo by G. W. Bowersox.

Description of the Material. In general, the Panjshir emeralds are a rich dark green (figure 5). The finest stones are similar in color to the fine emeralds found at the Muzo mine in Colombia. The local miners claim that the Panjshir emeralds of the best color and quality come from the Mikenj and Darkhenj mines.

Gem-quality crystals over 10 ct are common. In fact, a lot of 10 crystals weighing a total of 374.5 ct was recently recovered from the Buzmal mine. The largest of these crystals weighed 190.5 ct (figure 6). Overall, the Panjshir material is larger and cleaner than emeralds found in the Swat (see Gübelin, 1982) and Gilgit regions of Pakistan.

Gemological Properties. A study of the few crystals and cut stones made available for this purpose showed the physical and optical properties to be quite normal for emerald: refractive indices, 1.578 and 1.585 (± 0.005); S.G., 2.71 (± 0.02); inert to ultraviolet radiation; and a typical spectrum with

sharp lines at 682, 679, 660, 646, 635, 612, 477, and 472 nm, and a broad absorption band between 560 and 600 nm. When the crystals were viewed with the microscope, two- and three-phase inclusions, growth zones, and fracturing were visible. It is interesting to note that the refractive indices and specific gravity of this material are somewhat lower than those for emeralds from the nearby Swat Valley in Pakistan (Gübelin, 1982).

Distribution and Production. Most of the Panjshir emeralds are transported (year round) in rough form to refugee camps in northern Pakistan. The trip takes approximately 20 days; all travel is by foot. The border area is particularly dangerous because explosive devices have been scattered throughout. From these camps the stones are purchased by Pakistan buyers from Karachi or by the very few Western buyers who travel to the area.

During the three weeks the author was on the Afghanistan border in September 1985, he viewed

approximately 4,000 carats of cuttable gem-quality emeralds from Panjshir. According to the miners with whom he spoke, production of emerald continues on a regular basis despite the war, and prospects for the future seem excellent in terms of the emerald resources available.

Emeralds have also been reported from Budel, in Nagarhar Province, south of Jalalabad (Afzali, 1981). The crystals appear to be relatively small (1–2 cm maximum); little else has been published on this locality.

TOURMALINE AND SPODUMENE FROM THE NURISTAN REGION

Literally hundreds of thousands of carats of good, gem-quality tourmaline and fine kunzite have emerged from the Kolum district of the Nuristan region northeast of Kabul since active mining began there in the early 1970s. This area is also known for its production of fine aquamarine (Bariand and Poullen, 1978; Sinkankas, 1981); however, because the author has had little experience with this material, and has not seen much recently, it is not covered in detail here.

The tourmalines and kunzites are found in pockets within the pegmatites that dot the Nuristan region (figure 2). The most active mines currently are Mawi and Suraj. In addition, Nilaw and Korgal have historically been important (Bariand and Poullen, 1978); Rossovskiy et al. (1978) report that between 1973 and 1975, more than 1,260 kg of gem-quality kunzite was mined from the Kolum district.

Access, Geology, and Mining. Access to this sparsely populated region is difficult even during peacetime conditions. From the Kabul–Jalalabad road go due north to Mehtar Lam approximately 20 km and then 40 km northeast to the village of Nuristan. The passable road ends several kilometers past Nuristan, and all further travel to the mines must be by foot. Bariand and Poullen (1978) report that they had to travel two full days along narrow gorges and rocky trails to reach the deposit at Nilaw.

The key geological features of the Nuristan region have been summarized in Bariand and Poullen (1978). The rocks of this area are quite varied, and include metamorphic (gneisses, schists, quartzites, and migmatites) and igneous (gabbros, diorites, and granites) rock types. Details of the regional geology can be found in Fuchs et al. (1974) and in Wolfart and Wittekindt (1980).

Gem-bearing pegmatites in Nuristan were first studied in the early 1970s by Soviet geologists (Rossovskiy et al., 1976; Rossovskiy et al., 1978; Rossovskiy, 1981). A number of separate pegmatite localities are known, but the most important gem producers seem to be those north of the village of Nuristan at Nilaw, Suraj, Mawi, and Korgal.

The pegmatites vary greatly in size and shape—in veins or lenses up to 40 m thick and up to several kilometers long. The pegmatites range from simple unzoned bodies to those that have complex internal zonation, but the latter group appear to be the more important gem sources. Major minerals include quartz, albite, microcline, schorl tourmaline, muscovite, and lepidolite, along with various minor phases. Crystals of gem tourmaline, spodumene, and beryl occur in cavities up to 50 cm across that are distributed along the central portion of the pegmatite. These crystals are quite remarkable in terms of their size, crystal perfection, and diversity of color. For example, Rossovskiy (1981) describes tabular, gemmy crystals of spodumene up to 45 cm long and “pencil” crystals of gem tourmaline up to 20 cm, both in a wide variety of colors.

For the most part, the crystals are found in soft, powdered clay that fills pockets within quartz-rich zones in the pegmatite. While the kunzite and tourmaline crystals usually occur in close proximity (within a few meters) of each other, only occasionally are the two gem minerals found in the same pocket. Because both are, for the most part, found *in situ* in the primary pegmatite, the crystals are usually well formed and complete.

Approximately 500 miners work the Nuristan region on a daily basis. To penetrate the hard pegmatite, they commonly use large drills. The gem-bearing areas of the pegmatite are usually encountered between 11 and 20 m below the surface. When they reach a pegmatite pocket, the miners remove the gem crystals by hand, using only a few small tools to scrape away the encasing clay. As with the emerald mines in Panjshir, the Nuristan miners usually work year round, in spite of the severe weather conditions that commonly plague the area.

Description of the Material and Gemological Properties. *Tourmaline.* Gem tourmaline from Nuristan occurs in an astonishing array of colors—various shades of pink (figure 7), green (figure 8), blue (see figure 1), and multicolored.

Bariand and Poullen (1978) describe the intense shades of blue and green tourmaline as the most valued. The cuttable crystals, which range up to 15 cm in length and 4 cm in width, also represent magnificent mineral specimens in themselves. For the most part, these crystals are well formed, often clean and free of inclusions and fractures, and, at the time they are purchased for cutting, are free of matrix. Color zoning perpendicular to the length of the crystal varies from sharp color transitions to a smooth grading of one color into another. Most of the crystals examined in this study were not color zoned.

Some data have been published on the Nuristan tourmalines. Leckebusch (1978) reported chemical compositions of these tourmalines, which are elbaïtes, and related the color zonation in individual crystals to variations in chemistry. Dunn (1974) examined a range of tourmalines from this area, in particular the colorless crystals, or achroïtes. For pale to deeply colored crystals, he reported refractive indices of 1.617 and 1.639 (± 0.003) with no particular correlation of these values with color. For the achroïtes, the indices were 1.615 and 1.633. The specific gravity ranged from 3.02 to 3.07.

Examination of a parcel of green, blue-green, and blue tourmalines revealed refractive indices of 1.619 and 1.639 and specific-gravity values of 3.04–3.09. The crystals displayed grayish blue to greenish blue pleochroism. They were inert to



Figure 7. This 200-ct carved rubellite exemplifies some of the finest tourmaline produced by the Nuristan region. The pendant was carved by Hing Wa Lee. Photo © Harold & Erica Van Pelt.



Figure 8. The intense green of this 12.25-ct cut tourmaline and accompanying 13 × 19 mm gem-quality crystal is one of the exceptional colors typical of the best Afghan material. These specimens are also representative of the high clarity frequently encountered in Nuristan tourmalines. Stones courtesy of Afghan Gems, San Francisco, CA. Photo © Harold & Erica Van Pelt.

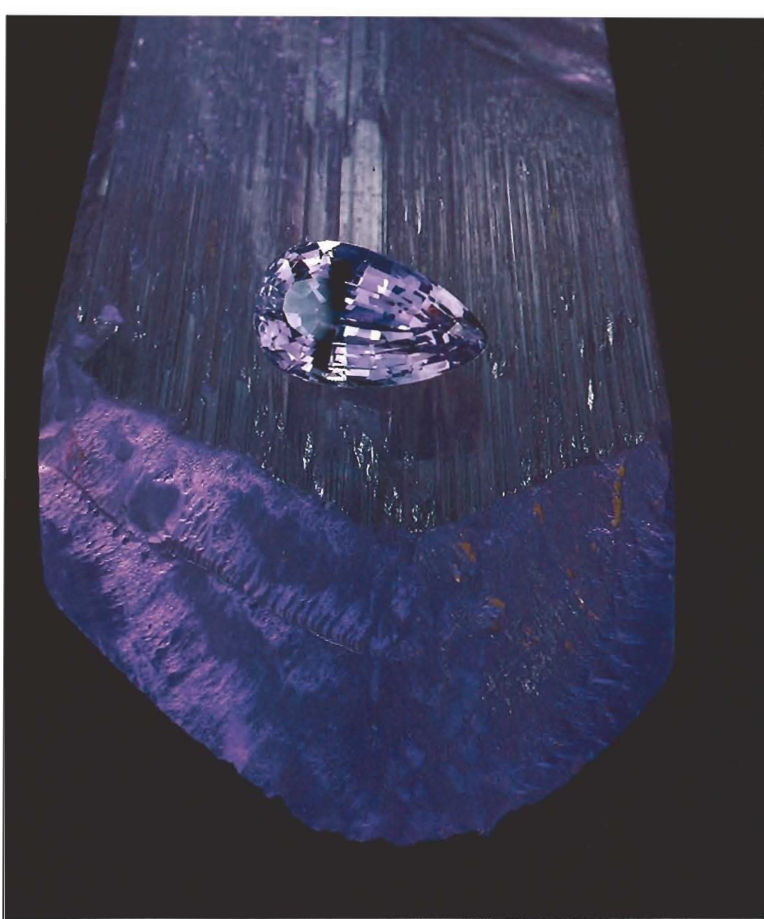


Figure 9. The Nuristan region also produces some of the finest kunzite crystals ever found, as can be seen from the 1243.7-gram crystal depicted here with a 45.07-ct pear-shaped gem cut from similar rough. The crystal displays its most intense color as viewed here along the c-axis. Stones courtesy of Gem Industries, Inc. Photo © Harold & Erica Van Pelt.

long- and short-wave ultraviolet radiation, except for some of the color-zoned crystals that were weakly fluorescent with a chalky bluish color under short-wave at the pale end of the crystal. Two-phase inclusions, fractures, and color zoning were visible with the microscope. In the hand spectroscope, bands at 495, 490 and 440 nm were present in the blue crystals, with an additional band at 540 nm present when the stone being examined was oriented perpendicular to the c-axis. The spectra displayed total absorption above 598 nm. The most distinctive feature of these tourmalines is their attractive blue to green color.

Spodumene. The spodumene crystals from the Nuristan region are among the finest examples of this mineral ever found (figure 9). Many details on the pegmatite deposits of spodumene are given in Rossovskiy et al. (1978) and Bariand and Poullen (1978). The transparent, gem-quality spodumene crystals from Nuristan come in a wide range of

colors—purple and pink (figure 10), as well as blue, green, and yellow. Some of these crystals are up to one meter in length. In general, they are well formed, with large, flat crystal faces, relatively sharp edges, a tabular shape, and are often twinned. As with tourmaline, the spodumene crystals are free of any attached minerals at the time they are sold to gem buyers. As is typical of spodumene, which is pleochroic, the crystals from this area display different hues when viewed in different orientations, with the strongest color for light passing parallel to the long direction (c-axis) of the crystal. Dunn (1974) describes some of the crystals as color zoned, but the crystals examined for this paper were more or less of uniform color.

From the study of a parcel of light pink spodumene crystal fragments and several additional faceted stones, refractive indices of 1.659 and 1.677 (± 0.003) and specific-gravity values of approximately 3.20 (± 0.02) were found. These fragments were pleochroic from brownish pink to pink. No features were visible in the hand spectroscope. When exposed to long-wave ultraviolet radiation, the fragments displayed a strong orangy

Figure 10. These three marquise-cut kunzites exhibit the variety of natural hues that are found in the Nuristan material. Counterclockwise from the top, these gems weigh 290.87, 58.52, and 40.88-ct, respectively. The stones are courtesy of Meredith Mills, Casper, WY. Photo © Harold & Erica Van Pelt.



pink fluorescence. When exposed to short-wave ultraviolet radiation, they exhibited a strong bluish pink fluorescence with a red phosphorescence that lasted for about one minute. When viewed with the microscope, the spodumene fragments revealed three-phase inclusions, growth tubes, and cleavages, and displayed twinning. In general, these properties are identical to those reported for Afghanistan spodumene by Dunn (1974) and Rosovskiy (1981).

Most spodumene exhibits the property of tenebrescence, which involves a reversible darkening and lightening of its color with changes in conditions (Claffy, 1953). Pure spodumene is colorless; the various colors (pink, purple, green, yellow) are due to the presence of trace elements such as manganese and iron. Manganese substitutes for silicon, and iron for aluminum, in the spodumene crystal structure. According to Hassan and Labib (1978) and Nassau (1983), a darkening of the color of spodumene to pink or purple (kunzite) can be brought about by exposure to a source of high-energy radiation (gamma or X-rays) that removes an electron from the manganese and changes its oxidation state from 2^+ to 3^+ . Further irradiation produces a coupled oxidation-reduction reaction involving both iron and manganese to turn the pink spodumene green.



These radiation-induced color changes are thermally unstable, and the color-change sequence described above can be reversed by exposure to daylight, ultraviolet radiation, or moderate heat of a few hundred degrees Celsius. The exact color-alteration behavior of spodumene, and the relative persistence of radiation-induced colors, will vary depending on the nature of the trace elements and the color-treatment history of the stones in question. Because it is colored by chromium, which in spodumene is not susceptible to oxidation or reduction, hiddenite does not exhibit changes in coloration under similar conditions.

When mined, spodumene emerges from the ground with a blue-violet or green color. This suggests that the crystals have been exposed to some natural source of radiation that produced these colors by the mechanism described above. According to the miners, leaving the crystals in the sun for several days, often after having boiled them in water, is sufficient to turn the material to an attractive purple or pink color. Fade tests were con-

ducted to document the thermal stability of the purple kunzite, and determined that heating crystal fragments to temperatures of 400°C for six hours was adequate to entirely bleach the pink color. Exposure of several pieces from a single pink crystal to direct sunlight produced fading to virtually colorless within several days (less than a week). As described above, the pink color can be restored by re-irradiation.

Distribution and Production. The mined crystals of tourmaline and spodumene are carried on the backs of the miners, who usually travel by foot approximately 560–640 km (350–400 mi.) over rough mountain terrain and through a border area dotted with land mines to reach Pakistan. The author purchased most of his material from miners whose primary trading area is the Bajaur Agency.

The Nuristan region has produced hundreds of thousands of carats of gem-quality tourmaline since 1980. The author estimates that approximately 2,000 kg of fine kunzite are being mined each year.

JEGDALEK RUBY

Although very little mining is being conducted at the current time because the area is so volatile politically, a number of fine rubies have been mined from the southern portion of the Sorobi district (again, see figure 2). Local miners refer to the main deposit as the Jegdalek mine. Although little research has been done on the geology of the ruby-producing area and the occurrence of the rubies, it is known that they are usually found *in situ* in marble cut by granitic intrusions of Oligocene age (Afzali, 1981). The crystals range in color from a light purple-red to a deep "pigeon's blood" red (figure 11). The best-quality stones are similar to those found at Mogok, in Burma. The author has seen fair-quality faceted stones as large as 10 ct, although top-quality rubies from this area rarely exceed 5 ct.

While current supplies appear to be small—the author saw fewer than 100 ct of gem-quality material during his most recent visit—communications from the miners indicate that the reserves are significant. Larger amounts of this material will most likely be available once the political situation in the area stabilizes.

Gemological Properties. Examination of a small number of cut stones and crystal fragments of ruby



Figure 11. The 1.36- and 1.70-ct rubies in this photo are representative of the finest "pigeon's blood" color from Jegdalek. Stones courtesy of Gem Industries, Inc. Photo © Tino Hammid.

produced the following properties of a typical stone: refractive indices, 1.762 and 1.770; specific gravity, approximately 4.00; moderate to strong fluorescence to long- and short-wave ultraviolet radiation; and purplish red to orangy-red pleochroism. In the hand spectroscope, absorption bands were visible at 469, 473, 660, 668, 693, and 694 nm, and a broad band from 520 to 560 nm. Under the microscope, fractures, small unidentified crystals, and needles thought to be boehmite were generally abundant. Some twinning was also noted. The most interesting feature was a strong blue color zoning present in some of the rubies (figure 12).

OTHER GEM MATERIALS FROM AFGHANISTAN

Much has been written about lapis lazuli from Afghanistan (e.g., Wyart et al., 1981). In recent years, however, the production and supply of lapis from Badakhshan has been greater than ever before, and many examples of superb material can be seen in gem markets worldwide (figure 13). In 1981, reserves of 1,300 tons were estimated (Afzali, 1981).

A single deposit of garnets has been found at Pachighram, in Nangarhar Province. Well-formed crystals of dark red almandine occur in Proterozoic schists. The garnet-bearing schists cover an area approximately 160–240 km wide and 800–1,100 km long (Afzali, 1981). However, the author has not seen any Afghan garnet for sale in the Pakistan trading centers during the last three years.

Small quantities of aquamarine are currently being mined in the area of Gur Salak, in Konar Province. The rough material occurs in pegmatites as well-formed crystals up to 2 cm thick and 7.5 cm long (1 × 3 in.). The crystals range in color from light blue to dark blue as well as various intensities of blue-green (figure 14).

The author observed a few morganite crystals during his most recent trip. These crystals, which ranged in color from pink to brownish pink to peach, were reported by Afghan miners to come from the mine at Mawi, in the Nuristan region. Spinel has historically been reported from Badakhshan, northeast of the lapis mines (Scalisi and Cook, 1983), but little spinel has been seen in recent years. A 1970s edition of *Afghan Development in Brief*, published by the Afghan government, reported that amethyst had been found in both Badakhshan and Kandahar. The author has not, however, seen any of this material in the local gemstone market.

CONCLUSION

Significant quantities of a variety of high-quality gem materials are now emerging from northeastern Afghanistan. More material than ever before

Figure 12. Unusual zones of strong blue color can be observed in some rubies from the Jegdalek mine. Dark-field illumination, magnified 35×. Photo by John Koivula.





Figure 13. The fine lapis lazuli currently coming from Afghanistan is well represented by the 16-mm-wide cuff bracelet and 17-mm bead necklace with carved lapis and diamond pendant-clasp (35-mm diameter) illustrated here. Photo © Harold & Erica Van Pelt.



Figure 14. This 5.7-cm-high crystal cluster, accompanied by a 75.8-ct faceted stone, is representative of the fine aquamarine that is also being mined in the Nuristan region of Afghanistan. Specimen courtesy of William Larson, Pala, CA; cut stone courtesy of the Los Angeles County Museum of Natural History. Photo © Harold & Erica Van Pelt.

has reached cutting centers in Thailand, Hong Kong, Germany, Brazil, and the U.S. While the present hostilities and war-like conditions in Afghanistan have made mining and subsequent transportation of the gem materials difficult, the need for capital appears to have stimulated mining operations to their greatest heights in many years. For example, greater amounts of fine-quality lapis lazuli are available now than at any time in recent decades. The reserves of tourmaline and spodumene, in particular—and to a lesser extent also emerald—appear to be good. Political conditions permitting, Afghanistan should continue to supply significant quantities of these gem materials for several years to come.

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A PROPOSED NEW CLASSIFICATION FOR GEM-QUALITY GARNETS

By Carol M. Stockton and D. Vincent Manson

Existing methods of classifying garnets have proved to be inadequate to deal with some new types of garnets discovered recently. A new classification system based on the chemical analysis of more than 500 gem garnets is proposed for use in gemology. Chemical, optical, and physical data for a representative collection of 202 transparent gem-quality stones are summarized. Eight garnet species are defined—grossular, andradite, pyrope, pyrope-almandine, almandine, almandine-spessartine, spessartine, and pyrope-spessartine—and methods of identification are described. Properties that can be determined with standard gem-testing equipment (specifically, refractive index, color, and absorption spectrum) can be used to identify a garnet as one of the eight species and, where appropriate, more precisely as one of several varieties that are also defined.

ABOUT THE AUTHORS

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Over the past two decades, the discovery of new types of garnets in East Africa has led to a realization that garnet classification systems based on the early work of gemologists such as B. W. Anderson are no longer entirely satisfactory. This article proposes a new system of classification, derived from chemical data on a large collection of transparent gem-quality garnets, that requires only determination of refractive index, color, and spectral features to classify a given garnet. Thus, the jeweler-gemologist familiar with standard gem-testing techniques can readily and correctly characterize virtually any garnet he or she may encounter, and place it within one of eight rigorously defined gem species: grossular, andradite, pyrope, pyrope-almandine, almandine, almandine-spessartine, spessartine, and pyrope-spessartine. Several varietal categories (e.g., tsavorite, chrome pyrope, rhodolite, and malaia*) are also defined.

In 1959, B. W. Anderson stated that "since chemical analysis is seldom possible in dealing with gem material, one has to rely on colour, absorption bands, and inclusions in addition to the density and refractive index in an attempt to place the garnet in its correct category." For all practical purposes gemologically, this is still the case. It was also known that the complexities of garnet chemistry made characterization difficult, such that "it cannot be said with certainty, therefore, that a red garnet having a refractive index of 1.771 and a density of 3.911 will consist exactly of 30 per cent almandine [sic] and 70 per cent pyrope [sic], since the presence of a small percentage of andradite will shift the proportions in favour of almandine, and the presence of grossular would produce a lowering

*Malaia has previously been spelled "malaya" in the gemological literature; the spelling used here is not only less confusing, but is also that used in East Africa, whence the word originated (C. Curtis, pers. comm., 1985).

effect on the values of the physical data" (Webster, 1983, p. 170).

Although chemical analysis is still not a practical routine test for the gemologist, it is an important tool in many related disciplines. Accurate, rapid, nondestructive chemical analysis became available to researchers in mineralogy in the 1960s with the commercial development of the electron microprobe (invented in 1949). However, the chemical work done by mineralogists (e.g., Reid et al., 1969) rarely includes information on color, clarity, or spectra that would make the data of real use to gemologists. On the other hand, gemology rarely ventured into new analytical areas during the 1960s and 1970s.

As a result, until recently the classification of garnets used by gemologists failed to benefit from these technological advances. The third edition of Webster's *Gems* (1975) describes six major types of garnets: andradite, grossular, spessartine, pyrope, almandine, and the pyrope-almandine intermediate series. The first three are considered discrete types with limited chemical variability (in spite of a brief introductory mention of a continuous series between almandine and spessartine). The series from pyrope to almandine, however, is divided arbitrarily into three parts based on refractive index and specific gravity according to a system devised by Anderson in 1947. The characteristic spectra for garnets, too, come from work done by Anderson 30 years ago (1953–1956).

Toward the end of the 1960s and through the 1970s, however, East Africa revealed a wealth of garnets, among which were some new types (most notably tsavorite and malaia; see Bridges, 1974, and Jobbins et al., 1978) that did not fit any existing definitions. Rhodolite, the characterization of which had already been in question, was also found in Africa and thus the debates on its terminology escalated (see, e.g., Martin, 1970, and Campbell, 1972). Some of the newer material has also presented problems in terminology (e.g., Curtis, 1980; Schmetzer and Bank, 1981; Gübelin and Weibel, 1975). It became evident that a thorough examination of gem-quality garnets—including chemical analysis as well as standard gemological tests—was needed to correctly identify the new material and provide a more definite and rigorous characterization of the established types.

This article reports the conclusions reached in a study that correlates the chemical compositions of an extensive collection of transparent, gem-

quality garnets with their optical and physical properties as acquired through routine gem-testing techniques. Many of our findings were published previously as groups of data were completed (Manson and Stockton, 1981, 1982, and 1984; Stockton, 1982; Stockton and Manson, 1982 and 1983). These papers have covered the five major garnet end members—pyrope, almandine, spessartine, grossular, and andradite—as well as garnets of intermediate composition (see figure 1). These data are assembled here into a unified system of description, classification, and nomenclature for garnets that is oriented toward the needs and practical methods of gemology (see table 1) and resolves many of the questions that have arisen with the newer types of garnets discovered.

THE GARNET GROUP

Gem garnets belong to a complex group of minerals that share the general chemical-structural formula $X_3Y_2Z_3O_{12}$, where X is an ion (generally Ca^{2+} , Mn^{2+} , Fe^{2+} , or Mg^{2+}) bonded to eight oxygen atoms in a dodecahedral formation, Y (Al^{3+} , Fe^{3+} , V^{3+} , Cr^{3+} , or Ti^{3+}) is bonded to six oxygen atoms in octahedral coordination, and Z (Si^{4+} or Ti^{4+}) is bonded to four oxygen atoms in a tetrahedral coordination (figure 2). When each site is occupied by only one type of ion, the result is identified as an end member of the garnet mineral group. For example, $Ca_3Al_2Si_3O_{12}$, pure *grossular*, is such an end member. Five end members can be used to describe virtually all gem garnets: *pyrope* ($Mg_3Al_2Si_3O_{12}$), *almandine* ($Fe_3Al_2Si_3O_{12}$), *spessartine* ($Mn_3Al_2Si_3O_{12}$), *andradite* ($Ca_3Fe_2Si_3O_{12}$); and *grossular*. The complexity of garnets arises from the fact that these various chemical constituents can be present in virtually any proportions in the composition of a single stone. In addition, Cr^{3+} , V^{3+} , and $Ti^{3+/4+}$ are important chemical constituents of gem garnets and all have had corresponding end members described. However, they occur only as minor or trace elements in gem-quality garnets, and will thus be discussed here as "impurity" ions or oxides rather than as end-member components.

Ambiguity in the use of terms such as *grossular* can result in confusion when discussing garnets. Often these terms are used both to refer to the above-mentioned theoretical pure end members and to denote actual garnets that are only more-or-less close in composition to the pure end member. To avoid such confusion in this presen-

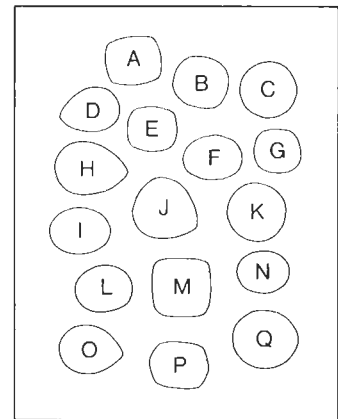
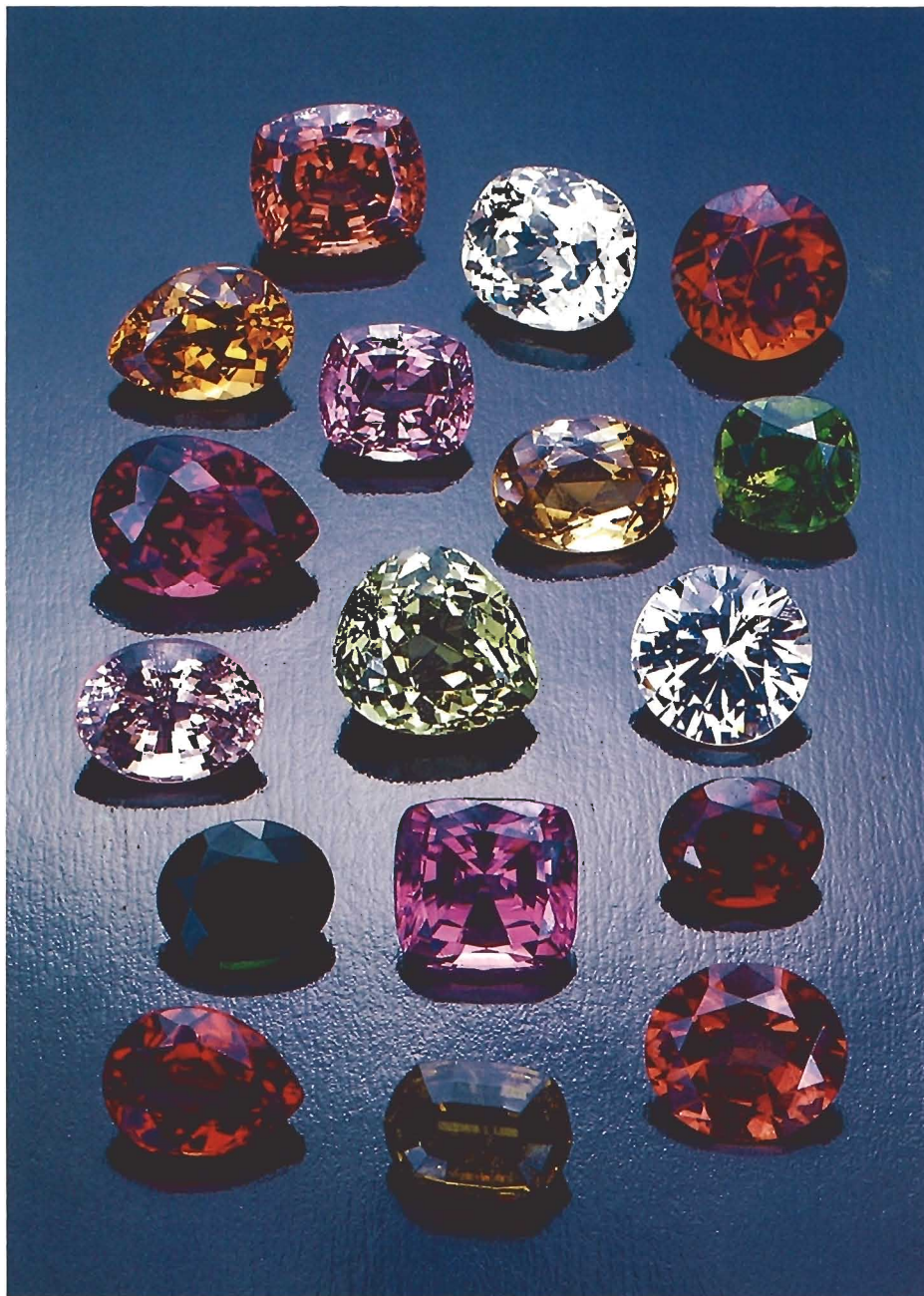


Figure 1. A selection of gem garnets from the study collection that shows the broad range of colors and chemical compositions encountered. These stones have been classified (in the system proposed in this article) as: A—malaya, B—grossular, C—pyrope-spessartine, D—hessonite, E—rhodolite, F—grossular, G—demantoid, H—color-change pyrope-spessartine, I—pyrope, J—tsavorite, K—grossular, L—tsavorite, M—rhodolite, N—chrome pyrope, O—spessartine, P—demantoid, and Q—spessartine (GIA catalogue numbers 234, 1/47, 8960, 7201, 5818, 5873, 1/167, 665, 1/132, 7202, 1/36A, 13319C, 1/84, 13113, 13047, 13234, and 5814, ranging in weight from 1.08 to 2.91 ct). Photo© Tino Hammid.

tation, all references to the theoretical end members will be italicized, as above.

DATA COLLECTION

More than 500 gem-quality garnets were examined and chemically analyzed over the past five years. From this group, we selected 202 stones that represent the full range of colors, physical properties, and chemical compositions that have been observed. For each of these 202 stones, we collected data on chemistry, color, visible-range absorption spectrum, refractive index, and specific gravity.

Chemical compositions were determined at least three times for each stone with a MAC automated electron microprobe, and then averaged and converted to end-member components. Color descriptions were obtained with a GEM ColorMaster and converted mathematically to CIE x, y, and z (or tone) coordinates. Absorption spectra were resolved with a Pye-Unicam 8800 dual-beam spectrophotometer as well as with a Beck hand spectroscope. Refractive indices were determined with a GEM Duplex II refractometer or prototype Duplex II with cubic zirconia hemicylinder for stones

TABLE 1. The proposed new system of garnet classification with key characteristics for identification.

Species	R.I. ranges	Hues	Spectral absorption features
Grossular	1.730– 1.760	Green through reddish orange, and colorless	None except with highly saturated orange to reddish orange stones (see variety hessonite), which show bands at 407 and/or 430 nm (see right).
Andradite	1.880– 1.895	Very slightly yellowish green through orangy yellow	None except with very slightly yellowish green to yellow-green andradites (see variety demantoid), which usually show a cutoff to about 440–445 nm and may also show additional bands as at right.
Pyrope	1.714–<1.742	Purplish red through reddish orange, and colorless	None when colorless; others with weak bands as for almandine and/or spessartine, or with a cutoff to about 440–445 nm and a broad 564 nm band that may be accompanied by additional bands (see variety chrome pyrope).
Pyrope-almandine	1.742–<1.785	Reddish orange through red-purple	Bands at 504, 520, and 573 nm, but may also show weak bands at 423, 460, 610, and/or 680–690 nm (see right).
Almandine	1.785– 1.830	Orangy red through purplish red	Bands at 504, 520, and 573 nm, as illustrated, but may also show weak bands at 423, 460, 610, and/or 680–690 nm.
Almandine-spessartine	1.810– 1.820	Reddish orange through orange-red	Cutoff to about 435 nm, and bands at 460, 480, 504, 520, and 573 nm, with more or less merging of the last four. In extremely dark stones, all the absorption regions will broaden further.
Spessartine	1.780–<1.810	Yellowish orange through reddish orange	Bands at about 410, 421, 430, 460, 480, and 520 nm, but the first three may merge to form a cutoff to about 435 nm. Weak bands at 504 and/or 573 nm may also be present.
Pyrope-spessartine	1.742–<1.780	Greenish yellow through purple	Bands at 410 and 430 nm, and usually at 421 nm, that occasionally merge to form a 435 nm cutoff. Also show some combination of bands at 460, 480, 504, 520, and 573 nm (see varieties malaia and color-change pyrope-spessartine). Examples are shown at right.

with indices over 1.800. Specific gravities were measured hydrostatically. Details of the microprobe operating conditions, correction program, and end-member conversion, as well as spectrophotometer parameters and actual data, are available on request from the authors.

CHEMISTRY

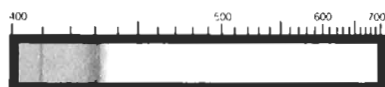
Although garnets theoretically may occur in any

mixture of the end members *pyrope*, *almandine*, *spessartine*, *grossular*, and *andradite*, the observations of this and other studies of gem garnets have enabled us to distinguish eight categories of garnets based on chemical composition: (1) grossular, (2) andradite, (3) spessartine, (4) almandine-spessartine, (5) almandine, (6) pyrope-almandine, (7) pyrope, and (8) pyrope-spessartine.

Grossular garnets that were examined for this

(hand spectroscope)

Varieties



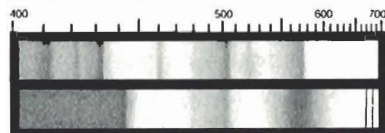
Tsavorite: a green to very slightly yellowish green variety of grossular. Shows no absorption spectrum visible with a hand spectroscope.

Hessonite: a yellow-orange to reddish orange variety of grossular. Shows no spectrum in lighter tones, but highly saturated stones have bands at 407 and/or 430 nm that are visible with a hand spectroscope (see left).

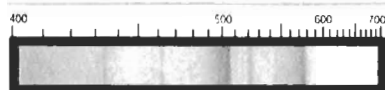


Demantoid: a very slightly yellowish green to yellow-green variety of andradite. Always shows a cutoff to about 440–445 nm, but may also show a pair of bands at 618 and 634 nm. Very intensely colored stones also show a pair of thin bands at 685 and 690 nm, as at left, and/or a broad absorption region centered around 600 nm.

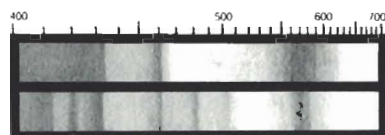
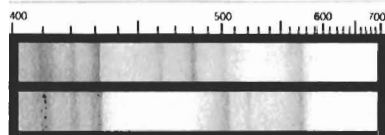
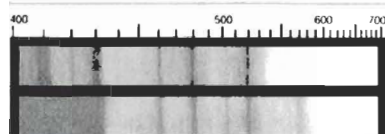
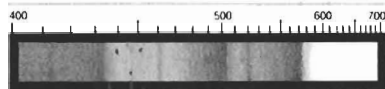
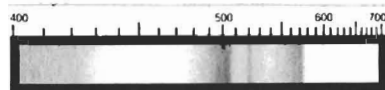
Topazolite: a yellow to orangy yellow variety of andradite. Shows no absorption features visible with a hand spectroscope.



Chrome pyrope: an orange-red variety of pyrope that shows a 440–445 nm cutoff, a broad band at about 564 nm, and usually also a pair of thin bands at 670 and 684 nm (see left). May also show a weak band at about 504 nm.



Rhodolite: a very slightly purplish red to red-purple variety of pyrope-almandine. Spectral features are the same as for other pyrope-almandines (see left).



Malaia: a yellowish orange to red-orange variety of pyrope-spessartine. Always shows bands at 410, 421, and 430 nm that occasionally merge to form a cutoff at about 435 nm. Also shows some combination of bands at 460, 480, 504, 520, and 573 nm. See examples 1 and 2 at left.

Color-change pyrope-spessartine: this is a variety of pyrope-spessartine that exhibits a distinct change in the appearance of its body color between incandescent and fluorescent (or daylight) illumination. Hues that have been observed under fluorescent light range from greenish yellow through purple. All stones show bands at 410, 421, and 430 nm that may be merged to form a cutoff at about 435 nm, as well as some combination of bands at 460, 480, 504, 520, and 573 nm. In stones with a strong change of color, the 573 nm band is notably broadened and strengthened. See last three examples at left.

study all consist of more than 75.0 wt.% grossular, with up to 19.0 wt.% andradite. As much as 0.23 wt.% Cr₂O₃, 2.44 wt.% V₂O₃, and 0.52 wt.% Ti₂O₃ were also measured in grossulars. *Pyrope*, *almandine*, and *spessartine* taken together never exceed 4.50 wt.% in gem grossulars.

All of the andradites studied consist of more than 95 wt.% *andradite*. Because their composition is so distinct, little needs to be said about their

chemistry. Although gem-quality andradites exhibit minimal chemical variability, this variability is significant with respect to different colors observed. Minor or trace levels of chromium and titanium are the most important additional elements [Cr₂O₃ ≤ 0.20 wt.% and Ti₂O₃ ≤ 0.10 wt.%].

The remaining garnets are composed of highly variable proportions of *pyrope* (0–83.0 wt.%),

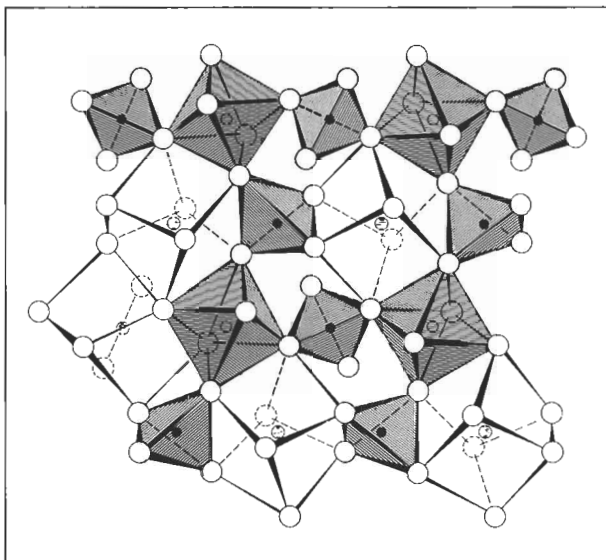


Figure 2. Schematic diagram of a portion of the garnet crystal structure. Hatched circles represent X cations, small open circles denote Y cations, black circles the Z cations, and large open circles the oxygen atoms bonded to the various cations (adopted from Novak and Gibbs, 1971).

almandine (2.0–78.0 wt.%), *spessartine* (0.2–94.0 wt.%), and *grossular* (0–24.0 wt.%). None contains more than 4.0 wt.% *andradite*. Figure 3 illustrates the relationship among these garnets with respect to their three major constituents. Heavily "populated" areas are mixtures of *pyrope* and *almandine*, *pyrope* and *spessartine*, and *almandine* and *spessartine*. Examples that approach pure *spessartine* exist, but neither *pyropes* nor *almandines* of such high purity have been encountered in gem-quality stones. There is discontinuity between the series *almandine-spessartine* and those of *pyrope-almandine* and *pyrope-spessartine*. The possibility exists, however, that the latter two may represent one continuous series; there are high *pyrope* stones that include substantial and roughly equal amounts of *almandine* and *spessartine*. On the other hand, there is no apparent reason why gem-quality garnets should not occur that fill any of these gaps. Discovery of new provenances for garnets might easily provide such stones; the *pyrope-spessartine* series, for example, was unknown prior to the discovery of such garnets in East Africa about 20 years ago. Thus, classification of stones in this chemical array seems likely to involve arbitrary decisions, at least insofar as chemical distinction is involved.

COLOR

Natural gem garnets occur in a wide variety of hues, from green through yellow and red to purple (figure 4). Some of these colors are characteristic of certain types of garnets. For example, intense greens are found only among *grossulars* and *andradites*. Generally, any green garnet will belong to one of these two species, although the study collection contains a single color-change *pyrope-spessartine* (GIA 96A) that is greenish yellow in fluorescent light or daylight—close enough to green to suggest that sweeping generalities about green garnets must be avoided. Colorless and yellow garnets have as yet been confined to the *grossular* category. Yellowish orange to reddish orange (including brown) garnets may be *grossulars*, *spessartines*, or any of various mixtures of *almandine*, *spessartine*, and/or *pyrope*. Red to purplish red garnets belong to mixtures of *pyrope* and *almandine*. Red-purple garnets may be *almandines*, *pyrope-almandines*, or color-change *pyrope-spessartines*. The few purple stones encountered have all proved to be color-change *pyrope-spessartines*.

ABSORPTION SPECTRA

There is considerable disagreement in the interpretation of many of the spectral absorption bands that may be observed in the visible-light range for garnets (see, for example, Manning, 1967 and 1972; Slack and Chrenko, 1971; Moore and White, 1972; Frentrup and Langer, 1981). Empirically, however, correlations can be made between certain absorption features and the chemical constituents typically associated with various colors. While these relationships should not necessarily be interpreted as cause and effect, they nonetheless fulfill our present needs for the identification and classification of gem garnets. Characteristic absorption spectra for the various types of gem garnets are illustrated in table 1 and discussed below.

Grossular. With the exception of some intense orange to reddish orange stones, *grossulars* do not exhibit any features visible with a hand spectroscope. For the exceptions, an absorption band can be resolved at about 430 nm. It is accompanied by a very thin band at 407 nm that can sometimes also be seen with a hand spectroscope. Less intensely colored orange and yellow *grossulars* exhibit increasing absorption toward the blue end of the spectrum, but no distinct bands. Greenish yellow

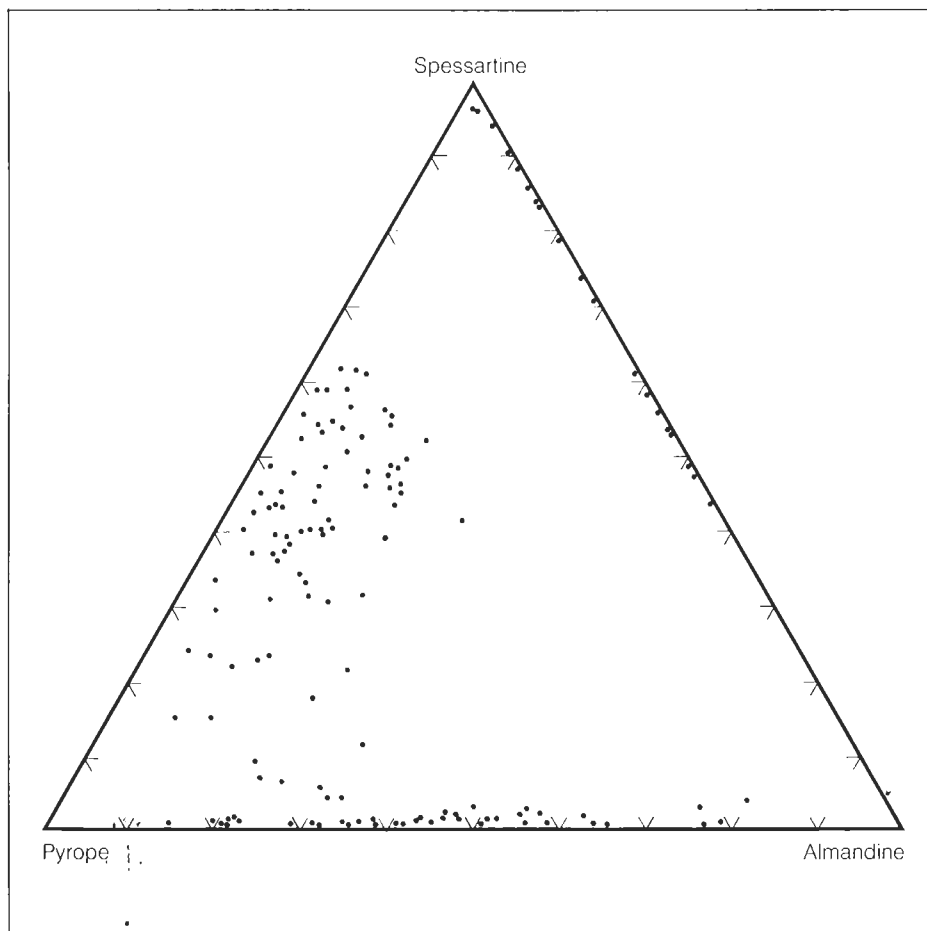
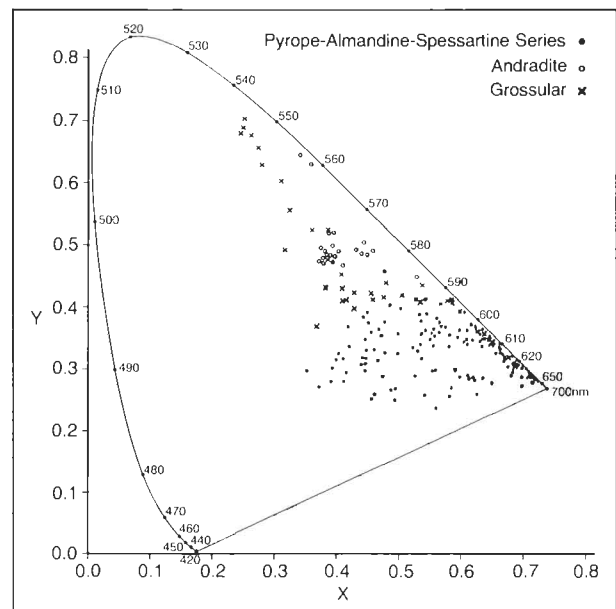


Figure 3. Compositional ternary diagram for garnets in the study collection that are composed primarily of pyrope, almandine, and/or spessartine (i.e., less than 25 wt.% grossular).

low to green grossulars have two broad regions of absorption centered around 425 and 600 nm that are too attenuated to be visible with a hand spectroscope.

Andradite. Very slightly yellowish green to yellow-green andradites invariably exhibit complete absorption to about 440–445 nm that is due to a very strong band centered at about 434 nm. Less yellowish and more intense green stones may also show a pair of bands at approximately 618 and 634 nm. Occasionally, with very intense green demantoids, a pair of thin bands is also visible at about 685 and 690 nm. In addition, all green andradites have a broad absorption region centered at about 600 nm that can be resolved with the spectrophotometer but not usually with a hand spectroscope. The single orangy yellow andradite examined showed no features with a hand spectroscope, but displayed bands at about 438 and 600 nm on the spectrophotometer. The 600 nm band was considerably weaker than its counterpart in the green stones.

Figure 4. CIE chromaticity diagram (tone level 5) with coordinate points plotted for the 202 garnets in the study collection. The range of hues extends from green to purple.



Pyrope. Pure *pyrope*, not found in nature, is colorless and has no absorption features in the visible wavelengths. (Colorless pyrope that exceeds 97% of that end member has recently been found, but not in gem sizes; Chopin, 1984.) However, gem-quality garnets high in *pyrope* vary considerably in color and spectral features. Some exhibit features common to almandine, spessartine, or both. More common are the intense, dark red pyropes with strong, broad bands centered at about 410 and 564 nm; the 410 nm band appears as a cutoff to about 440–450 nm when observed with a hand spectroscope. Some of these stones also reveal a pair of narrow bands at about 670 and 684 nm.

Pyrope-Almandine. Pyrope-almandine garnets display spectra consistent with that described below for almandines.

Almandine. High-*almandine* garnets exhibit strong bands at 504, 520, and 573 nm, as well as weaker bands (not usually visible with a hand spectroscope) at 420, 460, 610, and 680–690 nm.

Almandine-Spessartine. Stones of mixed *almandine* and *spessartine* content exhibit spectra with strong features contributed by both end members: a 435 nm cutoff, with a usually distinct band at 460 nm, and bands at 480, 504, 520, and 573 nm that generally merge into a single broad region of absorption.

Spessartine. Garnets with a high *spessartine* content exhibit a spectrum that, at the least, contains bands at 407, 411, 421, 430, 460, 480, and 520 nm. The first four bands, however, are very strong and overlap in such a way that they appear in the hand spectroscope as either two broad bands at about 410 and 430 nm (a weak 421 nm is also sometimes visible) or as a cutoff to about 435 nm. Bands at about 504 and 573 nm are at times present, but they are invariably weaker than the others and apparently relate to the amount of *almandine* in a given stone.

Pyrope-Spessartine. Garnets composed primarily of *pyrope* and *spessartine* invariably have strong bands in the blue, as in spessartines, and usually bands at 504, 520, and/or 573 nm. However, these bands vary considerably in relative strength, and 460 and/or 480 nm bands may also be present in some specimens.

The pyrope-spessartines also include the color-change garnets, which have a 435 nm cutoff due to a strong set of overlapping 407, 411, 421, and 430 nm bands, and in most cases a broad band centered at approximately 573 nm. Bands at about 460, 480, 504, and 520 nm may also be visible with a hand spectroscope in some specimens. In lighter-colored specimens, individual bands may be resolved in the blue. Occasionally, the 573 nm band is too weak to be resolved, in which case only 407–411, 421, and 430 nm bands, as well as very weak 460 and 480 nm bands, are visible.

PHYSICAL DATA

A graphic distribution of refractive-index and specific-gravity data for the 202 garnets studied (figure 5) reveals three relatively distinct groups. Andradites have a considerably higher refractive-index range (≥ 1.880) than any other type of garnet (≤ 1.816). The specific-gravity range for grossulars is lower than that of any other garnet examined: Gem grossular has not yet been observed to exceed 3.66, while the lowest value for any specimen that might be visually mistaken for grossular is 3.75 (pyropes, however, have been observed to have densities as low as 3.67). The remaining coordinates form more or less of a continuum between 1.731–1.816 and 3.75–4.29. There is so much overlap in specific-gravity ranges for the various types of garnets (again, see figure 5) that the usefulness of this property is questionable. Moreover, the difficulty of accurately measuring density as well as the considerable variability introduced by the presence of inclusions suggests that this is not a reliable characteristic for the identification and classification of gems. The graph also shows that there are minor discontinuities in the distribution of the observed refractive indices, but all of these gaps, with the probable exception of that separating andradite, are small enough that they could disappear with additional data.

DISCUSSION

Classification of garnets has been impeded not only by the complex compositional variability of the material itself but also by a lack of well-defined and well-characterized terminology. Thus, debates on the use of varietal terms (e.g., Trumper, 1952; Anderson, 1959; Martin, 1970; Curtis, 1980; Schmetzer and Bank, 1981) suffer largely from a case of building castles on sand. Before defining specific gemological terminology, we need to ex-

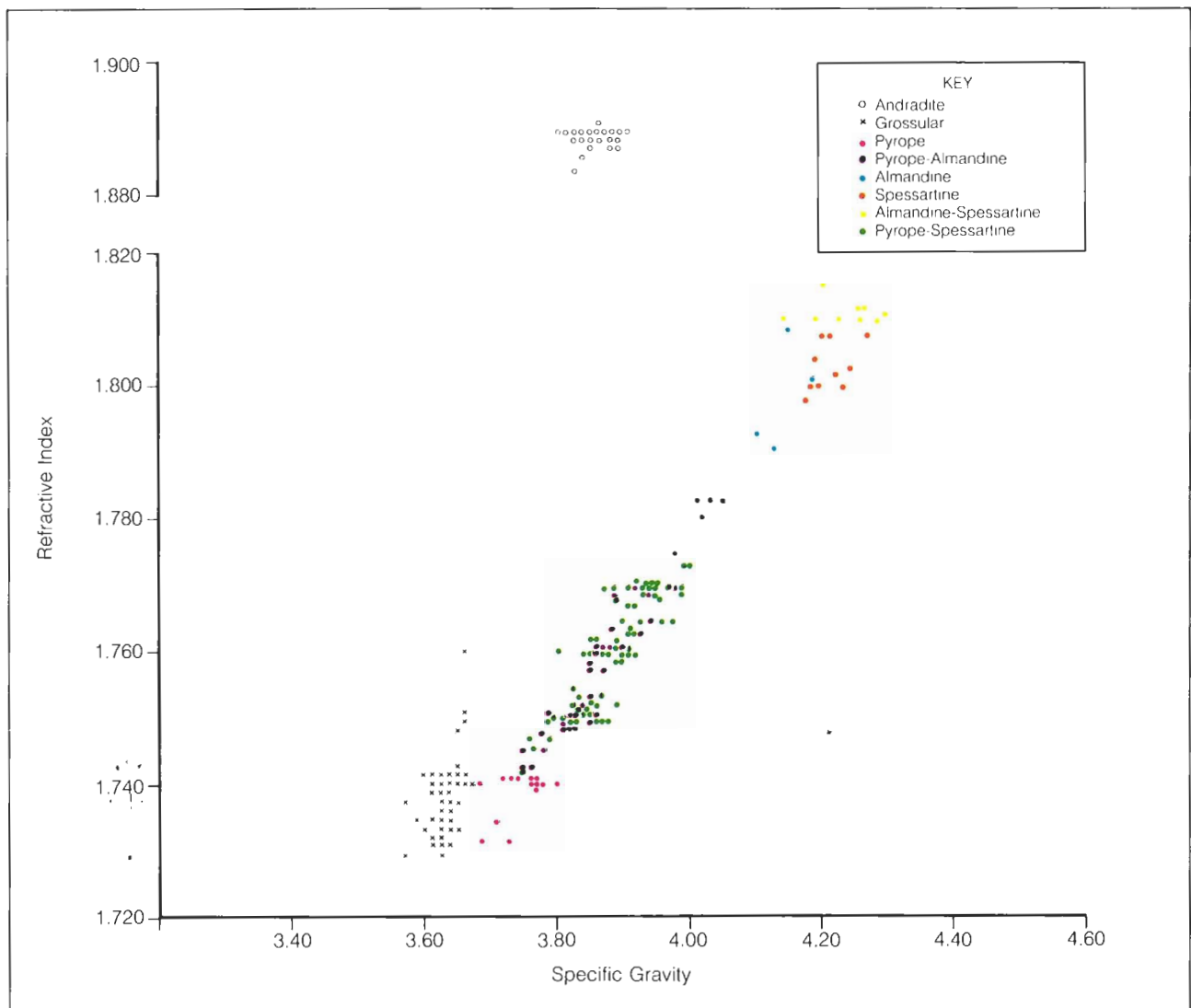


Figure 5. Refractive-index and specific-gravity coordinates plotted for the 202 gem garnets in the study collection. Apart from the separation of andradites, no obvious distinctions appear on the basis of either property individually or both properties together.

amine what is meant mineralogically by the terms *series*, *species*, and *variety*; determine whether these definitions can be practically applied to gemology; and, if they cannot, decide what modifications are needed to provide gemologists with a working system that can be used to classify mineral group gems such as garnets.

Mineralogical Terminology. According to the seventh edition of *Dana's System of Mineralogy* (Palache et al., 1944, Vol. 1, p. 3), a series consists of "minerals sharing a continuous variation in their properties with a change in composition." A mineral species has been defined as "a natural inorganic substance which is either definite in chemical composition and physical characters or varies

in these respects between definite natural limits" (Winchell, 1937, Pt. 1, p. 1); this is the fundamental unit for classification in mineralogy and, as such, has been well characterized. Varieties have been defined as subdivisions of species that "may have distinctive physical properties . . . or chemical composition" (Mason and Berry, 1968, p. 198). In the latter case, it has been proposed that an adjectival modifier that indicates the chemical variability be prefaced to the appropriate species name. Varieties distinguished by characteristic physical properties such as color may be affixed with a special name. This practice, however, has only recently been widely recognized by mineralogists, so the bulk of mineralogical classification does not reflect this nomenclature, nor do all min-

eralogists agree to its usage even now. In fact, the multitude of ways in which the variety concept has been applied is confusing, to say the least (see, for example, Hey, 1955, p. xiii).

The garnet group has been subdivided into "species" (almandine, grossular, etc.) that represent end members of chemically continuous series (Deer et al., 1963). However, the use of the species concept to subdivide the garnets contradicts the foregoing definition, since there is a lack of "definite natural limits." Varieties such as rhodolite and hessonite are occasionally included in mineralogical references but, aside from a brief mention of color and a vague identification of their species, they are not defined.

Gemological Terminology. While mineralogical classification is somewhat inconsistent, it is still the best precedent available to gemology. This inconsistency, however, allows a great deal of flexibility in gemological classification without extensively contradicting mineralogical precedents. Since the concept of species as defined by mineralogy (see above) is inadequate with respect to mineral groups such as garnets, we propose that, for gemological purposes, the *species* subdivision of a mineral group be defined as *a naturally occurring inorganic substance that has a definite crystal structure and a fixed (natural or arbitrary) range of chemical composition within the compositional limits of its mineral group*. A species will thus have characteristic ranges of properties, including ones that can be determined by gemological techniques. Similarly, we recommend that the gemological concept of *variety* be explicitly defined as *a subdivision of a species that may be differentiated either by distinctive physical characteristics such as color and phenomena or by consistent minor chemical disparity*.

CONCLUSIONS

Proposed Classification of Gem-Quality Garnets. Table 1 outlines the proposed classification of gem garnets based on correlations among the data discussed in this article and organized according to the definitions of species and varieties discussed in the preceding section. Transparent gem garnets can be divided into eight species; a number of these are subdivided further into specific varieties. Most of the varietal terms recommended for use in gemology are based on color: tsavorite, hessonite, demantoid, topazolite, rhodolite, and malaia.

There are still many garnets that have not been given variety names, and these should be referred to only by terminology that incorporates the appropriate species name. This latter practice discourages the proliferation of special, frequently confusing, terms. Thus, while a purplish red pyrope-almandine is a rhodolite, a red stone of otherwise similar properties would be referred to only as pyrope-almandine. Chrome pyrope is a chemical variety based on the presence of appreciable amounts of Cr^{3+} that produce a characteristic color and spectrum. The varietal modifier *color-change* is recommended for pyrope-spessartines of any color that exhibit that phenomenon. (Change-of-color pyropes have also been found, in certain peridotite rocks and as inclusions in diamonds, but as yet no stones have been encountered that are large enough to be cut as gems. Should this occur, however, such stones would be called "color-change pyropes.")

Observed ranges of refractive indices were extended to cover the gaps between the observed data. For example, we encountered no specimens that have spessartine:pyrope ratios of more than 2:1 and less than 90:1. However, there is no reason to think that such stones could not occur and, given the correlation between refractive index and chemistry, we can extrapolate and predict the properties of garnets that we have not encountered yet but that we might expect to come across in the future. Thus, while we know of no spessartines with refractive indices below 1.798, or pyrope-spessartines with R.I.s above 1.773, we have drawn the boundary between these two types of garnet at 1.780.

The boundaries and property values expressed in this classification system are not necessarily consistent with interim groupings discussed in previous articles on this extended study of garnets, most especially with respect to the first in the series (Manson and Stockton, 1981). It was with this eventuality in mind that we reiterated in each of those papers that properties and terms discussed prior to this article were entirely provisional. Only comparison of all the data on a full range of gem garnets has enabled us to identify what appear to be useful and logical divisions.

We have avoided the issue of determining which suffixes, *-ine* or *-ite*, should be applied to species names in those cases where they have been disputed. Both forms are in common usage and both adequately communicate the intended idea,



Figure 6. These three garnets all look very similar to one another, but they differ considerably in their properties and chemical composition. Clockwise, from lower right, they are grossular (hessonite), spessartine, and pyrope-spessartine (malaia).

so we leave the choice to individual preference. It should also be pointed out that this proposed system of classification is designed specifically for use by gemologists and does not imply either acceptance by mineralogy or even the suggestion that it should be adopted by mineralogists, although it can be clearly and unambiguously understood by mineralogists.

Determination of Garnet Species. The identity of a given stone can be established by the combined use of color, refractive index, and spectral features, according to the values provided in table 1. While determination of only one or two properties is at times adequate to identify the species and/or variety of a given garnet, it is recommended that the practicing gemologist determine no less than all three properties (i.e., refractive index, color, and absorption spectrum) whenever possible before confirming the identity of a stone. Thus, given a stone of a particular color (its most easily observable property), once its refractive index is measured, its identity rests on the determination of its spectrum. For example, three stones of almost identical appearance (see figure 6) are submitted for identification. According to color, possible identities are grossular (hessonite), pyrope, pyrope-almandine, almandine, almandine-spessartine, spessartine, or pyrope-spessartine; only andradite is eliminated, as reddish orange and red-orange colors do not occur in that species. The stone at lower right in figure 6 has a refractive index of 1.758 and the spectrum shown in figure 7a; reference to table 1 will show that this stone must be grossular (variety hessonite). The stone at lower left has a refractive index of 1.795 and the spectrum in figure 7b; this stone must, therefore,

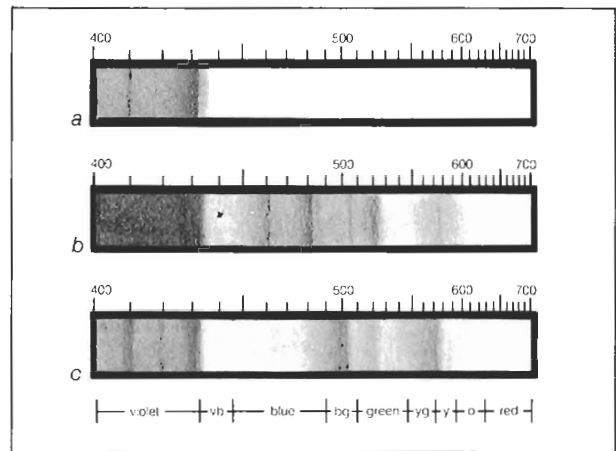


Figure 7. Absorption spectra of the three garnets in figure 6: (a) grossular (hessonite), (b) spessartine, and (c) pyrope-spessartine (malaia). In conjunction with refractive indices, these spectra will distinguish the three similarly colored garnets from one another.

be a spessartine. The third stone in figure 6 (top center) has a refractive index of 1.765 and spectral features as shown in figure 7c; the properties as summarized in table 1 indicate that this garnet must belong to the species pyrope-spessartine (variety malaia).

Separations of garnet species are straightforward in most cases, but there are borderline cases that may present difficulties, especially among the garnets that are mixtures of *pyrope*, *almandine*, and/or *spessartine*. Figure 8 will help illustrate how decisions can be made, along with the following list of paired species and their key distinguishing features:

- Pyrope can be distinguished from any other garnet except grossular on the basis of its low refractive index (<1.742).
- Pyrope vs. grossular can be determined by spectrum or, if colorless, by refractive index (colorless grossular will be ≥ 1.730 , while colorless pyrope will be <1.730).
- Pyrope-spessartine vs. pyrope-almandine can be distinguished by spectrum (the latter has no 410 and 430 nm bands) and frequently by color (pyrope-spessartine occurs in oranges not encountered in pyrope-almandines). Moreover, color change occurs only in the pyrope-spessartines.
- Pyrope-spessartine vs. almandine can be determined by R.I. (<1.780 and ≥ 1.785 , respectively) as well as by spectrum (lack of 410 and 430 nm bands in the latter).
- Pyrope-spessartine can be distinguished by refractive index from both spessartine and almandine-spessartine, since the latter two exceed the top R.I. value of <1.780 for pyrope-spessartine.
- Pyrope-almandine vs. almandine can be determined by R.I. (<1.785 and ≥ 1.785 , respectively).
- Pyrope-almandine vs. spessartine can be distinguished by spectrum (no 410 and 430 lines in the former), usually by color, and by R.I., except for a narrow range of overlap between 1.780 and 1.785.
- Pyrope-almandine vs. almandine-spessartine can be distinguished by R.I. (<1.785 and ≥ 1.810 , or over the limits of a standard gem refractometer) and by spectrum (the former has no 410 and 430 nm lines).
- Almandine can be separated from spessartine by spectrum (no 410 and 430 nm bands in the former) and by color (the former are predominantly red, the latter predominantly orange).
- Almandine vs. almandine-spessartine can be determined by spectrum (the former has no 410 and 430 nm lines) and if a C.Z. refractometer and high-R.I. liquid are available, by refractive index as well.
- Spessartine vs. almandine-spessartine can be distinguished by spectrum (weak but distinct bands at 480, 504, 520, and/or 573 nm in the former, as compared to a broad region of ab-

sorption between 470 and 580 nm in the latter; both have strong absorption in the blue) in conjunction with color (more orange in spessartines, and more red in almandine-spessartines).

The most difficult separations that have been encountered are those close to the border between spessartine and almandine-spessartine (see figure 8), where identification depends on subtle differences in color and spectra, and at the boundary between pyrope-spessartine and pyrope-almandine, where the decision depends on the visibility of the 410 and 430 nm bands. Under no circumstances, however, should we have to classify a garnet simply as "garnet;" the very worst one can do is decide that a stone is near the boundary between two species, although such cases should be rare.

Figure 8 displays a large unlabeled trapezoidal area in its center, bounded by pyrope-spessartine, spessartine, almandine-spessartine, and almandine. No gem garnets have yet been reported to have chemical compositions that would place them in this region. Should such garnets be encountered, however, it is most likely that they would represent an expanded range for the almandine-spessartines.

In the past, specific gravity has been used in conjunction with refractive index to classify garnets. Although we generally discourage the use of this property in gemology, it nonetheless can provide some useful indications. Grossulars have so far been observed to have densities below those of any other species of gem garnet, although by only an extremely small margin. Almandines, spessartines, and almandine-spessartines in the study collection invariably had specific gravities above the range observed for pyropes, pyrope-almandines, and pyrope-spessartines. Once again, however, the potential for overlap of these ranges is great. In the event that a refractive index cannot be determined for a sample of questionable identity, the determination of specific gravity may assist the identification by making use of figure 5, but it should be used with caution.

The system of classification for gem garnets that has resulted from this study is totally consistent with chemical variability within the garnet group. Application of the system, however, depends entirely on the use of practical gemological techniques: color, refractive index, and absorption spectrum as determined with a hand spectroscope.

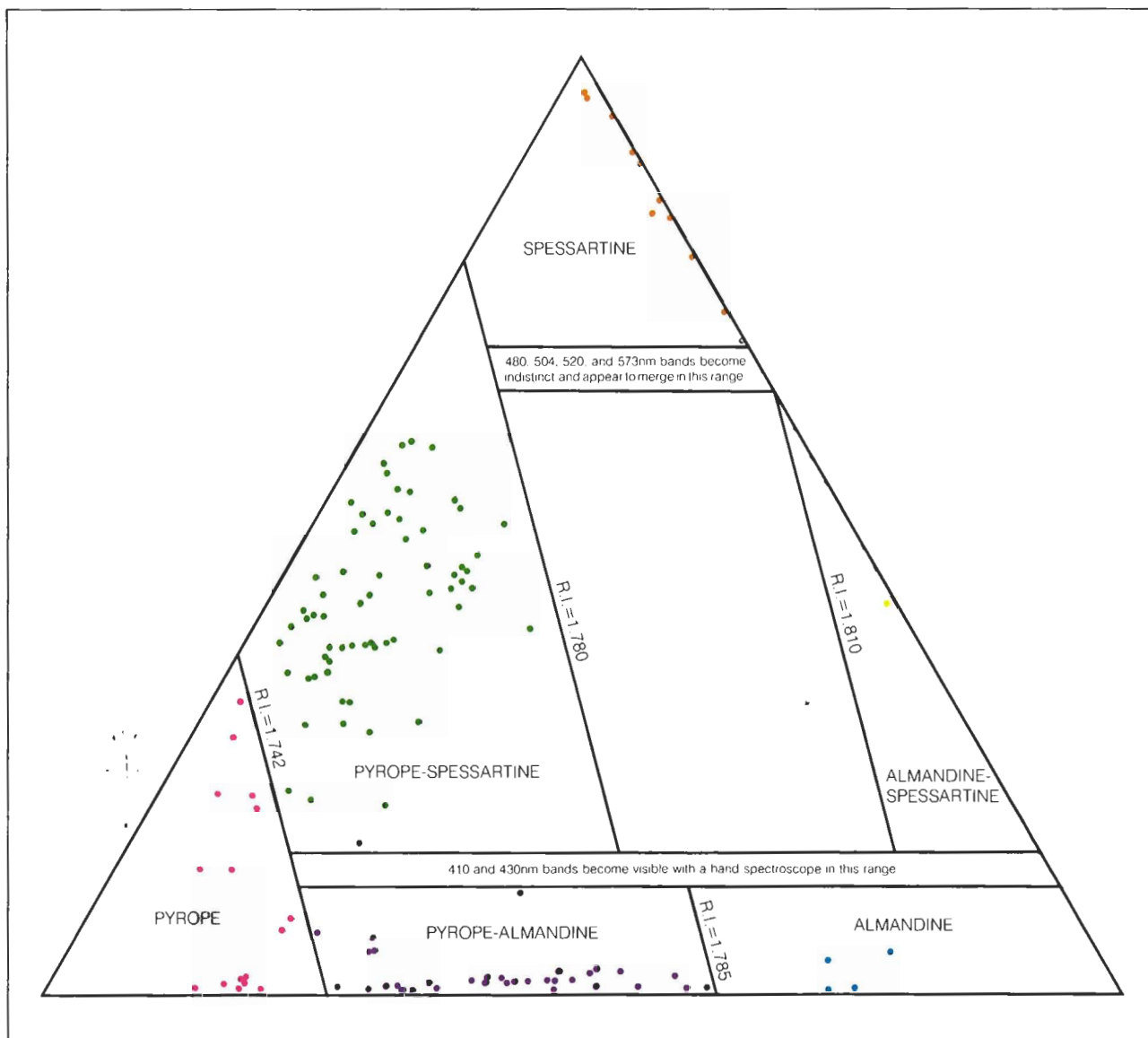



Figure 8. Ternary diagram with data points based on molecular percentages for the garnets of mixed pyrope, almandine and/or spessartine composition in the study collection. (Figure 3 is based on weight percentages, and so has a slightly different appearance with respect to the location of data points.) Superimposed are important refractive index and spectral boundaries that can be used to distinguish among the six proposed garnet species labeled, as discussed in the text. The locations of these boundaries were determined by correlations with the chemical compositions determined in this study.

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NOTES • AND • NEW TECHNIQUES

AMETHYSTINE CHALCEDONY

By James E. Shigley and John I. Koivula

A new amethystine chalcedony has been discovered in Arizona. The material, marketed under the trade name "Damsonite," is excellent for both jewelry and carvings. The authors describe the gemological properties of this new type of chalcedony, and report the effects of heat treatment on it. Although this purple material is apparently a new color type of chalcedony, it has the same gemological properties as the other better-known types. It corresponds to a microcrystalline form of amethyst which, when heat treated at approximately 500°C, becomes yellowish orange, as does some single-crystal amethyst.

Chalcedony is a microcrystalline form of quartz that occurs in a wide variety of patterns and colors. Numerous types of chalcedony, such as chrysoprase, onyx, carnelian, agate, and others, have been used in jewelry for thousands of years (Webster, 1983). These several kinds of chalcedony owe their coloration in part to finely disseminated mineral impurities, particularly the oxides and hydroxides of iron, that originate in the environments of chalcedony formation.

In the near future, a significant quantity of massive purple chalcedony mined in Arizona will be marketed in the form of cabochons and carvings under the trade name "Damsonite" (figures 1 and 2). Our examination of this material demonstrates that it is a microcrystalline form of amethyst quartz. Although it is likely that purple chalcedony has been found previously, a survey of the mineralogical and gemological literature indicates

that this is one of the few reported occurrences where an amethyst-like, or amethystine, chalcedony has been found in quantities of gemological importance (see Frondel, 1962). Popular gem hunters' guides, such as MacFall (1975) and Anthony et al. (1982), describe minor occurrences in Arizona of banded purple agate, but give no indication of deposits of massive purple chalcedony similar to that described here. This article briefly summarizes the occurrence, gemological properties, and reaction to heat treatment of this material.

LOCALITY AND OCCURRENCE

The purple chalcedony described here has been found at a single undisclosed locality in central Arizona. It was first noted as detrital fragments in the bed of a dry wash that cuts through a series of sedimentary rocks. A subsequent search of the adjacent hillsides uncovered the major in-situ de-

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Acknowledgments: The authors thank J. D. Porter of Boulder City, Nevada, for supplying the purple chalcedony used for our examination, and Richard T. Liddicoat, Jr., for suggesting this study. The authors drew in part on an earlier unpublished study of this material carried out by W. John McLean of the Colorado School of Mines Research Institute in Golden. We also acknowledge the assistance of Randy Heuser for use of the electron microprobe at the California Institute of Technology in Pasadena.

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Figure 1. This purple chalcedony cabochon (approximately $21 \times 8 \times 5$ mm) is set in yellow gold and accented by diamonds and pearls. Photo © Tino Hammid.

posit of the chalcedony. The material occurs in veins and massive blocks up to 1 m thick enclosed in the weathered sedimentary host rock. Massive pieces (up to 100 kg each) of purple chalcedony have been removed from this area. Hot springs and deposits of opalized silica in the immediate vicinity suggest that the veins of massive purple chalcedony were deposited from low-temperature silica-bearing solutions by normal depositional processes similar to those that typically form chalcedony in other sedimentary environments (for further general information, see Frondel, 1962). At the present time, all of the readily accessible purple chalcedony has been removed from this locality and mining has stopped. However, the total tonnage reserves on hand are sufficient to supply the jewelry market with several thousand carats of purple chalcedony per year for the foreseeable future. Current plans call for distributing the material only in finished form through a marketing company.

DESCRIPTION OF THE MATERIAL

As with most other chalcedony, the purple material is a tough microcrystalline aggregate that occurs in dense, compact masses with a wax-like appearance (figure 3). In thin section under the microscope, the chalcedony is seen to consist of tightly packed microcrystalline (typically five micrometers across) grains of quartz in random arrangement. In thin pieces (less than 1 mm), the chalcedony is semitranslucent to translucent with a reddish cast, but almost all thicker pieces are opaque. It displays a dull conchoidal fracture on broken surfaces, but takes a vitreous luster when polished. The color of the chalcedony can best be described as a grayish, slightly reddish purple, but the tone, saturation, and sometimes the hue of the material vary within the deposit (figure 4). Approximately one-half of the chalcedony mined thus far reportedly is the darker purple, while the remainder represents the lighter shades. Some of the purple chalcedony is veined by thin seams of a reddish brown material that appears to be either an iron oxidation product such as hematite or goethite, or

Figure 2. This 5-in. (12.5-cm) high "kuan yin" figure was carved from a single piece of purple chalcedony. Photo © Tino Hammid.





Figure 3. A large block (20 × 10 × 10 cm; 8 × 4 × 4 in.) of rough purple chalcedony. Photo © Tino Hammid.

an iron-stained type of chalcedony (jasper). Also noted on a few pieces were black dendritic plumes of what appear to be one of the manganese oxides such as pyrolusite. The chalcedony displays no particular tendency to fracture along these veinlets nor along other features such as color boundaries.

GEMOLOGICAL PROPERTIES

The gemological properties of this material, as determined by standard tests, were found to correspond closely to those of both chalcedony and amethyst. These are summarized in the insert box. A comparison of the visible absorption spectra of both purple chalcedony and amethyst is shown in figure 5.

Several cabochons of the purple chalcedony were examined with the microscope. At relatively low magnification (approximately 40×) all of the samples studied showed clusters of tiny dark brownish red to orange, slightly irregular, spherules of secondary iron compounds, possibly hematite or goethite (figure 6). The color in the chalcedony appeared to be slightly darker around the clusters, giving the material a mottled appearance at this magnification. The reddish color of these inclusions is quite reminiscent of the red-orange spots seen macroscopically in the type of chalcedony known as bloodstone.

ORIGIN OF COLOR

Electron probe microanalyses performed on this material by C. M. Stockton showed that it contains 0.2–0.4 wt.% iron as Fe_2O_3 . Iron as a trace element is responsible for the color of amethyst (Holden, 1925). The iron, in the form of Fe^{3+} , substitutes for Si^{4+} in the quartz crystal structure and

produces several kinds of color centers. Irradiation of these color centers causes the absorption of light, resulting in a purple coloration (see Cohen, 1956; Nassau, 1983). The depth of the purple color is directly related to the iron content (Fron del, 1962).

To test for the presence of dye in the purple chalcedony, we placed fragments of the rough material in a variety of solvents. Using a standard procedure for dye extraction (Kumar, 1981), we found no evidence of dye in the purple chalcedony.

Figure 4. A selection of purple chalcedony cabochons showing the range of color of the material. Photo © Tino Hammid.



GEMOLOGICAL PROPERTIES OF PURPLE CHALCEDONY

Refractive index

Spot method: 1.54
Flat surface: 1.535–1.539 (birefringence 0.004)

Specific gravity

Heavy liquid: 2.61 (average of measurements of 7 stones)
Hydrostatic method: 2.60 (average of 4 measurements on 1 stone)

Visible-light spectroscopy

No sharp bands noted in either transmitted or reflected light

Visible-light spectrophotometry

Increasing absorption toward the ultraviolet, with a superimposed broad absorption band centered about 540 nm

Ultraviolet fluorescence

Inert to long-wave and short-wave ultraviolet radiation

Hardness

Near 7 on the Mohs scale

Microscopy

Abundant dark brownish red spherules scattered throughout material

Color

Reddish purple to red-purple hues with low saturation (1–2) and low to moderate tone (2–5), according to the terminology of GIA's Colored Stone Grading system

HEAT-TREATMENT EXPERIMENTATION

Samples of the chalcedony were heated to see if a color change would take place similar to that known to occur in single-crystal amethyst (Nassau, 1984). It has long been recognized that the heating of amethyst will produce citrine, and that subsequent re-irradiation will reinstate the purple color. Several cabochons, ranging from light to dark purple, were selected for heating and were then sawed in half to provide test and control samples. The test halves were heated using a Blue M Labheat muffle furnace with a temperature range up to 1000°C. For this heating, the test samples were placed in pure quartz sand in an alumina crucible. Heating was done in 100° increments, each lasting one hour. The test halves were compared to the control halves at the end of each heating increment. A change in appearance was first

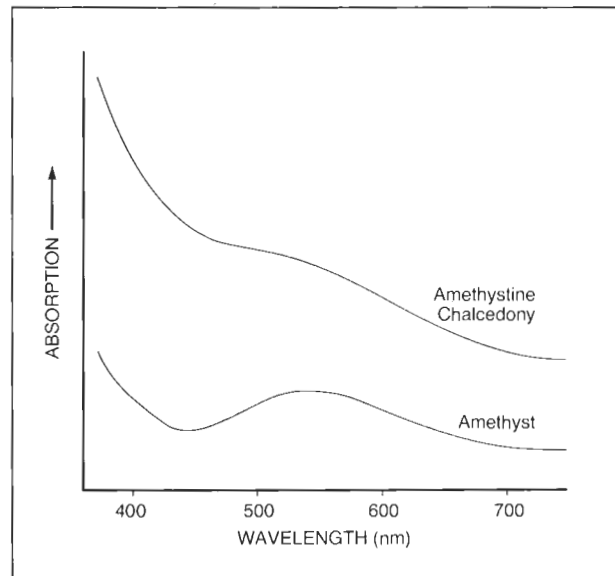


Figure 5. Visible absorption spectra of purple chalcedony and amethyst. Both spectra show increasing absorption toward the ultraviolet and a broad region of absorption (centered around 540 nm) that is more pronounced in the amethyst spectrum. Samples were thin slices of purple chalcedony (0.59 mm thick) and amethyst (2.82 mm thick) with parallel-polished windows.

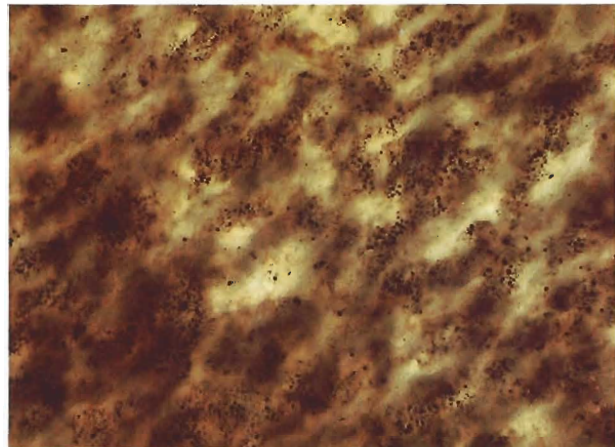


Figure 6. Tiny spherules of secondary iron compounds concentrated in color-rich areas in the purple chalcedony. These spherules rarely occur as large as 0.1 mm. Note the orange "iron-stained" color of the chalcedony around these spherules. Transmitted light, magnified 40x. Photo by John Koivula.

noted at 500°C. At approximately this temperature, the heated halves took on a grayish orange to brown tone that, after heating another 50°C to approximately 550°C, brightened in the case of the

darker purple cabochons to an orange color similar to that of most citrine. The stones held this color to 800°C, at which point they began to bleach out. At 1000°C many of the stones had bleached to a grayish white; only those that originally had been the darkest purple still retained any orange coloration. It was also noted that pale-colored purple cabochons when heated never attained any orange body color but instead took on a brownish gray tone. Only those stones that possessed a dark purple color to begin with showed a color change to orange (figure 7).

These results are generally consistent with data on the heat treatment of amethyst reported by Neumann and Schmetzer (1984). In their study of amethyst from over 20 localities, they documented the color-change behavior for amethyst heated between 300° and 560°C for several hours. They found that amethysts with a preponderance of color centers associated with interstitial iron atoms (iron atoms located between silicon and oxygen atoms) turned green when heat treated (i.e., "greened" amethyst). Only amethysts that contained small amounts of iron, presumably in the form of small particles of hematite (Fe_2O_3), became orange on heating. We have already noted the abundance of tiny, reddish brown spherules of secondary iron oxides in the purple chalcedony. We believe that the color change of this purple chalcedony to orange with heating can be attributed to the presence of these hematite or goethite spherules. The intensity of the orange color produced by heat treating amethyst seems to be related to the intensity of the original purple color (Fron del, 1962; Neumann and Schmetzer, 1984). We observed a similar change in the purple chal-



Figure 7. Deep purple amethystine chalcedony cabochon before (left) and after (right) heat treatment to 550°C. Photo by John Koivula.

cedony, with only the darker purple test samples taking on an orange color with heating.

CONCLUSION

This new type of chalcedony from Arizona is very tough and durable and comes in a wide range of purple shades. It is easily identified by standard gemological testing procedures, and appears to be colored by the same color-center mechanism as amethyst. There is enough material to amply supply the market. Thus, many possibilities exist for its use in jewelry and carvings.

While the occurrence of purple chalcedony in Arizona appears to be unusual, we do not believe this occurrence to be unique, considering the relative abundance of chalcedony in many areas of the world. It is somewhat surprising, however, that other occurrences have not been more widely publicized.

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THE PEARL IN THE CHICKEN: PEARL RECIPES IN PAPYRUS HOLMIENSIS

By K. Nassau and A. E. Hanson

There are 75 recipes for the treatment of gemstones in an Egyptian papyrus copied from a work that was compiled about 200 B.C. This includes 10 recipes involving pearls, among which are two that involve feeding the pearl to a chicken. New experiments are described which confirm the validity of one such process. The other eight recipes are discussed briefly.

About 200 B.C., Bolos of Mendes, an Egyptian chemist of whom little else is known (Sarton, 1927; Partington, 1970), compiled a multivolume set of papyrus rolls under the title *Baphika* ("Dyeing"), which dealt predominantly with the techniques of coloring various substances. This work included sections on metallurgical processes, on the dyeing of wool and other objects, and on various techniques of "improving" gemstones by coloring. All copies of this work, which were presumably available in major libraries such as the one at Alexandria, have been lost, as was the fate of many works from pagan antiquity. Before this happened, however, the whole or parts of this text had been circulated in copies made by scribes.

Pliny, the Roman historian of the first century A.D., may have known this work:

And furthermore, there are treatises by authorities, whom I at least shall not deign to mention by name, describing how by means of dyestuffs emeralds and other transparent coloured gems are made from rock-crystal, or a sardonyx from a sard, and similarly all other gemstones from one stone or another. And there is no trickery that is practised against society with greater profit. I, on the other hand, am prepared to explain the methods of detecting false gems, since it is only fitting that even luxury should be protected against deception. (Book 37, Chapters 75 and 76; from Eicholz, 1962)

Only three sources based on the work by Bolos survive. Sometime in the late third or early fourth century A.D., a scribe made copies of two lengthy excerpts in a Greek bookhand on papyrus sheets. Both were acquired in Alexandria, Egypt, by Johann d'Anastasy, a Swedish-Norwegian vice-consul in Alexandria in the 19th century. One

part, consisting of 14 papyrus folia dealing with metals, gems, and cloth dyeing, is now in the Kongelige Biblioteket in Stockholm and is designated *Papyrus Holmiensis*, or *P. Holm.* (Lagercrantz, 1913; Caley, 1927; Halleux, 1981); the other, containing sections on metals, on cloth dyeing, and a short *materia medica* glossary (possibly not present in the original text), is now in the Rijksmuseum van Oudheden in Leyden (The Netherlands) and is called *P. Leyden X* (Caley, 1926; Halleux, 1981). Other copies, generally of small fragments only, some overlapping with parts of *P. Holm.* or *P. Leyden*, have been found in miscellaneous manuscripts from the 13th century and later; these were collected in the late 19th century by Berthelot (1888, 1893) in a series of volumes dealing primarily with alchemical topics.

The recipes in *P. Holm.* and *P. Leyden* deal in a very simple, factual manner with technical processes. Unlike most other alchemical or magical recipes (Taylor, 1949), a number of these recipes are quite practical and involve processes that are still in use today. Included in *P. Holm.* are 10 recipes involving pearls, among which are two that require feeding the pearls to chickens. The current paper provides a new, contemporary translation of these recipes,* describes other versions that have appeared in the literature, and then discusses the results of experiments conducted by the authors to test the validity of these ancient recipes.

THE PEARL-IN-THE-CHICKEN RECIPES IN P. HOLM.

Among the 75 gem-related recipes in *P. Holm.* are 10 that specifically deal with pearls; these are

*Translations of *P. Holm.* have appeared in German (Lagercrantz, 1913), in English (Caley, 1927), and in French (Halleux, 1981), but these were made without specific knowledge of the technology for altering color in gemstones. One of the present authors has recently investigated this area in depth (Nassau, 1984a), thus providing the impetus for a new translation and interpretation. A brief outline has appeared in the cited work (Nassau, 1984a) as well as elsewhere (Nassau, 1984b); a full translation is being prepared (Nassau and Hanson, forthcoming).

TABLE 1. Summary of pearl treatments in *P. Holm*.

Pearl treatment	Recipe no.	Ingredients used		
		Milk	Mercury	Other substances
Cleaning	10			Honey, fig root
Cleaning	11	+		
Cleaning	12	+		Natron (sodium carbonate), earths, oil of mastic
Cleaning	13, 23	+	+	
Cleaning	25, 60			Chicken cleaning
Cleaning	61	+		Hydrated quicklime
Mordanting	13, 22, 23			Alum, vinegar
Coloring ^a	22		+	Pimpernel, houseleek, spurge
Manufacturing	18	+	+	Mica, gum tragacanth, wax, egg-white

^aThis process may not have been intended to be used on pearls but rather on other gemstones. The word pearl appears only in the title, and an analogous recipe in Berthelot (1888, Vol. 2, p. 363, No. 47; Vol. 3, p. 348) applies to quartz.

summarized in table 1. Eight of these involve the cleaning of dirty pearls and one describes the coloring of pearls. The last is a recipe for making an imitation pearl. Two of the cleaning recipes involve feeding the pearl to a chicken:

No. 25. Whitening for a Pearl

A pearl which has become encrusted is made white in this way: give it to a chicken to swallow, thereupon cut it [the chicken] open and you will find it has become white.

A similarly worded recipe specifying sunset to sunrise and a thirsty chicken appears in Berthelot, 1888 (vol. 2, p. 369, no. 8; vol. 3, p. 354). Berthelot, 1893 (vol. 2, p. 175, no. 104) mentions one that includes among other ingredients lemon juice and uses a pigeon slaughtered after two hours; Berthelot, 1888 (vol. 2, p. 330, no. 38; vol. 3, p. 316) provides one that uses a chicken or a pigeon with no time interval specified.

Halleux (1981, p. 189, Note 3) tried to test this process using a "fake gemstone" and a duck! This was not a valid check, since a "fake gemstone" would not react with gastric juices the way a pearl would.

No. 60. Cleaning a Pearl

Whenever a real pearl becomes dirty and has lost its lustre, the Indians clean it in this way: they cast the gem as food to a rooster in the evening. In the morning they search the droppings and discover it has been cleaned inside the bird and that it possesses in addition a whiteness not inferior to the original.

An additional version of the cleaning-in-a-chicken process is noted by Kluge (1860):

The 'Asiatic Journal' reports (January 1825) that in Ceylon those pearls that have lost their sheen with

the passage of time are given to chickens to swallow and then they are killed after one minute. The pearls are then found in the stomach and are as beautiful as at that moment when they were removed from the mollusk. Such a polishing can be imagined to derive from the worm-like motions in the muscular stomach of the birds. (Translated from the German)

The process described in recipes 25 and 60—and the parallel recipes in Berthelot (1888, 1893) and in Kluge's report—seem reasonable when one recalls that pearls are composed of layers of tiny crystals of the aragonite (and possibly the calcite) form of calcium carbonate, held together by about 10% of conchiolin, an organic substance (Webster and Anderson, 1983). Accordingly, the acid gastric juices of the stomach and the grinding action of the gizzard might be expected to dissolve the stained surface layer of aragonite and so improve the appearance of a dirty-looking pearl.

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Dr. Nassau is a research scientist residing in Bernardsville, New Jersey; and Dr. Hanson is professor of Greek and Latin, Fordham University at Lincoln Center, New York, New York, and curator of papyri, Princeton University Library, Princeton, New Jersey.

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All photos are by K. Nassau.

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The Halleux (1981) experiment with a "fake gemstone" could not have confirmed this pearl-cleaning process and, since no other modern attempts to test the validity of this process appear to have been published, new experiments were clearly desirable.

To understand the significance of such a process, a brief description of a chicken's digestive processes is required (Sturkie, 1976). As shown in figure 1, the food eaten by the chicken first passes through the esophagus into the crop. Here food is held under moist and mildly acidic conditions (pH about 4.5) until there is room for it in the stomach, if the chicken has not eaten for some hours, then the residence time in the crop is very brief and food moves rapidly into the stomach.

The stomach consists of two parts: (1) the proventriculus, where gastric juice (containing hydrochloric acid and the protein-digesting enzyme pepsin) is added and where the residence time is very short; and (2) the gizzard, where there is a longer holding stage under strongly acidic conditions at a pH as low as 1.4 (Sturkie, 1976). Since the chicken has no teeth to grind up its food particles for maximum exposure to the digestive juices, this process is performed by strong contractions of the muscular walls of the gizzard acting on pebbles that the chicken has pecked up along with its food. The digested food next moves into the intestines for absorption; the addition of pancreatic juice now neutralizes the acid and produces conditions that would not be expected to affect a pearl. The total digestive process normally

takes about three hours. The pebbles remain in the gizzard for a week or even longer.

THE NEW PEARL-IN-THE-CHICKEN CLEANING EXPERIMENTS

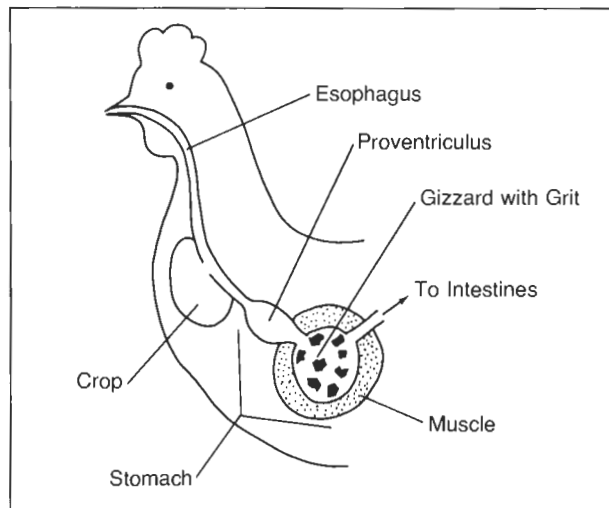
The First Three Experiments. The first part of this study used eight soiled typical round Japanese cultured *Pinctada martensi* pearls. The pearls were color matched into two sets (nos. 1A and 1B to 4 and nos. 5 to 7; nos. 4 and 7 were not treated so that they could serve as the color standard for their respective groups) and then washed, carefully weighed, and measured before use. All drilled pearls were drilled through so that the hole could be cleaned out before weighing. These pearls ranged from 6.8 to 7.8 mm in diameter and had a cultured layer about 0.35 mm thick grown over mother-of-pearl beads; details of the growth and characteristics of such pearls may be found in Webster and Anderson (1983).

The chickens used were adult (about one year old) male White Leghorns at the Poultry and Small Animal Research Facility, Cook College, Rutgers University; the experiments were conducted shortly before the birds were to be dispatched for other purposes. The feeding and recovery were supervised by Mr. M. J. Sennell of that facility. A total of four experiments were conducted.

The first experiment was an attempt to duplicate the process described in recipe 60 using two pearls, nos. 1A and 1B. Neither had appeared in the droppings the next morning or even after 46 hours, at which time the chicken was dispatched. Only two small fragments were found in the gizzard; they are shown in figure 2 and measurements are given in table 2. Both of these pearls had been split by the grinding action and at least 0.8 mm had been dissolved or ground from the surface of the largest remaining piece; all of the cultured nacre had been removed. The grinding and acidic conditions in the gizzard are obviously strong enough to destroy a pearl completely. Also, it is clear that the pearls were being treated like gravel and would not have passed out of the gizzard overnight; this aspect of recipe 60 is clearly wrong.

In the second experiment, the milder conditions in the crop were examined by exposing pearl no. 2 for only one hour in a well-fed chicken so as to maximize the holding time in the crop. The pearl was indeed found in the crop; it had lost no weight (the slight increase recorded probably corresponds to absorption of a little moisture) and its

Figure 1. The digestive system of the chicken.



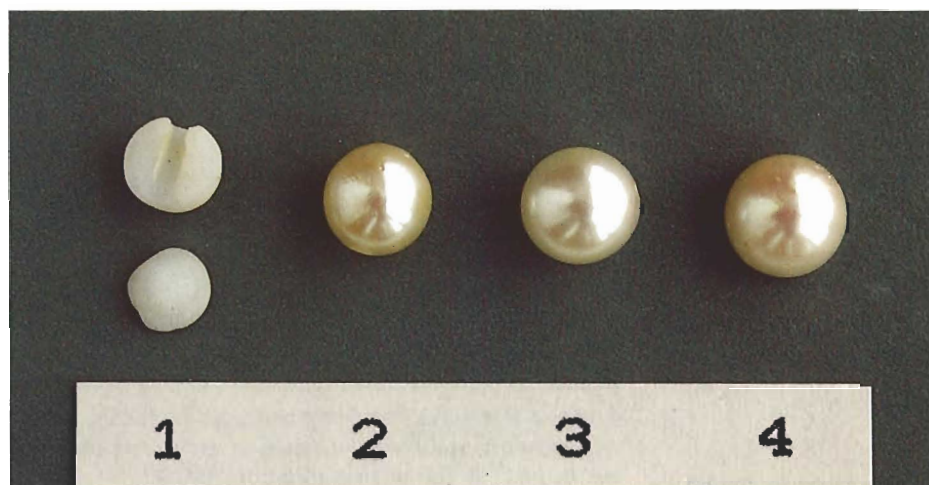


Figure 2. Pearls no. 1, 2, and 3 from the first three pearl-in-the-chicken experiments; no. 4 is the untreated color match.

appearance was unchanged, as shown in table 2 and figure 2. The one-minute treatment time given by Kluge (1860) is therefore clearly incorrect.

In the third experiment, pearl no. 3 was fed to a chicken that had not eaten overnight, so that the pearl should move rapidly through the crop. This pearl was recovered from the gizzard after two hours and was found to have lost 0.0160 g, which corresponds to a thickness of 0.034 mm, using a specific gravity of 2.7 in the calculation; see figure 2 and table 2. This pearl has lost about one-tenth of its cultured layer. It is interesting that the rate of loss of 0.017 mm per hour in this experiment was essentially the same as the 0.018 mm per hour loss recorded in the first experiment.

The pearl used in this third experiment is now much lighter in color than it was before the exper-

iment and it still possesses an excellent luster—the brilliant reflection of light at the surface—and an excellent orient—the rainbow-like sheen produced by the diffraction of light at the surface (Webster and Anderson, 1983; Nassau, 1983). Accordingly, one can conclude that recipe 25 represents a valid way of cleaning a pearl by removing a thin layer from the surface while maintaining an excellent surface quality.

The Pearl-in-Acid Experiment. An obvious question that arose at this point was: Can one use a dilute acid to achieve this same end? Either in vivo in the chicken or in vitro in the test tube, the dissolving action, using hydrochloric acid as the typical gastric (Sturkie, 1976) or experimental acid, is:



The amount of dissolution found with the third experiment corresponds to the evolution of 2.4 cc of carbon dioxide gas, assuming the presence of 10% conchiolin. Accordingly, pearls no. 5 and 6 (see table 3) were exposed to different concentrations of dilute hydrochloric acid (1:100 and 1:400, respectively) with occasional stirring at room temperature. The loss of weight approximately equal to that of the third experiment required 20 minutes and three hours, respectively, for the two pearls, so that these concentrations bracket the rate of loss that produces the desired results in a chicken.

Both of these pearls did lighten considerably, but they lost much of their luster as well as most of their orient (figure 3). Examination under the microscope showed considerable surface pitting, in contrast to the smooth surface retained by

TABLE 2. The first three pearl-in-the-chicken cleaning experiments.

Variables	Pearl no.		
	1A/1B ^a	2	3 ^b
Time in chicken(hours)	46	1	2
Location of pearl	Gizzard	Crop	Gizzard
Initial diameter ^c (mm)	7.5/7.8	6.8	7.4
Initial weight (g)	1.2135	0.4353	0.5695
Final weight (g)	0.2530	0.4357	0.5535
Weight loss (%)	79.2	0.0	2.81
Thickness lost (mm)	0.8	0.0	0.034 ^d

^aTwo pearls used; weights and weight loss are total, thickness lost is for one pearl only.

^bThis was performed after the chicken had fasted overnight.

^cColor reference pearl no. 4 shown in figure 2 is 7.7 mm in diameter.

^dCalculated from weight loss; equals half of diameter loss. Direct measurement was not possible because the pearl was not perfectly round.

TABLE 3. The pearl-in-acid cleaning experiment.

Variables	Pearl no.	
	5	6
Conc. HCl in water (vol.)	1 in 100	1 in 400
pH	0.9	1.5
Time (hours)	0.3	3
Initial diameter ^a (mm)	6.9	7.0
Initial weight (g)	0.4733	0.4852
Final weight (g)	0.4612	0.4696
Weight loss (%)	2.56	3.22
Thickness lost ^b (mm)	0.032	0.038

^aColor-reference pearl no. 7 shown in figure 4 is 7.0 mm in diameter.

^bCalculated from weight loss.

chicken-cleaned pearl no. 3 (which was still slightly rough to the tooth, however). In addition, loose shreds of conchiolin were seen on the surface of pearls no. 5 and 6. When this was removed by rubbing pearl no. 6 between the fingers with a very mild abrasive (White Rose All Purpose Liquid Cleanser with Mild Abrasive—containing calcium carbonate), the surface remained pitted; the luster improved slightly but the orient did not improve significantly. For details, see table 3 and figure 3.

The reason for this difference in behavior clearly derives from the specific conditions in the chicken's gizzard. It is well known that during metallurgical etching and electrolytic deposition or polishing (Lowenheim, 1953) the presence of additives can modify a rough surface into a smooth one; the various enzymes, food particles, and organic substances present in the gizzard may provide this same function in the chicken; the grinding action of the gizzard may also help in keeping the surface smooth. An additional factor involves the conchiolin exposed when the acid dissolves the aragonite crystals from the surface of the pearl; this can be removed in the chicken both by the grinding action and by the attack of the protein-digesting enzyme pepsin present in the gizzard, thus maintaining a smooth surface.

It may well be that some type of mild tumbling used in conjunction with a suitably modified acid solution, possibly combined with pepsin, could produce results as good as those in a chicken, but no further experiments were performed on this point.

The Fourth Experiment. The fourth and final chicken experiment explored several additional



Figure 3. Pearls no. 5 and 6 from the acid cleaning experiments; an abrasive has also been used on no. 6; no. 7 is the untreated color match.

questions: Can larger pearls be treated? Can several pearls be treated at one time? What is the reaction of freshwater pearls? What is the effect on an abraded pearl? The results are summarized in table 4 and figures 4 to 6. In this experiment, additional *Pinctada martensi* saltwater pearls as well as baroque cultured freshwater *Unio* pearls (Sweaney and Latendresse, 1984) were used.

Eight pearls were fed at one time to a chicken, but one was spit up (unnoticed at the time) and is therefore omitted from the data. The average weight loss of 4.05% after three hours corresponds to a loss rate of 1.35% per hour, which is close to the 1.72% per hour loss for pearls no. 1A and 1B and the 1.40% per hour loss of pearl no. 3. Some variability in weight loss can be seen in table 4, which suggests that the pearls did not all move from the crop into the stomach at the same time. The treatment of several pearls at one time is thus clearly feasible, but only with some loss of control.

Well-matched color reference pearls were not available for this experiment, but a definite lightening of the color was observed in the saltwater pearls, as expected. Of the freshwater pearls, one (no. 11) lightened in color but two others (nos. 12 and 13) turned slightly yellowish. The luster and orient of these seven pearls were generally unchanged except for the black pearl, no. 14, which lost most of its strong rosé and green overtones; it was, however, of extremely poor surface quality to begin with.

To test the effect of this procedure on abraded pearls, pearls no. 10 and 15—which were similar in size, luster, and orient (but not in color)—were abraded with a fine file so that a flat spot was created on each, extending well into the mother-

TABLE 4. The fourth pearl-in-the-chicken cleaning experiment.

Pearl no.	Type ^a and description	Min and max. dimensions (mm)	Initial weight (g)	Weight loss ^b (%)	Change in appearance ^c
8	S, green-yellow	7.3	0.4645	4.89	Somewhat lighter
9	S, silver-gray	7.4	0.5248	2.78	Somewhat lighter
10	S, yellow-white ^d	6.8	0.4564	4.55	See text and figures 5 and 6
11	F, blue-gray	14.5 × 5.8	0.7500	5.17	Somewhat lighter
12	F, gray-white	7.6 × 6.9	0.5255	3.52	V. slightly yellower
13	F, gray-white	9.4 × 8.8	1.1251	3.72	V. slightly yellower
14	F, black	10.5 × 7.3	0.7261	3.75	Less orient, less surface color

Average: 4.05

^aS = near-round cultured saltwater *Pinctada martensi* pearl; F = baroque cultured freshwater *Unio* pearl.

^bAll of the pearls were exposed for three hours after the chicken had fasted overnight; all were found in the gizzard.

^cCharacteristics not listed did not appear to change significantly.

^dThe abrasion-matched (but not color-matched) pearl no. 15 shown in figure 5 is 7.0 mm in diameter.

of-pearl seed. Pearl no. 10 was then fed to the chicken as part of the fourth experiment, while pearl no. 15 was held back as the control. As can be

Figure 4. Pearls no. 8 to 14 from the fourth pearl-in-the-chicken experiment; the bottom row shows three of the pebbles also recovered from the gizzard.

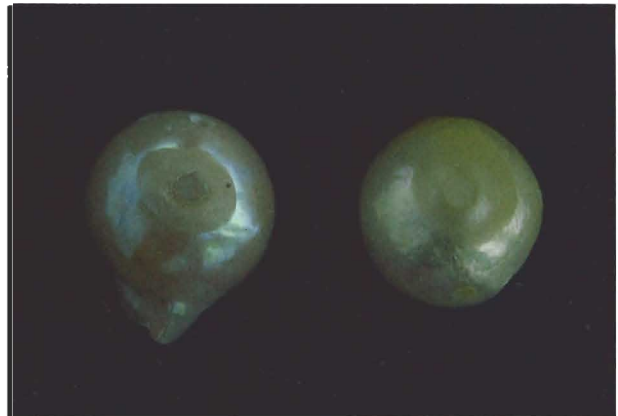


Figure 5. Pearls no. 15 (left) and no. 10 (right). Both were abraded, but only no. 10 was then "polished" in a chicken.

seen at least partially in figure 5, the rough nacre surface of pearl no. 10 was polished in the gizzard to produce a quite acceptable luster and an excellent orient. Microscopic inspection shows the presence of slight circular ridges on this part of the pearl, corresponding to the concentric layers of nacre.

Another region of pearl no. 10, which showed prominent surface ridges, had been filed down to flatten the surface. Here, too, the file marks disappeared during the treatment and an excellent luster and orient resulted, as shown in figure 6. It should be pointed out that such ridges and other irregularities appearing over a spherical seed are produced by irregular deposits of conchiolin (and possibly aragonite) in non-nacreous form, as can be seen in the cross-section of such a baroque saltwa-



Figure 6. Ridged area of pearl no. 10 which was first abraded and then polished in a chicken.

ter pearl shown in figure 7. Abrasion to improve the surface of a pearl can obviously be performed only by remaining within the nacreous layer, but the rough filed surface can then be polished in a chicken by following the described procedure. It should, however, be noted that a ridged appearance originating from the deeper nacre layers may still be visible through the translucent upper layers even though the surface is now smooth; this is the case for part of pearl no. 10, as seen in figure 6.

These experiments demonstrate that the ap-

Figure 7. A baroque *Pinctada martensi* pearl cut in half to show non-nacreous regions between the spherical seed and the irregular surface.



pearance of some pearls may indeed be improved by the pearl-in-the-chicken process described in *P. Holm.* recipe 25. Since nacre is removed, it is obvious that surface stains would be removed along with the nacre.

THE OTHER PEARL RECIPES

A summary of the other eight pearl recipes in *P. Holm.* is given in table 1; new translations have been prepared (Nassau and Hanson, forthcoming).

The "law of similarity" (Frazer, 1947)—or "principle of analogy" (Lloyd, 1966)—influenced the thinking in many early societies and can be recognized in some of these recipes. According to this habit of thought, like affects like: If you wish something to be white, then place it in contact with a white substance and it will acquire the quality of whiteness. This might explain the use of milk in five of these recipes, particularly milk from a *white* dog (specified in recipes nos. 11 and 61). Milk is only very slightly acidic and a specific chemical interaction with a pearl would not be expected. Again, mercury, with its metallic sheen, might have been expected to intensify a pearl's orient by similarity and analogy.

Of the six pearl-cleaning recipes of this group, one (no. 11) uses cold milk only and two (nos. 13 and 23) heat milk with mercury, although it is not actually specified if the pearl is immersed while the mixture is still hot. Three recipes (nos. 10, 12, and 61) use poultices, sticky or congealing substances, which are applied to the pearl and then

rubbed (nos. 10 and 61) or peeled (no. 12) off. Two of these (nos. 12 and 61) are applied cold, but the third is applied hot; heat can damage a pearl. In all of these recipes, no more than a mere physical removing of surface dirt appears to be involved; one suspects that soap would do as good a job.

Mordanting is involved in two of the cleaning recipes (nos. 13 and 23) and in the coloring recipe (no. 22). A mordanting step, most frequently employing alum and vinegar, was used in Greco-Roman times in the major process for dyeing wool and has continued to be so used until quite recently (Taylor and Singer, 1956). It involves the precipitation of finely divided aluminum hydroxide onto the fabric and the subsequent attachment of a dye to this powder. As a result, the dye becomes more intense in color and does not fade as rapidly in sunlight. Although it would almost certainly not have served any useful function for cleaning a pearl, mordanting must have seemed a step that might be useful—a slight etching produced by the vinegar, perhaps—and probably did no harm. A mordanting step could be more meaningful to a coloring (dyeing) process such as that described in recipe no. 22, although it may be that this recipe was never intended to be used on a pearl. Merely from the list of ingredients it is not possible to guess what color would be produced by this mixture.

Finally, there is recipe no. 18, which instructs how to make an imitation pearl from a paste. The use of ground-up mica seems appropriate here since this would tend to give a surface shimmer to the imitation, much as does the "fish-scale essence" that has been used to make imitation pearls since 1656 (Webster and Anderson, 1983). No less than three of the ingredients, used in equal amounts, could be expected to contribute to the hardening of the kneaded mass: gum tragacanth, wax, and egg-white. One suspects that the product would not have been a very convincing pearl imitation except to the quite inexperienced.

CONCLUSION

The chicken-cleaning experiments here reported, as well as other duplication experiments currently under way, indicate that many of the 2,000-year-old recipes given in *P. Holm.* represent valid gemstone-treatment processes. Pliny, writing in the first century A.D., described the sugar-acid agate-dyeing process, the use of foils, dyeing, the

oiling of emerald, the making of triplets, and even the clarification of amber (Nassau, 1984a and b). *P. Holm.*, based on the even earlier writings of Bolos, provides us with details of some of Pliny's more obscure passages (it explains, for example, the "softening" of "diamond" with warm goat's blood) and adds such treatment processes as the cracking and dyeing of quartz and the oiling of emerald with Canada balsam. This unique manuscript represents an early comprehensive technical text and attests to the antiquity of gemstone-treatment processes.

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Gem Trade LAB NOTES

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BERYL, Bicolor

Recently sent to the Los Angeles laboratory for identification was an interesting 9.66-ct bicolored (light blue and colorless) modified emerald-cut stone (figure 1). Subsequent testing revealed that this stone was beryl. The following properties were observed: refractive indices of 1.563–1.570, no reaction to long- or short-wave ultraviolet radiation, and a broad absorption band of moderate strength centered at 427 nm in the visible spectrum of the blue portion of the stone. This spectral absorption is typical of many aquamarines. There was no absorption spectrum for the colorless section. Examination with the microscope revealed inclusions that are typical of beryl. Very prominent, distinct, angular and straight parallel growth features were confined to the blue portion.

This is the first time that we have seen a faceted bicolored beryl consisting of aquamarine and goshenite. We have, however, seen similar color zoning in beryl crystals, particularly those from Nigeria. In the Nigerian crystals that we examined, light green and colorless color zoning was more common than was light blue and colorless, perhaps because these crystals had not yet been heat treated.

RK

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

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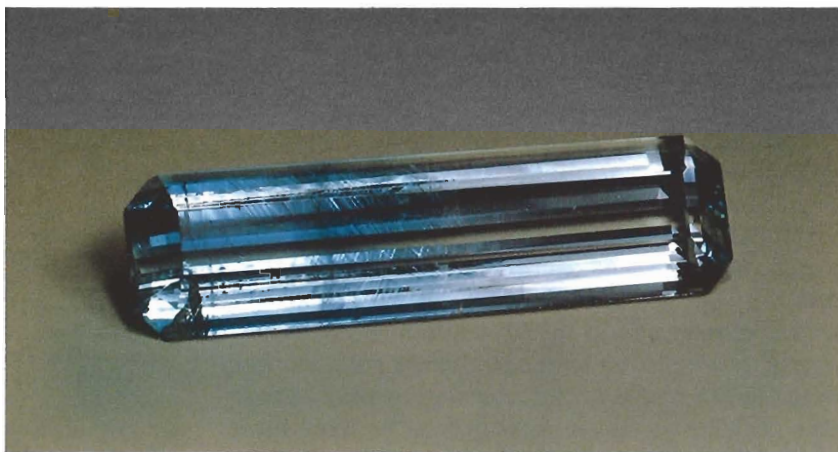


Figure 1. This 9.66-ct bicolored beryl consists of both aquamarine and goshenite.

DIAMOND

Heat-Induced Color Change in Diamond

One of our clients often shares with the New York laboratory unusual diamond specimens from his family's mining operation in Guyana. Many of the rough diamond crystals that they mine have a green "skin" caused by natural irradiation staining.

Recently, our client donated a parcel of four diamond crystals. All except the largest piece (1.12 ct) were greenish in color. Our client explained that the largest crystal was green when mined, but it turned yellow-brown when it was sawed by a laser. Figure 2 shows the now yellow-brown lasered crystal next to another crystal which approximates the original color. Note the "step-like" laser saw marks on the

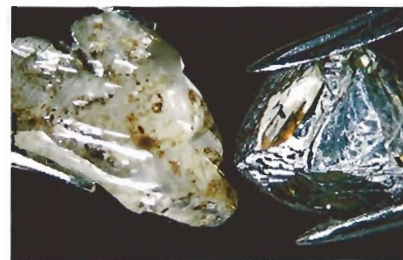


Figure 2. The diamond on the left turned yellow-brown during laser sawing. It was originally green like the stone on the right. Magnified 15x.

yellow-brown stone. When a green-skinned diamond is heated, the green areas will often change to brown or yellow, just as green diamonds are changed from dark green to yellow or brown by heat treatment. In this case, the heat of the laser

(1200°–1300°C) was enough to effect this color change. RC

Diamond With Natural Internal Irradiation Stain

Green and brown surface irradiation stains have traditionally been used to identify natural color in green diamonds. These characteristic stains are a result of natural irradiation within the earth. Occasionally, a near-colorless or very light yellow diamond may also have some natural irradiation stains. Theoretically, such a stone could be artificially irradiated to produce a green color. Consequently, these stains are not proof of natural origin of color, but only an indication. Unfortunately, not all artificially treated diamonds exhibit the 592 nm (5920 Å) absorption line that, when present, has been considered characteristic of artificially irradiated diamonds.

A 2.40-ct very light yellow pear-shaped diamond was submitted to the New York laboratory for a damage report. During the initial examination we noted a natural brown irradiation stain on the girdle. While examining the flaw in question (an inherent fracture) we noticed a natural irradiation stain within the stone on one of the planar surfaces of the fracture (figure 3). This is the first time the laboratory has seen an irradiation stain inside a diamond. It was located at a depth of approximately

Figure 3. Internal irradiation stain on a fracture in a diamond. Magnified 20×.

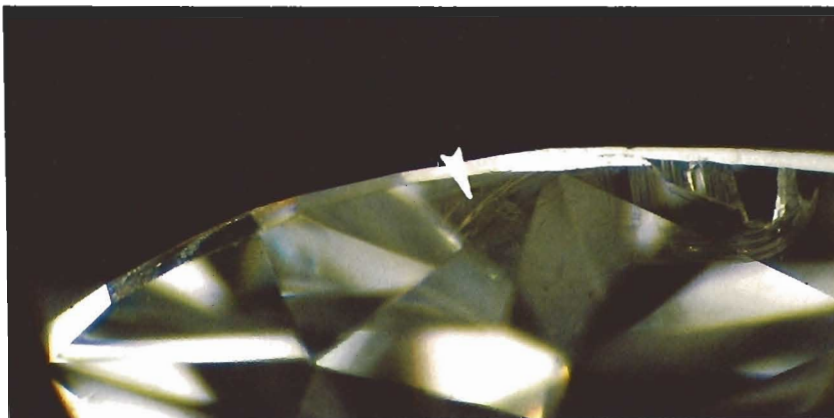


Figure 4. The two parts (4.72 ct and 2.41 ct, respectively) of a piggyback diamond.

1 mm. We can only speculate as to the cause of the interior staining. Perhaps a radioactive liquid infiltrated the fracture at one time. RC

Piggyback Diamond

A Maryland jeweler recently encountered a very unusual diamond



Figure 5. The piggyback diamond illustrated in figure 4 is shown here assembled as it would be in the mounting.

ring. The ring was set with approximately 15 pear-shaped diamonds of about one carat each. In the center was what appeared to be a large, approximately 9 to 9.5-ct, yellow pear-shaped stone. However, on closer examination the stone was found to actually be two diamonds mounted one directly below the other and held in place by the mounting; no cement was used to hold the two stones together. The center "stone" was removed from the mounting and sent to GIA to photograph and examine. The top section, a thin pear-shaped window diamond with no pavilion, weighed 4.72 ct and measured approximately 17.50 × 12.55 × 2.46 mm deep. The bottom "pavilion" portion was a complete pear-shaped brilliant that weighed 2.41 ct and measured approximately 12.50 × 7.23 × 4.48 mm deep. The two separate components are shown in figure 4. This type of deceptive assemblage, known as a piggyback diamond, is seen only occasionally in the trade, and few jewelers are even aware that such items exist. As illustrated in figure 5, when assembled this stone looks remarkably good. It is generally good practice to be suspicious if a large diamond is mounted in such a way that only the culet area and crown are visible. John I. Koivula



Figure 6. This cubic zirconia was cut to simulate a 10-ct fancy yellow octagonal modified brilliant-cut diamond.

FANCY DIAMOND SIMULANT, Yellow Cubic Zirconia

Over the past few years we have noticed an unusual interest on the part of diamond dealers and cutters in large, off-color, light yellow, emerald-cut diamonds. We eventually learned that these stones were being recut as octagonal modified brilliants. The light yellow could become fancy light yellow or even fancy yellow because the new cuts intensify and deepen the apparent color.

It now appears that this technique has been used on diamond simulants as well. A client recently submitted to the New York laboratory a ring set with what she thought was a 10-ct fancy yellow octagonal modified brilliant-cut diamond (figure 6). However, routine testing proved the stone to be yellow cubic zirconia. This is the first time we have seen cubic zirconia cut to imitate a fancy yellow octagonal modified brilliant. Figure 7 shows two of the facet arrangements seen on this style of cut. RC

Melted GARNET-and-GLASS Doublet

It is quite probable that the 1.69-ct garnet-and-glass doublet recently examined in the New York lab (fig-

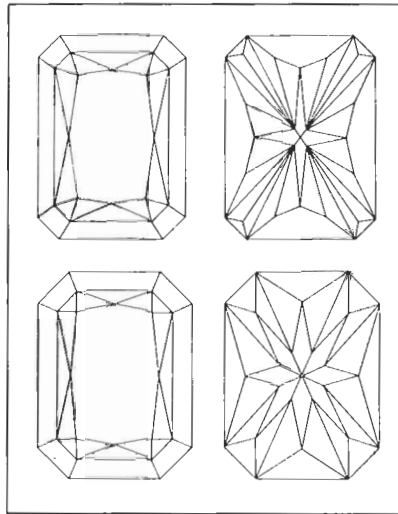
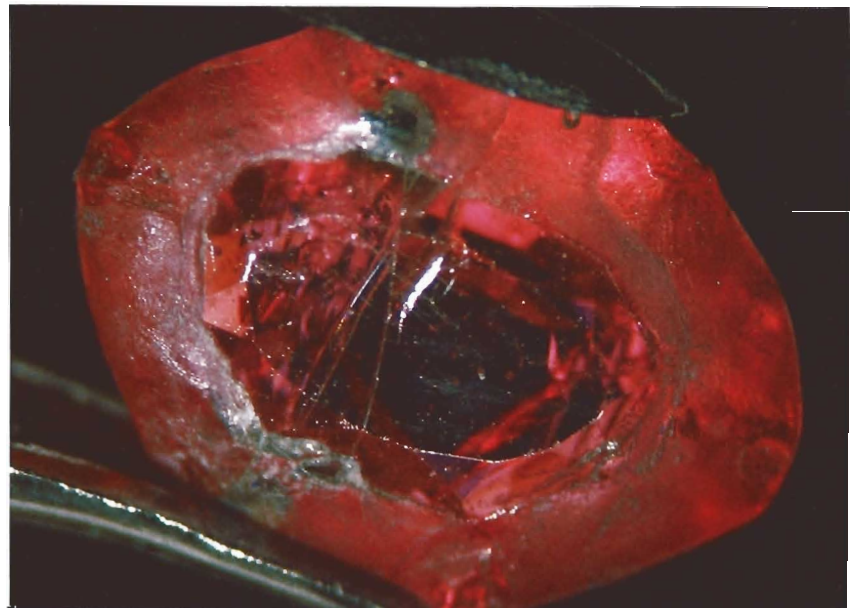


Figure 7. Facet diagrams of two different octagonal modified brilliant cuts.

ure 8) was mistaken for a natural gemstone and left in its setting during repair work, even though the repair work required heat. The red glass, which constitutes the main portion of the doublet, is obviously distorted and has even melted over the edges of the thin garnet crown. Certain types of glass often have a

Figure 8. Heat-damaged 1.69-ct garnet-and-glass doublet. Magnified 20x.



very low melting point, and the glass in this particular doublet even melts easily when touched with the thermal reaction tester. Also note where the hot prongs of the setting left indentations along the girdle of the glass. RC

Carved JET

Figure 9 shows an opaque black carved urn measuring approximately 12.1 x 6.3 x 31.8 cm (4¾ x 2½ x 12½ in.) high that we received in the Los Angeles lab for examination. Our client questioned whether the material was in fact "black amber." This term is sometimes used in the trade for jet, a form of fossilized wood altered to brown coal. The carving had a waxy luster, was fairly soft, and was easily scratched with a pin. Although it had a poor polish, we were able to obtain a vague refractive index reading of 1.59, considerably lower than the 1.66 figure that is usually listed in the gemological literature for jet.

When the piece was exposed to ultraviolet radiation, both long and short wave, a faint orangy fluores-



Figure 9. This carved urn, 12.1 × 6.3 × 31.8 cm, is believed to be jet in spite of its low refractive index.

cence became visible. A thermal reaction test produced an organic odor typical of burning coal. In addition, the material left a brown streak on an unglazed porcelain plate, also indicating that it might be some type of coal. We were satisfied that this was jet, or coal, in spite of the low R.I. KH

Oiled LAPIS LAZULI

An importer of fine lapis lazuli beads that had reportedly originated in Afghanistan was perplexed by an apparent difference in luster among the beads. He suspected that some of them had been oiled to improve their appearance.

After establishing that the 10-mm beads shown in figure 10 were in fact lapis lazuli, the New York laboratory used the thermal reaction tester and magnification to examine the beads for oil or paraffin. All of the beads showed the characteristic evidence of oil being drawn to the surface by the heated probe. Some of the beads had heavy concen-

trations of oil in the drill holes and fine cracks. Oil rather than paraffin was indicated because the liquid did not turn white on cooling as paraffin will. No evidence of blue dye was observed when the beads were examined with the microscope or were checked with an acetone solvent.

Oil or paraffin treatment has been used historically to "set" dye in such stones as jade, lapis lazuli, and tumbled amazonite. Although we are certain that the beads we examined were not dyed, we do not know why oil treatment alone was used, unless it was to cover a poor polish.

RC

PEARLS

Conch "Pearls"

Both the Los Angeles and the New York laboratories had the opportunity to examine a selection of pink calcareous concretions, commonly referred to as conch "pearls," that ranged in weight from 0.67 ct to 5.10 ct. Figure 11 gives some indication of the range of colors and shapes in

which conch pearls occur. The client who submitted them to us stated that the conch pearl that is second from the right in the top row in figure 11 seems to be the classic shape of the better-color ones.

Our client represented the owner of the conch pearls, who is a commercial supplier of conch meat. These particular conch pearls were reportedly found in the waters off the islands of St. Christopher (also known as St. Kitt) and Nevis in the Lesser Antilles of the Caribbean. As to the rarity of these conch pearls, we were informed that in 12 months of shipping over 25,000 lbs. of conch meat, which represents approximately 54,000 conchs, only four large (5–10 ct) and a few dozen smaller "pearls" were found. Our client informed us that the best pink colors are found in the outer parts of the conch near what the divers call the horn, a hook-like muscle that the conch uses to pull itself along. The color and translucency of the "pearl" are poorer the farther back into the animal the "pearl" is formed.

Figure 10. These 10-mm beads of Afghanistan lapis lazuli were found to have been oil treated.





Figure 11. A selection (0.67–5.10 ct) of calcareous concretions known in the trade as “conch pearls.”

Opaque brown to yellow conch pearls are also found, but these are usually discarded because of their unappealing appearance.

All of these conch pearls showed the characteristic flame-like structure. Note the two center pieces in the bottom row of figure 11. These represent one pearl that was sawed in half, revealing an interesting cross-sectional coloration and structure.

RK

Imitation $\frac{3}{4}$ Cultured Blister Pearls

It has been said that imitation is the sincerest form of flattery. In the jewelry trade, imitations are usually confined to popular, well-established items, such as diamonds. It was therefore unusual for the New York laboratory to examine an imitation of something relatively new to the pearl market: the $\frac{3}{4}$ cultured blister pearl (figure 12). This type of pearl was previously described in the

Figure 12. A 17-mm imitation $\frac{3}{4}$ cultured blister pearl.



Summer 1981 (p. 104) and Winter 1983 (p. 235) issues of *Gems & Gemology*.

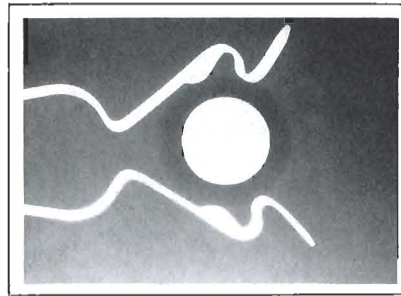
One of our clients bought a large selection of what he thought were variously colored $\frac{3}{4}$ cultured blister pearls in Hong Kong. Upon X-ray testing one of these “pearls,” we determined that it was made out of plastic with a solid metallic core to give it weight (figure 13). Figure 14 shows the crazing that occurred on the surface of the plastic when the “pearl” was immersed in safety film cleaner for X-radiography.

RC

RUBY, with Unusual Inclusions

Some time ago, the Los Angeles laboratory was asked to identify an attractive purplish red oval mixed-cut stone that weighed slightly over one

Figure 13. This X-radiograph of the imitation pearl shown in figure 12 reveals a metal core and a plastic surface.



carat. Standard gemological tests identified the stone as a ruby which was inert to short-wave ultraviolet radiation but fluoresced a weak red to long-wave ultraviolet radiation. When the stone was viewed with magnification, some of the inclusions were quite puzzling. Very fine “silk”-like inclusions were arranged in layers that fanned out into veils. These inclusions resembled the wispy veil-like inclusions that sometimes occur in Czochralski synthetic stones. We also noticed two parallel twinning planes and a small iron stain in one corner of the stone which indicated natural origin. Since our findings were not conclusive, we asked the GIA Research Department to analyze this ruby by means of X-ray fluorescence to determine the trace elements that would indicate natural or synthetic origin. The trace elements that were found in this ruby were mainly chromium, iron, and gallium; no elements that would suggest a synthetic origin were found. On the basis of these tests, we concluded that this stone was indeed a natural ruby that happened to have very unusual inclusions that mimicked those sometimes seen in some synthetics.

KH

SPINEL, Color Change

In the Winter 1984 issue of *Gems & Gemology*, we reported on an attrac-

Figure 14. The surface of the imitation pearl shown in figures 12 and 13 was crazed when the bead was immersed in safety film cleaner. Magnified 10x.



tive natural spinel that exhibited a color change from pinkish purple when viewed with fluorescent illumination to purplish pink under incandescent light. One of the interesting features of this stone was the moderate chalky yellowish green fluorescence it exhibited when exposed to long-wave ultraviolet radiation. The Los Angeles lab recently had the opportunity to examine another interesting natural spinel. This spinel showed a weak color change, more of a tonal change really, from light grayish purple to medium grayish purple. This stone also exhibited a chalky yellowish green fluorescence (very weak) when exposed to long-wave ultraviolet radiation. It was inert to short-wave ultraviolet radiation, as was the previously mentioned color-change spinel.

RK

Synthetic SPINEL, Color Change

Of the many types of synthetic spinel, the color-change or "alexandrite-like" variety is the one least often encountered in the laboratory. The Los Angeles laboratory recently examined a synthetic color-change spinel with a "rather believable" color change from dark bluish green when viewed with fluorescent illumination to dark brownish green under incandescent lighting. This is in contrast to the unrealistic color change exhibited by the very commonly encountered synthetic color-change sapphire. Despite the realistic color change, this type of synthetic spinel can be readily identified with standard gemological tests.

RK

Synthetic ZINCITE

In New York, we recently examined a 4.05-ct transparent yellow round brilliant. At first glance, we thought it might be a synthetic rutile or the unusual tetragonal cubic zirconia. When the stone was tested, the R.I.



Figure 15. New hydrothermal synthetic zincite on the left, accidental synthetic zincite furnace products on the right.

proved to be over the limits of the refractometer, the polariscope revealed a uniaxial optic figure, the specific gravity was 5.70, and a hardness of approximately 4-4½ was determined. There was no diagnostic spectrum. At the request of our client, a sample of the rough was sent to

the Applied Gemology Division of the Research Department at GIA, where X-ray diffraction analysis proved the material to be synthetic zincite.

The client indicated that this material is the by-product of an industrial process used in Poland. However, its softness precludes its use in jewelry. A rare, vivid red zincite does occur in nature; it is prized by collectors both as rough material and when faceted.

Synthetic zincite has been produced experimentally by at least two methods, hydrothermal and vapor growth. Figure 15 (left) shows a new hydrothermal specimen that weighs 20.2 grams and measures 33 mm long. The larger of the two accidental products on the right is a 5.3-gram piece from a furnace fragment that originally weighed 171 grams. The assorted colors of the hydrothermally grown synthetic zincite shown in figure 16 are the result of various impurities. Figure 17 shows examples of synthetic zincite grown by the vapor growth method.

RC

Figure 16. The various colors of this hydrothermally grown synthetic zincite are caused by the use of different impurities. The large black specimen is 43 mm long and weighs 52.1 grams.



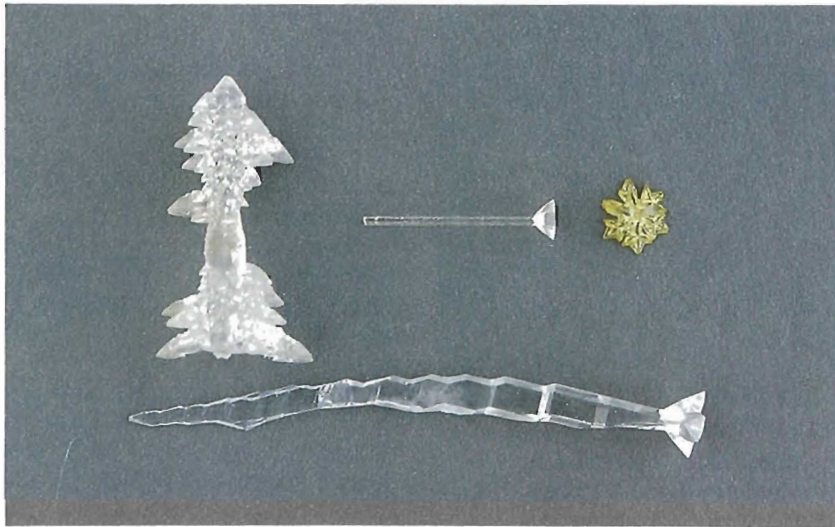


Figure 17. These crystals of synthetic zincite were produced by the vapor growth method. The largest specimen is 45 mm long.

UNCLASSIFIED ODDITY

In the Spring 1983 issue of *Gems & Gemology* (p. 49), we discussed an item under "Unclassified Oddities." We stated that "although we know it is of organic origin, we have no idea what creature created it, or how it was formed." Recently, I received a telephone call from GIA student

Michael Patterson of Florida, who believed that he could identify the item in question, shown here in figure 18. He thinks it is the lens from the eye of a fish that has been boiled. In his experience, when the fish is boiled the lens turns white and becomes quite hard. This seems to be a reasonable explanation, since our ob-



Figure 18. This broken concretion with a bead-like core (13 mm in diameter) may be the lens from a boiled fish eye.

ject was found in a can of fish sold as cat food, which surely would include parts of a fish not normally used for human consumption. The light beige color could be the result of staining from the oils present in the can. Our thanks to Mr. Patterson for taking the time to call us with this explanation. CF

FIGURE CREDITS

Figures 1, 9, and 11 were supplied by Shane McClure. Chuck Fryer took the photos used in figures 4, 5, and 18. Dave Hargett furnished figures 2, 3, 6, 8, 10, and 12-14. Dr. Kurt Nassau very kindly allowed us to use his photographs for figures 15-17.

5TH ANNUAL

GEMS & GEMOLOGY MOST VALUABLE ARTICLE AWARD

The Winter issue marks the end of the 1985 *Gems & Gemology* volume year. Once again, we are asking you, our subscribers, to participate in the 5th Annual Most Valuable Article Award. We count on you to give our authors the recognition they deserve for the time and effort invested in their articles. We also need to hear your feelings about *Gems & Gemology* — we value your opinion and want the journal to continue to reflect your needs and interests.

Your ballot is located on the insert card inside this issue. Please choose three articles from 1985 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, detach the postcard ballot and drop it in the mail (postage is prepaid if mailed in the U.S.). Ballots must be received by March 10, 1985 to be included in the final tally.

The winning articles will be announced in the Spring 1986 issue of *Gems & Gemology*. Cash awards of \$500, \$300, and \$100, respectively, will be given to the authors of the articles that place first, second, and third in the balloting.

GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Electron microscopical investigation of oriented magnetite and amphibole in black star diopside. C. F. Wöensdregt, M. Weibel, and R. Wessicken, *Schweizerische Mineralogische und Petrographische Mitteilungen*, Vol. 63, 1983, pp. 167–176.

Black star diopside from Namakkal, Tamil Nadu, in southern India is shown to contain oriented inclusions of magnetite. Two sets of inclusions lie in the (010) plane of the host diopside. When a cabochon is cut with its base perpendicular to the b-axis, the two sets of inclusions intersect at an angle of 104° to produce the ob-

served fourfold asterism. Oriented inclusions of an unknown amphibole mineral are also present. *JES*

Fracturing in Canadian hessonites. J. I. Koivula, *Journal of Gemmology*, Vol. 29, No. 7, 1985, pp. 579–583.

Mr. Koivula reports on his microscopic examination of hessonites from the Jeffrey mine, Asbestos, Quebec, Canada. The purpose of the investigation was to determine the cause of the numerous fractures in these grossular garnets, as the fracturing is not typical of hessonites from other localities (e.g., Sri Lanka or East Africa).

Using both dark-field and transmitted illumination, the author was able to rule out thermal expansion from either fluid inclusions or from acicular diopside crystals as the cause of the fracturing. When the shadowing technique was applied to a polished crystal section, the original rhombic dodecahedral structure (that existed in the specimen before the surface was ground away) was revealed. This indicated that significant strain was, indeed, present. When polarized light was used, strain colors traced the original growth features of the crystal. This strain pattern was noted in all of the rough and faceted hessonites examined.

Noting continuous growth oscillation between both the rhombic dodecahedral and the trapezohedral habits of the rough specimens, the author concludes that zoned internal strain was responsible for the fracturing commonly observed in these hessonites.

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

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

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

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Six photomicrographs well illustrate the various lighting techniques used in this investigation. RCK

Mechanism of thermal conversion of colour and colour centres by heat treatment of amethyst. E. Neumann

and K. Schmetzer, *Neues Jahrbuch für Mineralogie Monatshefte*, No. 6, 1984, pp. 272–282.

The color of amethyst is caused by color centers associated with trace amounts of iron. The iron occurs at two sites in the quartz crystal structure. Either the iron atom substitutes for a silicon atom or it is located in an interstitial space between silicon and oxygen atoms. Heat treatment of amethyst converts it to yellow, yellowish brown, green, or even colorless. In this detailed study of 117 natural and synthetic amethysts, representing 20 localities and both the Russian and Japanese synthetic production, the heat treatment behavior of amethyst was documented. The experiments involved heating the amethyst samples in air at between 300° and 560°C for several hours. The following general sequence of colors was noted: violet–colorless–green–yellow–brown, although not all samples displayed the entire sequence of changes. However, the temperatures necessary for the development of a distinct color change were found to be different for samples of various intensities of the original violet color, even for amethysts from the same locality. All transformations in color were found to occur gradually and in steps. Heating at higher temperatures for shorter periods resulted in the same changes as did heating at lower temperatures for longer periods.

The colors observed before and after heat treatment can be described as follows: (1) the violet is related to a broad absorption band at 550 nm; (2) the green is associated with a broad absorption band centered in the infrared at 720 nm; and (3) the yellow relates to a broad absorption band in the ultraviolet region that contributes to an increasing absorption in the visible region from red to violet. During heat treatment, the latter two bands increase in intensity parallel or subsequent to a decrease in strength of the first band. However, the relative intensities of the band in green quartz, caused by an interstitial iron–type color center, and the yellow color of citrine, attributed to iron particles (presumably Fe_2O_3), are strongly variable. Thus, the heat treatment of an amethyst to either green quartz or citrine mainly depends on the relative intensities of both absorption bands. The dominant intensity band produced by heat treatment gives rise to the appropriate color. However, the factors responsible for the development of both color centers in different concentrations in amethyst are still unknown. JES

Note on inclusions in diopside from Ala, Piedmont, Italy. B. Jackson, *Journal of Gemmology*, Vol. 19, No. 6, 1985, pp. 486–489.

The fluid inclusions in a slightly yellowish green faceted diopside from Ala, Piedmont, Italy were examined using

a freezing-stage microscope. The subject was frozen to $-70^{\circ}C$ and then slowly warmed to room temperature. During freezing it was noted that at $-37^{\circ}C$ the gas bubble contracted and all of the liquid froze into a coarse-grained solid. Upon warming to $-36^{\circ}C$ partial melting began. By $-1.9^{\circ}C$ all of the frozen liquid had melted. The temperatures at which the melting and freezing occur indicate that the liquid is a mixed saturated saline brine with the major component being sodium chloride. The cubic daughter crystals in some of the inclusions are therefore thought to be halite. In addition, some other unidentified solid phases in the fluid inclusion cavities were observed and illustrated. The author concludes that on the basis of the presence of various necking-down features, of the general crystallographic orientation and patterning of the negative crystals, and of the optical continuity that exists between the inclusions and host, that the inclusions are almost certainly pseudosecondary in origin. JIK

Pearls and the discovery of America. P. Francis, Jr., *Leisure* *Journal*, Vol. 38, No. 12, 1985, pp. 1512–1516.

Author Peter Francis, Jr., presents a review of the role that pearls played in the discovery and subsequent exploration of the New World during the 15th, 16th, and early 17th centuries. Explorers such as Columbus, Vespucci, de Soto, and Balboa sailed the islands of the Caribbean in search of treasure. The natives of these islands were relatively unconcerned with the value of the pearls that they had amassed over time while gathering food from the sea. On learning this, the explorer exploited the natives, tricking them to turn over their pearls in exchange for cheap gifts, or forcing them to make dangerous, and often fatal, dives. The pearls were shipped to Spain, and then traded throughout Europe.

As other, lesser known, explorers braved the interior of the new continent, they found that the island natives had accumulated stores of freshwater pearls. However, word of previous exploitation had preceded the adventurers, and these natives were much more wary of the white man's propositions. Even so, within a relatively short time, the large, ancient mollusk beds were fished out, and by the end of the 17th century the great American pearl age was over.

This article includes information rarely reported in the pearl literature. SAT

South Sea pearl importers look to new sources. D. Gordon, *National Jeweler*, Vol. 30, No. 17, 1985, pp. 84–85.

Although the demand for South Sea pearls is increasing, the supply is declining. This article briefly discusses the production of three areas known for these cultured pearls: Australia, Burma, and the Philippines.

Both Australia and Burma are producing fewer cultured pearls. Australia's reduced production is attrib-

uted to the relocation of its largest cultivator to Indonesia. Burma's production has declined steadily since all industry in that country was nationalized in the early 1960s; the quality of their product has also fallen. The quality of Australian pearls, on the other hand, is high; one U.S. importer states that the pearls from Australia are the only high-quality pearls on the market at the present time.

The Philippines is a country whose role as a major producer of South Sea pearls is still in the balance. Several U.S. importers interviewed explained that the quality of pearls cultivated in the islands has declined in recent years. The quantity is said to have also dropped. It is reported that no more than 3,000 to 5,000 pearls are successfully cultivated; of these, 80% are low quality. The three factors to which this situation is attributed are the political atmosphere of the Philippines together with geographical and biological obstacles. Other U.S. importers agree that recent crops have been small; however, they are optimistic that the Philippines will eventually fill the gap created by the dwindling crops of other South Sea pearl cultivators. *Lorraine G. Gruys*

A spectroscopic study of irradiation coloring of amazonite: structurally hydrous, Pb-bearing feldspar. A.

M. Hofmeister and G. R. Rossman, *American Mineralogist*, Vol. 70, No. 7/8, 1985, pp. 794–804.

Amazonite, a popular cabochon gem material, is a blue to green variety of the potassium feldspars microcline and orthoclase. Twenty-six amazonite specimens from a number of localities were investigated to analyze the color of this material and understand its origin.

The color of amazonite is caused by radiation and is known to involve the presence of both lead and water in the feldspar crystal structure. Four color types can be distinguished: (1) a blue, low-lead microcline-perthite with absorption bands at 625, 385, and 330 nm and increasing absorption toward the UV; (2) a green, high-lead orthoclase with a single band at 720 nm plus increasing absorption toward the UV; (3) a blue-green microcline intermediate type; and (4) a light blue, low-lead microcline with bands at 330 and 385 nm, a broad band at 643 nm, and increasing absorption toward the UV. The variation in color is controlled by the relative position and strength of these visible and ultraviolet absorption bands. Differences in absorption spectra, in turn, are associated with a limited range of lead content and structural state.

The irradiation-induced blue or green color can only arise in potassium feldspars having both structurally bound water and small amounts of lead (Pb^{3+} or Pb^{1+}). A model is proposed for amazonite coloration in which gamma radiation is thought to dissociate water molecules into H° and OH° radicals. Both radicals interact with other constituents in the feldspar to produce the lead-related color centers responsible for the coloration. *JES*

A 'three-phase inclusion' in an emerald from South Africa. H. W. Schrader, *Journal of Gemmology*, Vol. 19, No. 6, 1985, pp. 484–485.

The author describes a three-phase inclusion found in a cabochon emerald from the Cobra Mine in South Africa. The photomicrograph provided of the three-phase inclusion, illustrated at 400 \times , shows a spherical gas bubble nested against a solid phase of square profile, all contained within a long, thin, tube-shaped void. The cabochon also contained other inclusions, such as mica plates, that are typical of South African emeralds. This is the first report of a three-phase inclusion in an emerald from this locality. *JIK*

Toramalli: a short history of the tourmaline group. F. Benesch and B. Wöhrmann, *Mineralogical Record*, Vol. 16, No. 5, 1985, pp. 331–338.

In this introductory article to an entire issue devoted to tourmaline, the authors present an interesting summary of the history of the tourmaline mineral group. Although it was not among the classical precious stones of the ancients, tourmaline was known in antiquity and has been studied for centuries. The writings of early Greek and Roman scholars make reference to a gemstone possessing an electrical attraction for other objects that undoubtedly was tourmaline. Tourmaline, still unrecognized as a distinct mineral, began appearing in jewelry during the Middle Ages. Early mining literature from Central Europe mentions a black variety of tourmaline called schorl. In the 17th and 18th centuries, gem tourmaline began to emerge from Brazil and Ceylon. The electrical and optical properties of tourmaline brought it scientific attention, resulting in its recognition as a distinct group of mineral species. In the 19th century there was an increase in the number of publications on tourmaline localities and on the compositional nature of this mineral. During this period, tourmaline also became very popular as a gemstone, a position it still holds today. *JES*

DIAMONDS

The Australian ideal design for round brilliants. M. Connellan and L. Possibon, *Australian Gemmologist*, Vol. 15, No. 7, 1984, pp. 219–226, 243–246.

In large part, this article is a mathematical derivation of some general equations for round-brilliant cutting angles. Before showing how they arrived at these expressions, the authors compare the effects of specific rays in a Tolkowsky-cut diamond to those in a stone cut according to their calculations. On the basis of some initial considerations about diamond's dispersion, they choose a sample ray incident on the bezel facet at 70° from the normal and trace it through the respective stone profile diagrams.

Connellan and Possibon use this comparison to

argue that their design (called the Australian Ideal Design, or A.I.D.) permits a more efficient release of fire from the crown than the Tolkowsky cut. As applied to diamonds, A.I.D. calls for a 39.66° pavilion angle, a 33.75° crown angle, and a 56% table. No actual photo comparison of an A.I.D. - cut diamond to a Tolkowsky-cut stone is shown.

The general mathematical expressions for the crown and pavilion angles in A.I.D. are developed from a pair of simultaneous equations. One of these equations corresponds to the brilliance condition: that is, light entering the table vertically exits through the bezel facet vertically. The other equation is derived (in a less than convincing way) from a supposedly optimum dispersion condition.

When the refractive index is plugged into the mathematical expression for the crown angle, a suitably programmed computer can solve for the particular value of this angle. However, the authors have found that in practice this calculated crown angle needs to be reduced by a few degrees, depending on the R.I., to be optically effective. The crown angle and the R.I. are then plugged into the other expression to solve for the pavilion angle. As pointed out in the article, this calculated pavilion angle changes very little over the R.I. range of 1.5 to 2.4. The authors claim that, for practical cutting, a pavilion angle of 39.40° may be used for all gem materials.

The authors also consider the star and upper-break angles in their design, calculate their respective values, and list them along with the crown and pavilion angles for a wide assortment of gem materials. Toward the end of the article, a cutting orientation for the blue sapphires having the greenish pleochroic color typical of Australian stones is outlined. *BFE*

Diamonds and death along the Vaal. J. Thompson, *Modern Jeweler*, Vol. 84, No. 10, 1985, pp. 46–49 and 108.

This article is a human interest story recounting a visit with Willem Van der Merwe, one of the independent diamond diggers still working the deposits along the Vaal River in South Africa. The reader gets a glimpse of the rigorous existence, personal attitudes, and occasional tragedies that mark the lives of these rugged individuals. In South Africa, some 260 licensed independent diggers still operate in much the same way as their predecessors did back in the great diamond rush of the 1870s. Since the apartheid laws prohibit black South Africans from obtaining digging licenses, the vast majority of these fortune hunters are white, the rest being of mixed race. Thompson describes the backbreaking toil these men go through for their usually meager finds. *BFE*

GEM LOCALITIES

Localization of lapis lazuli bodies of Badakhshan and their mineral zonation. G. A. Yurgenson and B. P.

Sukharev, *International Geology Review*, Vol. 27, 1985, pp. 230–237.

The lazurite, or lapis lazuli, deposits at Sar-e-Sang, Afghanistan, have been famous since antiquity, but only in modern times has the geology of this unique occurrence been investigated. This article reports the results of a recent geological field study which focused on the nature of the lapis lazuli mineralization in this area.

The lazurite occurs in marbles of the Sakhi formation, which also includes schists, gneisses, amphibolites, and quartzites. The formation is intruded by igneous migmatites, granites, and pegmatites. Three types of lazurite mineralization have been identified: (1) minor bodies of small zones 2–3 m long and up to 20–30 m thick, which are located directly at the contact between the granitic rocks and the host marble; (2) larger bodies up to 40 m in maximum dimension, which occur at diopside- and pyrite-rich zones within the marble—and which represent the most widespread type of lazurite occurrence and contain the best-quality lapis lazuli; and (3) sheet-like zones of lazurite mineralization, which developed along layers in the marble up to 6 m thick and 450 m long.

Details of the mineralogy and structural features of each of these types of lazurite deposits are provided. Formation of lazurite is attributed to a chemical reaction between the host marble and high-temperature hydrothermal solutions generated by the intrusive igneous rocks. The article concludes with a list of exploration criteria that would apply to discovering new lazurite deposits. *JES*

INSTRUMENTS AND TECHNIQUES

Color grading issues: systems and standardization. J. D. Rouse, *Lapidary Journal*, Vol. 38, No. 12, 1985, pp. 1518–1530.

A number of issues relating to colored stone grading and various grading systems are examined by the author. First are the various methods of illumination. Because of the many variables that affect its quality, daylight is not recommended as a standard. Incandescent light suffers from an unbalanced distribution of visible wavelengths, and various fluorescent sources (and their relative deficiencies) are also discussed. The suggestion is made that when a light source is being selected for color grading, its Kelvin temperature, color-rendering index, and spectral power distribution in the visible spectrum should all be considered.

Several systems for describing color are examined. These include some based on opaque colored reference chips (Munsell, West German Manual DIN 6164, and Inter-Society Color Council—National Bureau of Standards) and those that match color using mathematical equations and instrumentation, e.g., the CIE system (Commission International de L'Éclairage). Problems in using these various systems to describe the color of

gemstones are noted. The view is expressed that a color grading system that conforms to the international color systems and has a sound scientific basis could be of real benefit to the industry. Such a system would be valuable as a tool for communication, as a vehicle for standardizing the colored stone industry, and as a means of generating confidence—and sales.

This article should be good reading for anyone interested in the subject of colored stone grading. RCK

Inclusions in a better light. J. I. Koivula, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 33, No. 1/2, 1984, pp. 43–47.

This short treatise by John Koivula notes the ever-increasing importance of the microscope in gemology that has resulted from the development of increasingly sophisticated synthetics. It then makes the point that, unlike many instruments, the microscope does not yield numerical answers, the more one studies inclusions, the more information the microscope yields. Various lighting techniques are also briefly described: dark-field, polarized lighting, oblique illumination, shadowing, transmitted light, and ultraviolet lighting. These are all well illustrated with six photomicrographs.

Having laid this foundation, the author proceeds to place inclusions "in a better light." Aside from their importance in separating natural from synthetic gem materials, inclusions can add to the beauty of a gem, for example, the inclusions that make possible the star and cat's-eye effects. With this perspective, inclusions can become helpful sales tools for the informed gemologist. To use the author's words, "through the microscope inclusions are as beautiful as their colorful homes." RCK

Refractometers with built-in LED illumination. P. Read, *Journal of Gemmology*, Vol. 19, No. 7, 1985, pp. 625–629.

This is a brief review of the use of yellow light-emitting diodes for refractometer illumination. These LEDs have peak emission in the 585 nm region, sufficiently close to that of sodium light for refractometer use.

The first commercial LED unit for refractometer use was manufactured by the Rayner Optical Company. It uses six LEDs with a life of about 50,000 hours. It is not really a monochromatic light source, since it has an emission bandwidth of 35 nm (measured at 50% relative emission points). By comparison, interference filters used in other refractometer light sources have bandwidths in the 5–20 nm range.

In 1983 Eickhorst introduced their GemLED refractometer, with a built-in light source consisting of three LEDs placed close to the prism, and a light level control. It operates on both batteries and alternating current.

Recently Rayner developed a refractometer with an integral twin-LED illuminator and an operating base that contains an AC supply unit, light-intensity control,

and battery. With this unit the LED element can be withdrawn, allowing the refractometer to be used with external light sources as well.

The main advantage of all of these LED units is their relatively low cost; the main disadvantage is their bandwidth, which to date has been too wide for some very fine discriminations. RCK

Editor's Note: Although similar to Read's article in Canadian Jeweller, July 1984 (see abstract in the Summer 1985 Gems & Gemology, p. 127), this update contains a graph of the spectral emission of a yellow LED and a diagram of the Eickhorst GemLED.

JEWELRY ARTS

Cellini. J. Pope-Hennessy, *Art & Antiques*, November 1985, pp. 66–69.

Sir John Pope-Hennessy, a leading authority on Italian art, presents a sympathetic, if somewhat unconvincing, interpretation of Renaissance master goldsmith Benvenuto Cellini's tumultuous life. He views Cellini's autobiography, which has been widely interpreted as highly exaggerated and boastful, as "not simply a record, but an apology for his (Cellini's) life." Sir John then presents select pieces of information to support his belief that Cellini was "a predestined man of genius" whose ambitions were thwarted by "frustrations and disappointments" largely caused by a world insensitive to his unique vision.

Cellini's works, such as his famous saltcellar and the bronze sculpture of Perseus, clearly demonstrate that he was indeed an accomplished artist. However, in reading this article, it seems equally likely that he may have created his masterpieces out of sheer egoism and egotism rather than any great artistic or religious convictions as Sir John suggests. For example, Cellini's marble crucifix, which Sir John calls "a work of incomparable accomplishment, the supreme marble sculpture of its time" and evidence of Cellini's "profound religious faith," was made to grace his own tomb.

This article was adapted from Sir John's book, *Cellini*, which was scheduled to have been published in late 1985. Perhaps the book will cover the artist's life in a more thorough fashion, and provide concrete references to substantiate his interpretation. SAT

Fashion for flowers. V. Becker, *Connoisseur*, Vol. 215, No. 883, 1985, pp. 41–43.

Although brief, this article on the naturalistic style of the French Second Empire (1852–1870) is nonetheless packed with information about the famous jewelers of that time.

Becker primarily focuses on the art of Oscar Massin, considered one of the finest jewelers of the period. She describes his background and development as a jeweler, sketching in the influences and inspirations of the Sec-

ond Empire style. The article is illustrated by a two-page photospread of necklaces, brooches, and earrings fabricated in diamonds, pearls, and platinum (the examples shown are not necessarily attributed to Massin, however). The jewels are like starched lace: stiff and formal but with a delicate fragility. By candlelight they must have been dazzling. A buyer's guide to Second Empire jewelry in New York, London, and Paris is included.

EBM

How an earthquake brought to light the opulent treasure of Popayán. N. Letson and P. C. Keller, *Smithsonian*, Vol. 15, No. 12, 1985, pp. 138–140, 142, 144, 146, and 147.

On March 31, 1983, a major earthquake rocked the city of Popayán, high in the mountains of southern Colombia. Although the quake devastated the city, including its newly restored cathedral, it brought to light one of the most dazzling collections of silver, gold, and emerald liturgical objects ever discovered.

During the 17th and 18th centuries, prominent Popayán families donated spectacular gifts to the church. These ornaments were the product of centuries of goldsmithing experience, and were fashioned from local deposits of gems and precious metals. Because of earthquake and political dangers, the ornaments were not stored at the cathedral, but in the homes of the families who donated them, and were publicly displayed on high holidays only. Thus, when the 1983 quake struck, the treasure remained unharmed.

The most interesting ornaments are a series of monstrances (called *custodias* in Colombia) made to hold the sacred Host. Each monstrance is typically two to three feet high, topped with a radiating superior circle known as the sun, with a round crystal window displaying the Host. The sun is supported by a central stem, sometimes in the shape of an angel or saint, which in turn rests on an elaborate base. Other ornaments in the collection include golden chalices, ecclesiastical crowns, and other jeweled holy vessels.

The fate of the liturgical collection of Popayán is uncertain; it may be transferred to the Museum of Religious Art in Bogotá. Wherever it rests, this collection has survived the rigors of time and nature, a reminder of an opulent, bygone era. Eight photographs by Harold and Erica Van Pelt, who accompanied the authors on their trip, richly illustrate the article. SAT

The role of gold in alchemy. Parts I, II, and III. G. B. Kauffman, *Gold Bulletin*, Vol. 18, 1985, No. 1, pp. 31–44, No. 2, pp. 69–78, and No. 3, pp. 109–119.

This comprehensive three-part article should appeal to laymen and experts alike. In part I, Kauffman reviews the antiquity, mystique, and mythology of gold through excerpts of ancient texts and presents various modern interpretations, such as that for the legend of Jason and the Golden Fleece. The brawny hero may indeed have

captured a fleece of gold, since sheepskins were commonly used as sluice boxes; the greasy, tangled wool trapped the wet gold particles. Kauffman goes on to discuss why gold has been so prized throughout history, and then introduces the origins, goals, and accomplishments of alchemy, crediting early alchemists with the discovery of many chemicals and basic laboratory techniques. A discussion of theories of matter (i.e., that all materials could be reduced to just a few elements) from various cultures concludes this section.

Part II deals with the quest for the Philosopher's Stone, an elusive, undefinable material with the power to transmute materials into gold and provide longevity or immortality. From this legend sprung the idea of potable gold, a drink the Chinese believed was the elixir of life. This belief has persisted, and *Goldwasser*, a liquor containing flecks of colloidal gold, is still consumed.

Part III is an unusual mixture of prose and science. The first section reveals official attitudes toward alchemy. Medieval monarchs often supported alchemists in their courts, but tortured or executed them when the gold failed to appear. A surprising number of clergymen were interested in alchemy, including St. Thomas Aquinas and Martin Luther. Kauffman goes on to discuss several clever examples of fraudulent transmutations. The section suddenly takes a more technical turn to modern alchemists and scientific alchemy. Many of the old alchemists' dreams have been accomplished by today's nuclear physicists and chemists. Ironically, in 1980, a bit of bismuth was finally transmuted into one-billionth of a cent worth of gold. The cost: \$10,000.

All three parts of the article are extremely well documented, and flow together smoothly. This summary of the myth, magic, and reality of alchemy is interesting reading. SAT

The treasures of Henri Moser. R. Mazzawi, *Aramco World Magazine*, Vol. 36, No. 1, 1985, pp. 28–35.

During the 1880s Henri Moser, a Swiss citizen and watchmaker, amassed an impressive collection of Turkic artifacts while traveling through Central Asia as a top aide to Russian military officials. Now housed in the Berne Historical Museum, Moser's collection contains a variety of exquisitely crafted items.

The personal jewelry shown in this article is deliciously sensuous. Intricate gold filigree work sheaths a razor-sharp dagger, a belt buckle set with tiny turquoise and jade cabochons clasps a wide leather strap, and delicate seed pearls dangle enticingly from airy gold earrings.

The untamed, proud beauty of the Turkic people is perhaps best symbolized by their horses—magnificent animals with the strength to travel swiftly across miles of desert. An excerpt from Moser's book, *Across Central Asia*, reveals how a very powerful *amir* (native ruler) presented a Russian official with a stallion caparisoned

with a *shabraq* (saddle blanket) embroidered with gold and pearls that almost covered the entire animal. A gold bridle encrusted with precious stones completed the gift.

Richly worked clothing also played an important part in diplomatic gift-giving. *Khalats* (ceremonial coats) and huge, melon-shaped turbans were fashioned from costly materials such as gold and silver brocade or satin and were sewn with gems and pearls. One Russian general received a gift of 210 *khalats* made from Indian cloth-of-gold, along with colorful Kashmiri shawls, rich carpets, jeweled swords, and 16 Turkoman horses loaded with treasure.

Eighteen photos highlight this article, which provides a fascinating glimpse into the culture, and treasures, of the Turkic people during the 1880s. SAT

RETAILING

America's new passion for affordable gems. D. Federman and E. Blauer, *Modern Jeweler*, Vol. 84, No. 2, 1985, pp. 47-57.

In the first section of this article, entitled "Gems," Federman presents several theories to explain the current popularity of "affordable" colored stones in the marketplace. Eight stones—amethyst, blue topaz (identified as owing its color to laboratory irradiation), citrine, rhodolite, iolite, aquamarine, and pink and green tourmaline (identified by suppliers as top sellers), are profiled in thumbnail sketches. Current sources and prices per carat are given for each, along with information on preferences for certain sizes and methods of fashioning. According to Federman, these eight stones (displayed in a photograph along with two others that remain mysteriously unidentified) comprise a "rainbow revolution" of color "as profound as any that has swept the industry."

In the companion section, "Jewelry," Blauer echoes the choices previously mentioned, but elicits comments from buyers and retailers. A series of photographs display these and other pastel-colored gems in contemporary jewelry designs.

The combined sections, although brief and limited in scope, convey enthusiasm for the market potential of the gems described. John Branning

Selling color: the rainbow still leads to a pot of gold. C. Kremkow, *Goldsmith*, Vol. 167, No. 5, August 1985, pp. 88-90, 94, and 96.

According to Ms. Kremkow, "colored stones may be a key to the survival of the independent jeweler." Ideally suited to a traditional jewelry store, colored stones make it possible to sell quality merchandise at almost every price level. She also points out that the majority of baby boomers have already purchased their engagement and wedding rings and are now ready to embrace today's exciting colored stone jewelry.

She urges jewelers to think of color as fashion. Today's women are increasingly looking for accessories to personalize their wardrobes. Jewelers can get the pulse of today's fashions by consulting magazines such as *Vogue*, *W*, *Women's Wear Daily*, and *Bride*. Stocking a dazzling array of both loose and mounted stones shows the customer that her options are almost limitless.

Kremkow advocates product knowledge and refers her readers to several different gemological institutions and associations, as well as to various books and trade publications. More than anything else, a trip to the mammoth annual gem and mineral show in Tucson will convince anyone of the impact that colored stones can have on their business. SAT

SYNTHETICS AND SIMULANTS

Gemmological properties of synthetic corundums coated by Lechleitner. M. Gunawardene, *Journal of Gemmology*, Vol. 19, No. 7, 1985, pp. 557-570.

This well-illustrated article reports on a new experimental material produced by Lechleitner—flame-fusion synthetic corundum preforms of various colors overgrown with a thin layer of synthetic corundum.

Magnification proved to be key in identifying this new material. The "seeds" themselves contain inclusions typical of flame-fusion synthetic corundum. Examination of the overgrowth with the microscope revealed the following: (1) with immersion and diffused illumination, a thin, colorless overgrowth layer; (2) a corundum-corundum contact zone showing the unpolished nature of the flame-fusion preforms used; (3) cavities on the surface of the preforms that appear as voids just below the surface of the coating; and (4) inclusions—irregularly distributed "net-like" cracks on the coating, often containing a solid substance, and fine healed feathers, some resembling those seen in flux-grown synthetic corundum and others similar to those seen in heat-treated natural rubies—any of which may penetrate deeply into the seeds.

The author cautions that this process will probably be used in the future to produce a synthetic surface coating on natural rubies and sapphires. RCK

Farbloser Chrysoberyll—natürlich oder synthetisch? (Colorless chrysoberyl—natural or synthetic?) K. Schmetzer, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 34, No. 1/2, 1985, pp. 6-12.

Natural chrysoberyls are colored by the presence of trace elements such as iron, chromium, or in rare instances vanadium. Those that contain iron are primarily yellow, yellowish brown, or brown. Iron and chromium are responsible for the most highly priced green variety, alexandrite. Colorless chrysoberyl is seldom encountered in the trade, and those found are said to be from Burma or Sri Lanka. The former, however, tend to have a

light greenish tone and therefore cannot be classified as truly colorless chrysoberyl. The two colorless samples investigated in this study were purchased in Sri Lanka. The physical and chemical properties of these two chrysoberyls were investigated in order to determine whether they were natural or synthetic. The data on the two chrysoberyls were compared to those of natural near-colorless, yellow, brown, and green chrysoberyls from different localities such as Sri Lanka, Brazil, USSR, Zimbabwe, and Tanzania. Further comparisons were done with synthetic alexandrite from three different producers.

The refractive indices, color, chromium and iron contents, and inclusions were sufficiently similar between the two chrysoberyls and the comparison stones that no conclusion as to origin could be drawn on the basis of these properties. However, X-ray fluorescence analysis, which revealed the presence of gallium in all of the natural specimens that were examined in the study, encountered no gallium in the two colorless samples. Although this suggests a synthetic origin, Dr. Schmetzer feels that it is insufficient evidence on which to base a firm conclusion. Five photomicrographs are included with the article.

MG

MISCELLANEOUS

Investing in gold. P. Cavelti, *Robb Report*, Vol. 9, No. 3, 1985, pp. 56–67.

For those looking to diversify their monetary portfolio, there are many ways to invest. In this article, gold is described as one such way. Mr. Cavelti presents various vehicles for investing in gold, including bullion, gold certificates, precious metals accounts, futures contracts, and options. One essential ingredient of a successful investment is knowledge of the commodity and, in this outlined report, the vehicles are well defined. Other areas touched on are precious metals funds and collectibles such as coins, medals, medallions, and jewelry.

The benefits and risks of investing in gold are discussed, and provide the reader with a well-rounded view of what to expect. Also considered are the various aspects of buying and selling, the parties involved, costs, liquidity, storage, insurance, and other particulars.

Although much more information can be written on gold, Mr. Cavelti sums it up nicely for both goldbugs and novices alike.

Nicholas A. Delre

Mineralogy: a historical review. R. M. Hazen, *Journal of Geological Education*, Vol. 32, No. 5, 1984, pp. 288–298.

This article traces the evolution of the science of mineralogy from its earliest beginnings approximately two thousand years ago up to the present time. This development is followed within the context of several basic questions that have provided a historical focus for much

of the research and speculation about minerals. These questions include: What are the origins of minerals, what are their characteristic chemical and physical properties, and how should minerals be classified? In discussing the changing concepts in each of these areas, important personalities and their ideas are cited. An extensive list is provided of the individuals who contributed to the development of mineral classification systems. In these few short pages, the reader is led to an appreciation of the historical background of mineralogy that provides a foundation for today's scientific study of minerals.

JES

Sweeping reassessment in the auction trade. D. C. McGill, *New York Times*, July 31, 1985, p. 1.

In recent months, the press has paid a great deal of attention to the practices of the two major New York auction houses, Sotheby's and Christie's. This article chronicles the events leading to the current controversy and details the policies being scrutinized.

The controversy comes in the wake of David Bathurst's resignation as chairman of Christie's after his admission during trial that he falsely reported the results of a 1981 auction. Among the policies under review are the setting of secret minimum prices or "reserves" on items, the reporting of private sales (made after the auction) as auction sales, and staff and board members bidding at their own auction houses.

The auction houses say the secret reserve is necessary to prevent collusive bidding practices by dealers and individuals. Opponents of the practice say it is misleading since it is often not clear after an item is "knocked down" by the auctioneer whether it has been sold or bought in.

False reporting of sales is said by some to stem from increasingly fierce competition among auction houses. Some houses believe that false reporting will prevent damage to a house's image by items failing to sell. In addition, prestige is boosted by reports of high sale prices. But observers fear that such reporting falsely inflates the market for the items reported sold.

Regarding bidding by staff and board members, both auction houses said that any staff member or owner wishing to bid or purchase at auctions must follow the same rules as outside purchasers, and that information about reserves and prearranged bids is never shared with house principals by the auctioneer. An official at the New York City Department of Consumer Affairs (which licenses auction houses and auctioneers) said that the department was investigating whether such bidding might constitute illegal "insider trading."

As a result of the ongoing debate over these issues, the Department of Consumer Affairs is considering revisions of city laws and fundamental changes in the way New York auction houses do business. Internal review by the houses themselves may also lead to significant policy changes.

David Thomas

GEM NEWS

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

DIAMONDS

China

Changma diamond deposit very active. Dr. Peter Keller, associate director of the Los Angeles County Museum of Natural History, visited the Changma diamond deposit in Shandong Province during September 1985. He reports that both the Victory No. 1 (consisting of two pipes) and the Victory No. 2 (a dike) mines are being actively worked, although current production is relatively small (approximately 2,000 ct of gem-quality stones per year). Brown, yellow, pink, and colorless diamonds have been found at this deposit; several gem-quality crystals in the 5–15 ct range were shown to Dr. Keller. An article on this deposit and other aspects of diamond mining in China is scheduled to appear in an upcoming issue of *Gems & Gemology*.

India

Alluvial diamond deposits. Habib Siddiqui, a mining consultant from Bangalore, reports that the states of Andhra, Pradesh, and Karnataka have the potential to produce approximately one million carats of diamonds per year. The river beds of the Chithravathi, Godavari, Hagari, Krishna, Pennag, Pennar, and Tungabhadra Rivers, and their off-shore deltas in the Bay of Bengal, all host alluvial diamond deposits. Mr. Siddiqui feels that these off-shore deposits are 10 times larger than those along the west coast of Africa. (*Gem and Jewellers Business Intelligence*, July 1985)

United Kingdom

Diamond futures market planned. The diamond futures market presently under consideration by the London Commodities Exchange is causing much controversy in the diamond trade. As it is currently proposed, the market would deal with pregraded parcels of 10 cut and polished gem diamonds, selected on the basis of similar clarity, color, weight, and quality of cut. The diamonds would be laser-inscribed with their qualifications and sealed in a tamper-proof package along with a microchip stating the details of each parcel's contents.

Those in favor of a diamond futures market maintain that the diamond market needs financing and that a diamond futures market with published prices would encourage banks to provide financial support. The market could also be conducted discreetly by way of video screen, which would facilitate hook-up with the world's major diamond bourses.

Skeptics, however, point out that there is limited intrinsic value for gem-quality diamonds outside of their use in jewelry, which accounts for only 20% of total world consumption of diamonds. This, plus the fact that there is little scope for diamond price fluctuation (the very essence of futures trading), presents a deterrent to a diamond futures market. There is also fear that the market would fall prey to speculators who would upset the present balance and perhaps cause another unnatural rise and fall in the diamond market.

De Beers remains noncommittal, but it is clear that a diamond futures market would depend on their release of rough to dealers and cutters. (*Mining Journal*, March 1 and September 13, 1985)

COLORED STONES AND ORGANIC MATERIALS

Australian opal "pineapple." In 1970, two very unusual specimens of opal replacing glauberite (a monoclinic sodium-calcium sulfate) were found at White Cliffs, New South Wales, Australia. The larger of the two specimens originally weighed 16.27 troy ounces, but was broken open when it was first recovered by the miners. The second specimen, shown in figure 1, weighs 13 troy ounces. Such crystal clusters of glauberite replaced by opal are very rare: fewer than 20 such specimens are known to exist today. Both of these specimens are currently housed in the Australian Museum in Sydney. (Terrence Coldham, Sapphex P.L., Sydney, Australia)

Emerald from Pakistan. Mike Ridding of Santa Barbara, California, and Jurgen Henn of Idar-Oberstein, Germany, report the existence of a new locality for emeralds in Pakistan. During their visit to Pakistan in fall 1985, they learned that this new occurrence lies north of the small village of Sassi, on the slopes of the Khaltaro Valley in the Haramosh Mountains of northern Pakistan. The deposit is located at 74°44'E and 35°59'N. Stones have been found at elevations as high as 4268 m (14,000 ft.). The emerald appears to occur in a number of small pegmatite deposits in association with schorl and albite. Distinct beryl crystals found in this pegmatite range from white through milky blue to green. Exploratory diggings to date have produced gem-quality emeralds up to 10 ct. The rough is, for the most part, light in color, but clean and bright (similar to recent light green beryls from Nigeria). Dark green stones have also been reported.

Pearl treatment update. According to Alan Macnow of the Cultured Pearl Associations of America and Japan, essentially all pearls are "color stabilized with a gentle oxidizing agent" after being removed from their shells to prevent a color change that would occur naturally when the pearl is exposed to light and air. Some pearls are bleached to lighten body colors and remove slight discolorations, while others may be color treated to give them a "lasting rosy glow" or a hue such as blue, magenta, or black. A few pearls are "safely irradiated" to impart a permanent dark blue or black color. (*Modern Jeweler*, November 1985)

Southeast Asia and China. The following information was supplied by Dr. Peter Keller, of the Los Angeles County Museum of Natural History, following his recent trip to these regions.

Burma. Burmese miners are crossing the border into Thailand to sell a variety of Burmese gemstones, including pale sapphires and rubies with excellent stars, as well as both large and small peridots and spinels, among them some magnificent spinel octahedrons and twins. These gems are also smuggled into Thailand for sale in Bangkok's gem market.

Kenyan rubies in Bangkok. Thousands of carats of rubies from Kenya, East Africa, are being sent to Bangkok for heat treatment to clarify the rubies rather than to alter their color.

Pailin sapphire district closed. Because of the influx of Vietnamese troops and artillery along the Cambodian border, the Pailin sapphire-mining district in Cambodia

Figure 1. Pineapple-shaped glauberite replaced by opal. Photo by Kate Lowe, courtesy of the Australian Museum in Sydney.

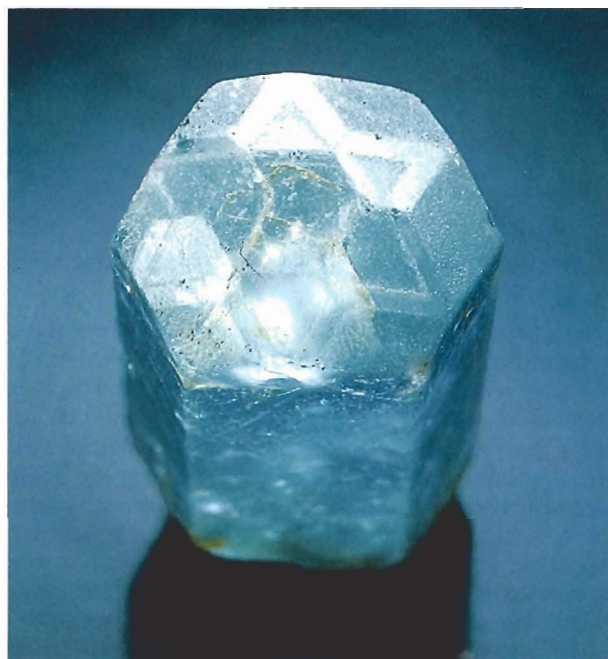


Figure 2. A 129-ct "Star of David" aquamarine crystal. This star was formed by natural "preferential" etching. Photo ©Tino Hammid. Specimen courtesy of David Humphrey.

is all but closed down. Cambodian miners have crossed the border into Thailand to continue mining for rubies and sapphires.

Sapphires from China. Dr. Keller also visited the alluvial sapphire deposit near Mingxi in Fujian Province. Although the current operation is largely exploratory, local geologists have identified 50 km² of sapphire-bearing alluvium in this region. For the most part, the sapphires are very dark blue, although yellow-green and green sapphires have been found. Gem-quality zircon and pyrope garnet also occur in association with the sapphires. More information on this locality will appear in an upcoming issue of *Gems & Gemology*.

"Star of David" aquamarine crystal. The Fall 1985 Gem News column reported on a sapphire crystal from Yogo Gulch, Montana, with unusual growth hillocks that formed a perfect six-pointed star. The termination of the medium-blue, 129-ct aquamarine crystal shown in figure 2 also displays a natural "Star of David." This star was created by natural "preferential" etching, a secondary process of partial dissolution that occurred after the formation of the crystal.

SYNTHETICS

"Diamond" synthesis process rediscovered. In a letter published in *Nature* in August 1905, physicist Charles

V. Burton claimed to have synthesized microscopic diamonds. In his letter, Burton briefly explained both his theory and experimental methodology as well as the "diamond" product he obtained. Burton's work in this area was somehow lost to the literature and was only recently rediscovered by Felix Sebba, a chemical engineer at Virginia Polytechnic Institute and State University in Blacksburg, Virginia. Sebba received funding from the National Science Foundation to recreate Burton's original experiment, which involves dissolving a small amount of calcium carbide into molten lead. Steam, at a temperature of 550°C, is passed over the lead-calcium alloy and reacts with only the calcium and not the lead. This forms calcium hydroxide, which is

insoluble in the lead and forms a whitish scum-like layer on the lead's surface. The carbon in the original calcium carbide has been left behind. But since carbon is less soluble in lead than in a calcium-lead alloy, the removal of calcium causes some of the carbon to crystallize out. When the resulting gray-colored crust is treated to remove all traces of calcium and lead salts, the remaining product is a considerable amount of black powder (graphite?) containing tiny diamond-like crystals. However, these crystals have not been conclusively identified as diamond. Dr. Sebba now wants to redo this experiment under more controlled conditions to see if larger "diamond crystals" can be made. (*Science News*, August 3, 1985)

ANNOUNCEMENTS

International Society of Appraisers Tucson Program. In response to the growing demand in the jewelry industry for educational programs in appraising, the International Society of Appraisers (ISA) has announced a full week of programs to be offered during the 1986 Tucson Gem and Mineral show. The ISA courses and seminars will be offered at the Holiday Inn Broadway (site of the GLDA Show) from Thursday, February 6, through Sunday, February 15.

ISA will be holding its 8th national conference in San Francisco, May 5-8, 1986, at the Cathedral Hill Hotel. The first graduates of the ISA/IU CAPP program will be honored at this conference, which will also offer 50 hours of lectures and hands-on workshops in areas related to gems and jewelry.

For more information regarding ISA's Tucson programming or any of the ISA Winter/Spring programs, contact: International Society of Appraisers, P.O. Box 726, Hoffman Estates, IL 60195, (312) 822-0706.

GIA now offers a new Home Study Jewelry Sales course which replaces their Jewelry Retailing course. This course has been totally updated and revised to reflect current industry trends and to meet the needs of jewelry salespeople everywhere. For further information, contact the

Gemological Institute of America, 1660 Stewart Street, Santa Monica, CA 90404. Telephone toll-free (800) 421-7250, ext. 235. In California, telephone (213) 829-2991, ext. 235.

Glynn Scholarship established for GIA Home Study. Fox's Gem Shop, Inc., of Seattle, Washington, has established a GIA scholarship as a memorial tribute to Ray Glynn. The scholarship is in recognition of Glynn's pioneering contributions to gemology and retail jewelry in the Pacific Northwest.

Fox's Gem Shop, Inc. and friends of Ray Glynn have donated a sizable endowment for the purpose of assisting students of the Pacific Northwestern states with their educational expenses while pursuing the GIA Home Study Graduate Gemology program. Two scholarships will be awarded yearly until the fund is depleted. Each will provide tuition for one of the three courses that make up the Graduate Gemology program: Diamonds, Colored Stones, and Gem Identification.

To be eligible for the scholarship, an applicant must be a legal resident of Alaska, Idaho, Oregon, Montana, or Washington state for at least one year immediately prior to the beginning of the period for which the scholarship is intended. The applicant must also be a citizen or legal resident of the United States.

Those interested in applying for the Ray Glynn Memorial GIA Scholarship should contact Booker Williams at GIA, 1660 Stewart Street, Santa Monica, CA 90404. Telephone toll-free (800) 421-7250, ext. 359. In California, telephone (213) 829-2991, ext. 359.

With the object of increasing business relations between Latin American countries and the rest of the world, the Latin American Trade Council is distributing free copies of the Latin American Import Export Directory. This directory was compiled to provide comprehensive and up-to-date information on general business facilities in Latin America required by overseas companies and organizations for the promotion of international trade and general business contacts. To obtain a copy of this directory, write to the Latin American Trade Council, Circulation Department, P.O. Box 12, San Jose 1007, Costa Rica.

The Science Reference Library (a division of the British Library) plans to publish two literature guides, one to mineralogy and the other to gemology. For further information, contact the External Relations Section, Science Reference Library, 25 Southampton Buildings, London WC2A 1AW, England.

GEM CUTTING: A LAPIDARY'S MANUAL

By John Sinkankas, 365 pp., illus.,
publ. by Van Nostrand Reinhold
Co., New York, NY, 1984. US\$46.95*

Although this book is primarily oriented toward those persons involved (or who wish to be involved) in the cutting of gem materials, it is nonetheless of interest to gemologists as well. In fact, all gemologists should be curious about the intricacies and craftsmanship of the lapidary's art—whereby an otherwise nondescript material is expertly transformed into a gem. Through an awareness of gem cutting, a finer and deeper appreciation of the lapidary's product will surely result, whether that product is a faceted stone, cabochon, bead, carving, or inlay work.

This third edition of *Gem Cutting* is well organized, and discusses lapidary techniques, including many supplemental ones, that may seem difficult and complicated at first. But the author's approach is so logical in its manner and seemingly elementary in its language that the text is both readable and easily understood by all. The book begins, logically, with the very basics, discussing the concepts and various methodologies of sawing, grinding, lapping, sanding, and polishing gem materials. In this new edition, basics are presented not only in the context of modern (e.g., diamond abrasive-based) equipment but also in the use of older tried-and-true techniques. The latter provides both historical interest and a convenient "how-to" methodology for those persons who wish to approach the lapidary art in a less expensive frame of mind and still achieve professional results. The more advanced gem-cutting techniques, such as faceting, intarsia work, carving, and the making of spheres, are likewise approached in a thorough and unpretentious manner. And in this new version, Sinkankas has included more specific cutting information for a wider range of gem materials.

Reading this book is like talking to a well-informed friend or next-

BOOK REVIEWS

Jeffrey M. Burbank, Editor

door neighbor. And even though the book is 357 pages of explanations, discussions, and recommendations, it doesn't seem as if that next-door neighbor is talking your ear off. This is because the book is organized in easily absorbable and informative chapters and sections that hold the reader's interest. In addition, each chapter ends with an appendix of books or articles for those who wish to look further into the subject. The book also features over 230 black-and-white photographs and line drawings that are instructive rather than decorative. This is not, after all, a coffee-table book. It is also well worth the price. As a gemcutter with 15 years' experience, I found this book gave me many insights into both new techniques and those in which I thought I was well versed. In short, this third edition of *Gem Cutting* combines the effectiveness of the best "how-to" book with the reliability of a solid reference work.

RICHARD HOMER
Instructor, GIA—Santa Monica

JADE FOR YOU: VALUE GUIDE TO FINE-QUALITY JADE

By John Y. Ng and Edmond Root, 107
pp., illus., Jade N Gem Corp., Los
Angeles, CA, 1984. US\$49.95*

Jade for You is specifically written with the retail jeweler in mind. From cover to cover, it is one practical and concise reference page after another. The book's intent is to provide the reader with an objective system of jade evaluation—although the book is not without flaws, it does fulfill its basic purpose in a very attractive package. However, one may want to

question the usefulness of yet another grading system for jade.

While the book begins with an all-too-brief and nontechnical discussion of the development of jade from source to jeweler, the authors are able to hold the reader's interest, drawing as they do from their personal experience and giving fresh insights on the jade market today. The book's main focus, however, is the seven factors for evaluating jade: (1) color and tone; (2) texture; (3) translucency or clarity; (4) desirable shape or balance; (5) size and dimensions; (6) polish; and (7) finish, including matching or graduation in the case of pairs or beads. The discussions of these seven value elements are quite complete; however, they are at times inconsistent, not only with respect to the commonly accepted trade terminology, but also with respect to the terminology used within the text itself. For example, Imperial jadeite is first described as being "highly translucent" with "rich tone," yet the authors' translucency scale presents "near transparent" as the highest value rating of translucency (and lists nothing as "highly translucent"). Likewise, in the tone scale, "very fine medium" and "very fine dark" are presented as the highest-valued tones (again, nothing is listed as "rich"). Yet, even with these and other slight confusions, the numerous pages of color and black-and-white photographs prove again that a picture is worth a thousand words. As each value element is discussed, a numerical rating from "most valuable" (5) to "least valuable" (1) is presented with accompanying photographs. This numerical scale is put to use later in the text.

Another chapter of the book, aimed at the retail sales staff, is devoted to jade symbolism. Seven pages of line drawings accompany the history and lore of dragons, bats, fu-dogs, the yin and yang, and more, to enhance the reader's sense of the mystique of jade carvings. However,

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

a chapter entitled "Jade Mimics and Fakes," is somewhat disconcerting in that the authors mention the destructive tests used to identify those substitutes that have been dye-treated.

With the discussions and ratings of the seven value factors complete, Ng and Root wrap up their evaluation system by "scoring" each of those elements and adding an "appeal factor" for each as well as totaling all the points. All of the foregoing seems to make the evaluation system somewhat cumbersome. However, the authors come right back with an excellent, easy-to-follow jade-inspection procedure, complete with more photographs. This is a must for the jade buyer.

So, if you are a retailer who wants to help your staff prepare for that all-important jade sale—or simply want to purchase jade for your own inventory—then *Jade for You* is indeed for you.

GARY ROSKIN
Instructor, GIA—Santa Monica

GEMS AND JEWELS: A CONNOISSEUR'S GUIDE

By Benjamin Zucker, 248 pp., illus., publ. by Thames and Hudson, New York, NY, 1984. US\$50.00*

The main purpose of this handsome book is to heighten the reader's interest in ruby, sapphire, emerald, diamond, pearl, amber, lapis, jade, turquoise, opal, and garnet. Mr. Zucker does this through his research into the background of each gem—especially its history and lore. Each chapter is filled with many beautiful photographs and provides essential information on the characteristics of these gems, their major sources, and the most desirable qualities in each stone. Each chapter is also introduced by a literary quote—ranging from Tavernier to Bob Dylan!

This book will, true to its title, appeal to the connoisseur and the collector, as well as to dealers and to

those who simply enjoy the beauty and mystique of gemstones. It is truly enjoyable to read: the text flows beautifully and effortlessly, and is set in an attractive typeface. The work is well organized and indexed, and good references are noted throughout. I especially liked the list of museums that display fine rare and important gems.

An important feature of the book are the 256 color photographs, which range in subject from gemstones and jewelry (both antique and modern) to inclusions and mining. All photos are well chosen and excellently reproduced.

This attractive book is well worth its \$50.00 price tag. I recommend it for everyone's gemological library: it's a showpiece in itself.

JAN ARNOLD
Instructor, GIA—Santa Monica

MANUAL OF MINERALOGY (AFTER JAMES D. DANA)

By Cornelis Klein and Cornelius S. Hurlbut, Jr., 596 pp., illus., publ. by John Wiley & Sons, New York, NY, 1985. US\$35.95*

Since it first appeared in 1837, James D. Dana's *System of Mineralogy* has evolved into one of the standard references on mineral classification. In 1848, Dana introduced a *Manual of Mineralogy* to serve as a textbook in introductory courses. The 20th edition of this classic textbook, revised by Klein and Hurlbut, continues the tradition Dana began almost 140 years ago.

Written for undergraduate college students with little or no background in mineralogy, the book has two main goals: to convey fundamental concepts that underlie the science of mineralogy, and to present a summary description of approximately 200 of the most common minerals. Both purposes are achieved in a manner that allows the student to quickly gain a basic understanding of a broad range of mineralogy topics.

The unifying theme throughout the book is that of crystal chemistry—the relationship between the chemical composition, internal atomic structure, and physical properties of minerals. The chapters of the book are presented in the following sequence: a history of mineralogy; the external morphology of crystals; the relation of external form to internal atomic structure; crystal chemistry and chemical composition; physical properties; X-ray crystallography; and systematic mineralogy. Furthermore, this edition of the mineralogy textbook is unique in that it contains a chapter that specifically deals with gemology. The material is well organized, complete, and readable. Several hundred high-quality photographs and line drawings illustrate key points. At the end of each chapter, selected references are given for additional reading on the subject. Extensive determinative tables in the appendix are especially useful for laboratory study and identification of unknown minerals. The overall quality of production of the book is excellent.

The book will be valuable to gemologists seeking a basic reference on mineralogy. Descriptions of all the important gem minerals are included along with discussions of topics such as crystallography, mineral compositions, physical properties, and the optical properties of minerals. Those seeking to learn more about gem minerals will benefit greatly from this reference work.

JAMES E. SHIGLEY
Manager, Research Department
GIA—Santa Monica

OTHER BOOKS RECEIVED IN 1985

The Barakat Gallery: A Catalogue of the Collection, Vol. 1, 319 pp., illus., publ. by The Barakat Gallery, Beverly Hills, CA, 1985. Faye Barakat introduces this catalogue, explaining that "Collecting has consumed most of my

time and thoughts for more than three decades, since I began learning as a child at the side of my father, grandfather, and renowned archaeologists. As the collection has finally taken shape as a mirror of ages and cultures, I feel an obligation to it and wish to share my experience and collection with all others who appreciate the art of collecting." Indeed, the book is splendidly and lovingly put together, photographs illustrating in faithfully reproduced colors 1,468 pieces—almost all of Middle Eastern and Pre-Columbian origin—which comprise a portion of the collection gathered by generations of the Barakat family. The wealth of beads, sculptures, pottery, carvings, scarabs, and coins makes for a most stimulating browse or design inspiration. Those involved in appraisal will appreciate the many examples for study, as well as the price list included.

Stephanie Dillon
San Clemente, CA

Benitoite: California State Gemstone, by G. D. Louderback, 76 pp., illus., publ. by Gemmary, Redondo Beach, CA, 1985, US\$5.00* Published to mark benitoite's official status as the California state gemstone, this reprint includes the two classic and definitive studies of the mineral—"Benitoite, a New California Gem Mineral" (1907) and "Benitoite, Its Paragenesis and Mode of Occurrence" (1909)—both authored by George Davis Louderback and originally published by the University of California in its *Bulletin of the Department of Geology*. Although the scientific material is now almost 80 years old, it is still astonishingly current (in part because no other discovery of gem-quality benitoite has been made since the initial one in 1906). However, more recent information is indeed available, and this reprint does

not, unfortunately, include an appendix or other modern textual apparatus to update the historical material. Nevertheless, it is a welcome and affordable reprint of two very hard-to-find classic papers on California's rare, endemic gemstone.

Jeffrey M. Burbank
GIA—Santa Monica

Diamonds from India, rev. ed., by K. Chhotalal, 102 pp., illus., publ. by The Gem & Jewellery Export Promotion Council, Bombay, India, 1984. This book is a revised edition of the 1983 book of the same title. Comprised of approximately 75% text and 25% statistical tables, it attempts to review all aspects of diamonds and provide more specific information on the Indian diamond trade. Included are sections that cover diamond rough, sorting, industrial-grade material, synthetics, cutting, Indian and other Asian cutting centers, the world diamond trade, prices of Indian polished goods, the Indian Diamond Institute Surat, and financial requirements of Indian diamond exporters. While a number of technical inaccuracies exist and the quality of the printing leaves much to be desired, this book may still prove of some value to those interested in the specifics of the Indian diamond trade.

Robert C. Kammerling
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The Magic of Indian Diamonds, by M. D. Dewani, 36 pp., illus., publ. by The Gem & Jewellery Export Promotion Council, Bombay, India, 1984. This brief booklet is "intended to give the layman some idea of the growth, problems and prospects of this largely cottage-based industry." It begins with a chapter that traces the modern history of the Indian diamond industry, beginning in 1963, and follows with chapters

on the early history of the Indian diamond trade and its revival in the 1950s. There are also brief sections on sources and supply of rough, sorting of rough, the art of the Indian cutter, and famous Indian diamonds. While this booklet has little to offer in the way of information that is not available elsewhere, the author does have some interesting comments in his chapter on the future of the diamond industry in India.

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Mountain of Light, by Dale R. Perelman, 194 pp., illus., publ. by Apollo Books, Winona, MN, 1984, \$US10.00* "The first piece which Akil Khan placed in my hands was the great diamond, which is a round rose, very high at one side. At the basal margin, it has a small notch and flaw inside." Jean Baptiste Tavernier further describes the stone as having "beautiful" color and weighing 280 ct. He says that when the Shah Jahan had received it, in rough form, it weighed 700.05 carats, and "had several flaws." Perelman offers various legends as to the origins of this stone—the fabled Koh-I-Noor—which was originally called Semantik Mani ("the Prince and Leader of All Gemstones"), but the 14th century marks the beginning of its known history. The author, now chatty, now melodramatic, tells the saga—generally written in blood—of the famous gray stone, reduced from rose to oval cut at the behest of Victoria's Prince Albert, and now weighing in at 108.93 ct. A helpful chronology summarizes the stone's adventures from 1304 to 1937 and its placement in the Tower of London. There is a bibliography of 58 books and three periodicals, nine black-and-white illustrations and one map accompany the text.

Stephanie Dillon
San Clemente, CA

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