GEM N·E·W·S

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THE 26TH INTERNATIONAL GEMMOLOGICAL CONFERENCE

On the occasion of its 500-year anniversary as a world leader in the gem-cutting industry, Idar-Oberstein, Germany, was a fitting site for the 26th International Gemmological Conference. The anniversary was commemorated by the German government through the issuance of an official postage stamp (figure 1).

In 1497 the gemstone industry in and around the towns of Idar and Oberstein was mainly concerned with the cutting of agate and other types of chalcedony. Today a wide variety of gem materials are cut in the Idar-Oberstein region. The area further prides itself on its role as a center for various kinds of training and commerce related to all types of gemstones, including diamonds. The region is home to the German Gemmological Institute, German Gemmological Association, German Foundation for Gemstone Research, German Gemstone Museum, the Diamonds and Gemstone Bourse, the Intergem trade fair, and numerous internationally acclaimed gem cutters and goldsmiths. A detailed history of Idar-Oberstein as a gem center has been published by Dr. Hermann Bank ("500 Jahre Edelsteinregion Idar-Oberstein [1497–1997]," *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 43, No. 3, pp. 129–152, 1997).

The first International Gemmological Conference was organized by Professor Karl Schlossmacher and Dr. Edward J. Gübelin in 1952. It has since become a biennial event, to which laboratory gemologists and gemological researchers from around the world are invited to present their latest discoveries.

This, the 26th IGC, was organized by Dr. Hermann Bank and Gerhard Becker, with assistance from Drs. Ulrich Henn and Claudio Milisenda, of the German Gemmological Association and German Foundation for Gemstone Research, and Dr. Jan Kanis of Veitsrodt, Germany. The conference took place from September 27 to October 3 and was attended by 50 official delegates from 24 countries. A total of 44 papers were presented. We are pleased to present abstracts from several of these presentations.

This section was prepared by Gem News editor John I. Koivula with the assistance of IGC participants Dr. Alfred A. Levinson and Michael E. Gray. Given space limitations, not all of the selected abstracts could be presented in this issue; some will appear in the Spring 1998 Gem News section.

DIAMONDS

Cathodoluminescence of yellow diamonds. Up to now, determination of "diamond type" has been based on spectroscopy. Junko Shida, of the Gemmological Association of All Japan, showed how cathodoluminescence can be used to classify yellow diamonds.

Diamonds are classified into the four main types (Ia, Ib, IIa, and IIb) based on their nitrogen contents; yellow diamonds are typically type Ia or Ib. However, mixed type diamonds (e.g., Ia + Ib + IIa) are well known. Substitution of elements other than nitrogen (e.g., hydrogen) also affects the properties of diamond, but these substitutions are not addressed in this classification system.

Ms. Shida described how, by interpreting zonal or sector structures and other features discernible by cathodoluminescence, one can distinguish various types of yellow diamonds (natural or synthetic), as follows:

- Type Ia ("cape" series): Blue and yellow zoned fluorescence.

- Type Ia (hydrogen rich): Irregular patchy blue and slightly chalky yellow fluorescence.
- Type Ib: Yellow, yellowish green, and orange-yellow fluorescence; fine lines due to plastic deformation in the direction of octahedral faces are also seen.
- Mixed type: Irregular patchy fluorescence of various colors.
- Irradiated diamonds (type not specified): Chalky blue and dull yellow fluorescence.
- Synthetic (type Ib): Different colors of fluorescence in every crystallographically distinct sector.

Diamond inclusions in corundum. Using laser Raman microspectrometry, George Bosshart of the Gübelin Gemmological Laboratory in Lucerne, Switzerland, has identified inclusions of diamond with graphite in sapphires from Ban Huai Sai, Laos. Diamonds and corundum have been found in the same secondary deposits, such as the sapphire-rich alluvial deposits of New South Wales, Australia. However, recognition of the coexistence of these two minerals as inclusions within one another is both relatively recent and rare.

An inclusion of ruby in diamond was first reported in 1981 (sample locality unknown) by Meyer and Gübelin (*Gems & Gemology*, Vol. 17, No. 2, pp. 153–156), and later by Watt (*Mineralogical Magazine*, Vol. 58, 1994, pp. 490–493) from Brazil. The reverse association—diamond inclusions in corundum—is a more recent discovery, as it was reported first by Dao et al. (*Comptes Rendus de la Academie de Science, Paris*, Vol. 322, No. IIb, pp. 515–522) only in early 1996. In this case, diamond inclusions accompanied by graphite and lonsdaleite (also a high-pressure polymorph of carbon) were identified in seven rubies from Vietnam. Later in 1996, Dr. I. Wilcock and G. Bosshart tentatively identified minute diamond inclusions (accompanied by graphite only) in two sapphires from Laos by Raman analysis.

The diamond inclusions in Ban Huai Sai sapphires are particularly important because the coexistence of diamond and corundum in the most significant primary diamond source rocks—deep-seated (peridotitic) ultramafic rocks—is considered unlikely, although theoretically possible. Diamond and corundum have been found in the same metamorphic (eclogitic) rocks on several continents. Knowledge of the conditions of coexistence of these phases (i.e., mechanisms by which the necessary temperature and pressure were obtained), and thus the likely geologic situation that accounts for their formation (e.g., metamorphic or igneous origin), should be forthcoming as newer analytical techniques become available.

The diamond pipeline into the third millennium. This two-part paper was presented by Menahem Sevdermish of Israel and Dr. Alfred A. Levinson of the University of Calgary, Alberta, Canada. In part 1, Mr. Sevdermish explained that De Beers's single-channel diamond marketing pipeline, which had been operative since the mid-1930s, is now obsolete. He suggested that it has been replaced by a pipeline that consists of three marketing channels: (1) the traditional channel for high-valued gem-quality diamonds, for which De Beers continues to maintain stability; (2) a channel based on small, low-quality diamonds cut in India; and (3) the Russian channel, which began to evolve in the early 1990s, but is as yet of undetermined status and potential. Each of the above channels operates—or is capable of operating—essentially independently, and each has its own organizational and distribution system. Mr. Sevdermish emphasized the role that small, Indian-cut diamonds play in the trade and how these have facilitated the creation of a homogenized mass market for inexpensive diamond jewelry, particularly in the United States.

In part 2, Dr. Levinson expanded on the modern dia-

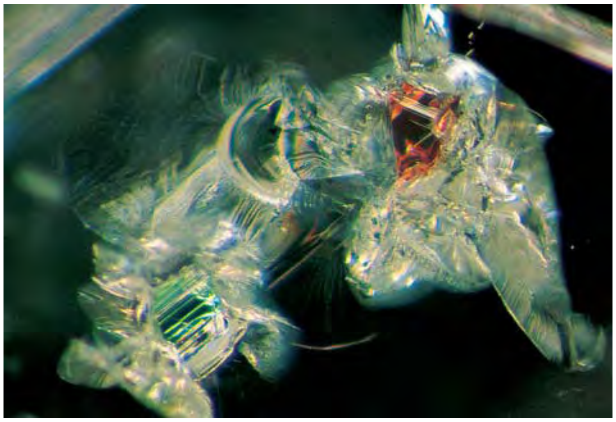
Figure 1. This complete sheet of postage stamps was issued in 1997 by Germany to commemorate 500 years of gem cutting in the Idar-Oberstein region. Notice the various gemstone cuts depicted on the upper and lower margins of the sheet. Photo by Maha DeMaggio.

mond-cutting industry of India and its position in the world diamond trade. Using statistics on the world production of rough, Indian import data on rough, and export data on polished diamonds, he traced the evolution of the modern Indian cutting industry from its inception in the early 1960s to the present. In 1996, India accounted for about 70% of the world's polished diamonds by weight and 40% by value. Calculations show that Indian cutters now produce about 800 million polished diamonds annually (about 8 out of 10 polished in the world), the vast majority of which are less than 0.03 ct (3 points). These small, generally low quality stones have spawned a new segment of the diamond jewelry market, which is readily affordable and amenable to mass marketing. Presently, about 50% of world retail diamond jewelry sales by value—and perhaps 75% by number of pieces—are based on diamonds cut in India. Approximately 700,000 people cut diamonds in India, but only about 200,000 do so full-time.

Mineral inclusions in large Yakutian diamond crystals. Representing the Institute of Mineralogy and Petrography in Novosibirsk, Russia, Dr. Nikolai Sobolev presented results of a study conducted with E. S. Yefimova and O. V. Sukhodolskaya on the mineral inclusions in a special collection of large (>10 ct) diamonds from the three major Yakutian mines: Mir, Udachnaya, and Aikhal. Nearly all of the 2,334 specimens studied were sharp-edged octahedral crystals typical of Yakutian diamonds.

Sulfides, olivine, and chromite are the major mineral inclusions in the diamonds from these three mines; however, the proportion of each varies from mine to mine. Sulfide inclusions dominate in diamonds from Mir, whereas olivine and chromite dominate in diamonds from Udachnaya and Aikhal. Peridotitic inclusions (figure 2) were found to be far more common than eclogitic inclusions (the latter were identified in about 3%–14% of the diamonds from the various mines), confirming the dominant influence of peridotites (particularly harzburgite) in the formation of diamonds from this locality.

Figure 2. Pyrope (red) and chrome diopside (green) are among the peridotitic inclusions identified in Yakutian diamonds. Photomicrograph by John I. Koivula; magnified 15×.



The morphology of natural gem diamond. Dr. Emmanuel Fritsch, of the University of Nantes, France, gave a status report on a study of the morphology of natural gem diamonds that he conducted with M. Moore and Dr. B. Lasnier. Although the morphology of natural diamonds has been studied for centuries, new analytical techniques and advances in our knowledge of crystal growth justify a revisit of this subject. Such studies are applicable to diamond faceting, the interpretation of diamond formation, and the differentiation of natural from synthetic diamonds. Dr. Fritsch reported that three growth morphologies are typical for natural diamonds: octahedral, cuboid, and fibrous.

Octahedral growth is common for most natural gem diamonds; such diamonds formed under conditions of low supersaturation of carbon. However, perfect octahedra are rare (most of those that are found come from the mines of Yakutia, Russia). Most octahedral diamonds are partially dissolved (etched) by kimberlite magma. Dissolution of the octahedral edges results in crystals that *look* like rounded rhombic dodecahedra. *Cuboid growth* does not mean growth of cube faces; rather, it refers to growth by undulating surfaces, each having a mean orientation corresponding to a cubic face. This type of growth is poorly understood, and only a portion of such a crystal is ever of gem quality. *Fibrous growth* forms opaque aggregates, and is the result of supersaturation of carbon and/or the presence of numerous inclusions that prevent the formation of octahedral faces. Fibrous growth never yields gem-quality material, but it can form overgrowths on gem diamonds (i.e., "coated crystals"). It is interesting that many large, valuable, nitrogen-free (type II) diamonds do not show any particular shape, for reasons that are still unknown.

All of the basic growth morphologies can be modified by various processes including dissolution, twinning, cleavage, fracture, and deformation. Thus, unusual shapes can result, such as that shown in figure 3. Note that perfect cubes and dodecahedra, composed of flat faces, do not exist in natural gem diamonds even though they may be depicted in idealized drawings in some reference books.

COLORED STONES AND INORGANIC MATERIALS

Identification of amber by laser Raman microspectroscopy. Thye Sun Tay, of the Far East Gemmological Laboratory in Singapore, discussed the results of a study conducted with Z. X. Shen, S. L. Yee, L. Qin, and S. H. Tang on the separation of amber from its various imitations, specifically more recent natural resins such as

Figure 3. This 0.60 ct slightly etched natural cleavage of a cuboid diamond from the Jwaneng mine, Botswana, shows the "skeletal" appearance that is sometimes formed during cuboid diamond growth. Courtesy of the Diamond Trading Company Research Center, Maidenhead, England; photo by John I. Koivula.

copal. Tay and his colleagues used a Renishaw Micro-Raman spectroscopy system with a near-infrared [782 nm] laser to help eliminate fluorescence problems encountered with lasers that operate in the visible-light region. They found the extended continuous scan feature of the Renishaw system useful to enhance weak Raman peaks, since peak strength and position are important for differentiating amber from amber-like substances.

New Zealand 'Kauri Gum.' Following a visit to the Otamatea Kauri Museum, North Island, New Zealand, Professor Herbert S. Pienaar, of the University of Stellenbosch in South Africa, reexamined the natural fossil exudate from the Kauri conifer, *Agathis australis*, known as "Kauri gum." In terms of polymerization and degree of solubility in methanol, this substance can be regarded as being either copal or amber, depending on its geologic age; amber is at least Middle Tertiary, while copal is younger.

To botanists, a gum is a water-soluble colloidal polysaccharide of plant origin (such as gum arabic), that becomes gelatinous when moist, but hardens on drying. Since "Kauri Gum" does not absorb water in this fashion, perhaps it should be referred to as "Kauri resin."

Inclusion-related fluorescence zoning in amber. Gem News editor John Koivula showed a series of slides illustrating distinctly zoned ultraviolet fluorescence patterns surrounding the legs of an arthropod within amber that appeared to be the remains of a whip scorpion (figure 4). This type of zoned fluorescence has been observed in several samples of natural amber containing fauna inclusions. It is most easily seen at and near the surface of the amber, immediately surrounding inclusions that have been cut through during lapidary treatment. The fluorescence patterning is probably the result of a chemical reaction between the amber resin and the animal. As this type of fluorescence has not been observed in any amber substitute or imitation, the reaction probably takes place over an extended period of time during the fossilization process. As such, when it is detected, inclusion-related zoned fluorescence is an indicator of natural origin.

New chrysoberyl deposits in India. Dr. Jayshree Panjikar, of the Gemmological Institute of India, Bombay, drew from research conducted with K. T. Ramchandran in her report on three new deposits of chrysoberyl that were discovered almost simultaneously in 1996, in the states of Madhya Pradesh, Orissa, and Andhra Pradesh, near the

Figure 4. The legs of what appeared to be a whip scorpion are exposed on the surface of this piece of amber (left). The ultraviolet fluorescence of the host amber is visibly zoned around the legs of the arthropod where they reach the surface (right). Photomicrographs by John I. Koivula; magnified 10×.

eastern coast of India. Geologically, this entire region consists mostly of Precambrian age garnet-sillimanite and garnet-biotite gneisses. Chrysoberyl is found within cross-cutting pegmatites or along their contact zones, and also in gravels derived from weathering of the pegmatites. Alexandrite, yellow chrysoberyl, and cat's-eye chrysoberyl have been recovered. Alexandrite is typically found in the contact zones, yellow chrysoberyl occurs within the pegmatites, and the cat's-eye variety occurs is scattered throughout the pegmatites.

Alexandrite with a moderate to intense color change has been found at Deobhog in the Raipur district of Madhya Pradesh; yellow chrysoberyl also occurs in this region. In Orissa, occurrences at Jerapani, Surjapalli, and Dakalga produce mainly yellow chrysoberyl. Alexandrite with a slight to moderate color change has been found at Surjapalli. Large quantities of cat's-eye chrysoberyl are found in the southern part of Orissa.

The Vishakhapatnam district of Andhra Pradesh has produced yellow chrysoberyl, small alexandrites with a moderate color change, and large quantities of cat's-eye chrysoberyl. Most of this material is heavily included.

All the varieties of chrysoberyl show typical refractive indices of 1.746 to 1.755, with a birefringence of 0.009. The specific gravity is slightly lower than normal, at 3.69. In the visible-light absorption spectrum, the alexandrite shows weak to intense chromium lines, whereas the yellow chrysoberyl shows a clear absorption line at 444 nm. Common internal features are sillimanite, rutile, biotite, apatite, and liquid-filled "feathers," as well as straight and angular zoning.

Although the three new chrysoberyl localities are separated from one another by hundreds of kilometers, they probably formed at approximately the same geologic time. The apparent continuation of the pegmatite series farther south, in the state of Kerala, suggests the possibility of additional deposits there.

Gem corundum from Australia and Southeast Asia. Dr. F. Lynn Sutherland, of the Australian Museum in Sydney (in collaboration with E. A. Jobbins, R. R. Coenraads, and G. B. Webb), and Dr. Dietmar Schwarz, of the Gübelin Gemmological Laboratory, presented two papers on similar topics: the chemical and gemological characteristics of gem corundum from the basaltic fields of Barrington, Australia, and Pailin, Cambodia. Both fields have remarkably similar gem suites, in that both suites represent two distinct geologic origins: "metamorphic" and "basaltic" (or magmatic). The two origins for corundum can be distinguished by mineral inclusions and chemistry (trace and minor elements). These distinctions are indicative of two different underlying corundum sources tapped by rising basaltic magmas, which transported the corundum to the surface.

"Metamorphic" corundum from both localities is characterized by inclusions of magnesian spinel and sapphirine (figure 5), whereas "basaltic" corundum contains inclusions of ferrian spinel, zircon, and Nb-Ta-U- and/or Th-rich oxide minerals such as pyrochlore. Chemical differentiation between the two types of corundum is possible using the elemental ratios Cr_2O_3/Ga_2O_3 and Fe_2O_3/TiO_2 (figure 6).

Dr. Schwarz extended the study to sapphires from Thailand and Laos and obtained similar results––a bimodal distribution of the sapphires on the basis of chemistry and mineral inclusions. Such similarities in the corundum suites suggest that sapphires of metamorphic origin coexist with sapphires of basaltic origin at other localities.

Bactrian emeralds. An ancient country in what is today northern Afghanistan bore the name Bactria, after its main city (now Balkh). In 314–305 BC, Theophrastes wrote in his famous handbook on mineralogy, *Peri Lithon*, that Bactria was a source for "smaragdos." This word, however, was used to describe not only emerald, but other green stones as well. Since that time, Pliny the Elder and others have repeated this information in their writings. D. E. Eicholz, who prepared the English translation of Pliny's *Natural History*, book 37 (1962), stated that "the Bactrian *smaragdus* is . . . a fiction."

D. H. Piat of Paris and F. H. Forestier of Beaulieu, France, reviewed the reality-or-myth question of the existence of Bactrian emeralds in light of some relatively recent discoveries, especially the 1970 discovery of emerald deposits in the of Panjshir Valley, 120 km northeast of Kabul. The geology of those deposits, and the physical, chemical, and gemological properties of emeralds found there were compared to those of other deposits. Also con

Figure 5. The intergrowth of sapphirine (an Mg-Al silicate; not to be confused with sapphire) in this 3 mm ruby specimen indicates a metamorphic origin. The specimen, from Gloucester Tops, Barrington volcanic field, New South Wales, Australia, was brought to the surface by an alkali basalt. Courtesy of G. B. Webb.

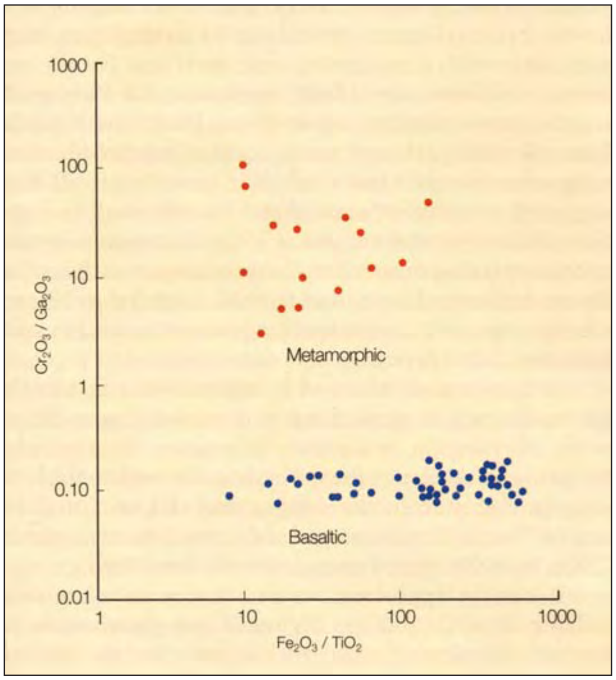


Figure 6. This graph illustrates the chemical distinction between corundum of metamorphic and basaltic origin based on ratios of the abundance of chromium, gallium, iron, and titanium as oxides. Corundum samples of metamorphic origin plot in the upper part of the diagram, while those of basaltic origin plot in the lower part. The data are based on samples from the Barrington field in Australia.

sidered were geographic factors: the presence of the Panjshir River drainage northeast of Kabul, the location of archaeological sites in the region, and the distribution of emeralds in the treasures of the historic kingdoms of the Indian peninsula. On the basis of this newly discovered evidence, the conclusion was reached that true emeralds could have been known in the country of Bactria in ancient times.

Emerald origin. To study the origin of emeralds, Israel Z. Eliezri and his colleague, Y. Kolodny, both of Israel, measured the isotopic composition of 10 emeralds from five major deposits. The geologic environment of emerald formation is primarily constrained by the availability of beryllium and chromium. Sources for these elements may be indicated by the oxygen isotopic composition ($\delta^{18}O$) of beryl. This composition is determined by the isotopic composition of the mineralizing fluid and by the temperature of formation.

Of the samples tested, the Colombian emeralds were the most $\delta^{18}O$ enriched, at $\delta^{18}O$ = 22‰ (per mil), which reflects their association with sedimentary rocks and a relatively low temperature of formation. The Brazilian and Zambian emeralds were noticeably lower ($\delta^{18}O$ = 12‰), which reflects their contact metamorphic origin at higher temperatures in association with pegmatites and schists. The Tanzanian emeralds, which are closely associated with basic volcanic rocks, had the lowest $\delta^{18}O$ values (8‰); whereas the Nigerian emeralds had a slightly higher value of $\delta^{18}O$ = 9.5‰, which probably reflects their relationship to granitic rocks.

The results of this study show a general correspondence between the isotopic composition of oxygen of the various rock types and the emeralds found in association with these rocks. The authors feel that isotopic analysis of oxygen in emeralds can serve as a means of determining their country of origin, in particular to distinguish Colombian emeralds from those of other deposits.

Origin of ancient Roman emeralds. In collaboration with C. Aurisicchio and L. Martarelli, Professor Giorgio Graziani of the University of Rome has studied the geographic origin of emeralds that were found in funeral stores at a necropolis of ancient Rome.

Nondestructive analytical techniques, such as infrared spectroscopy and scanning electron microscopy, were used to characterize these emeralds. The resulting characteristics were compared to those of emeralds from known localities that ancient Romans might have had access to, such as Habachtal (Austria), India, Upper Egypt, and the Ural Mountains in Russia. The most useful information came from two regions in the infrared: 3,500–3,700 cm^{-1} and 400–1,100 cm^{-1}. The spectral features suggested that these emeralds probably came from Upper Egypt.

Blue quartz from Madagascar. Decorative quartz from Madagascar, showing a blue color caused by inclusions, was discussed by Dr. Emmanuel Fritsch, of the University of Nantes, France. Using a combination of SEM-EDXRF and Raman analysis, Dr. Fritsch and his colleague, Professor Bernard Lasnier, identified numerous inclusions in this material. Lazulite (figure 7) apparently causes the blue color. Other inclusions present are: ilmenite or titanomagnetite as rounded black grains, rutile as reddish brown rounded grains, apatite as colorless rounded grains, zircon as colorless-to-gray rounded grains, celestine and anhydrite as corroded colorless inclusions, hematite as red-brown hexagonal platelets, a monoclinic amphibole species as colorless elongated prisms, colorless mica as platelets with rounded edges, and svanbergite as a corona around some of the lazulite inclusions.

Lazulite is not the only mineral inclusion known to cause blue color in quartz. Finely disseminated inclusions of ajoite, azurite, chrysocolla, dumortierite, papagoite, and tourmaline have also been seen to cause visible blue coloration in otherwise colorless quartz.

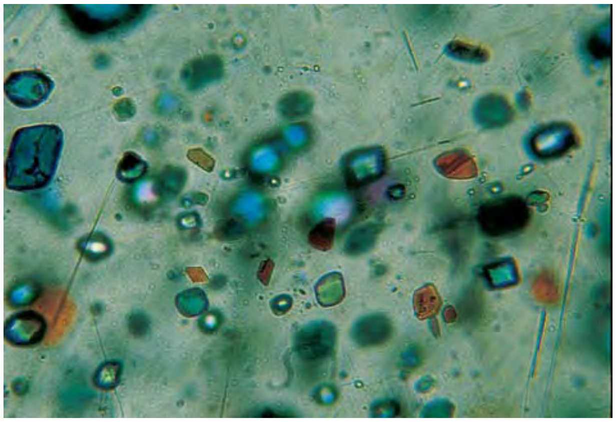


Figure 7. Blue lazulite and red-brown hematite are among the inclusions seen in quartz from Madagascar. The lazulite inclusions impart an overall blue color to the quartz. Photomicrograph by Bernard Lasnier; magnified 60×.

Ornamental stones and other gems from Bolivia. Dr. Jaroslav Hyrsl, of the Mineralogy Department of Charles University in Prague, Czech Republic, reported on the gemstones of Bolivia, which he divided into four basic groups: economically important gemstones, rare collector's stones, ornamental stones used by ancient Indians, and ornamental stones that are mined today.

Although numerous economically important gemstones are present in Bolivia, few of the deposits are large enough to mine. Bicolored amethyst-citrine ("ametrine"), the most important gem material of Bolivia, comes from the La Gaiba region. The Anahí mine is the best-known occurrence of ametrine; it also produces amethyst and natural (not heated or irradiated) citrine. Small diamond crystals weighing up to 1 ct occur in Permian glacial sediments in several rivers in the northern part of Bolivia. These alluvial deposits were prospected in the 1920s and considered uneconomic; several kimberlites have since been discovered in Ayopaya Province. A few opaque to translucent blue sapphires were found recently in alluvium in the Potosí Department, but they do not exceed a few millimeters. Very dark almandines up to ~1 ct are also present in alluvium in the Potosí area. Aquamarine is known from pegmatites in the San Ramon area, but the cut stones (up to 2 ct) are very pale. Crystals of smoky quartz (up to 50 cm long) and green tourmaline are also known from these pegmatites. Emerald crystals up to 1 cm long are known from the eastern Santa Cruz area, but no cuttable material was found until recently. The second significant modern occurrence of dark green chromium chalcedony (the first being the "mtorolite" deposit in Zimbabwe) is in eastern Bolivia's Chiquitania region, where this ornamental gem occurs as veinlets in a silicified laterite overlying ultrabasic intrusives.

Among the rare collector's stones are transparent purple apatite crystals from a tin deposit at Llallagua; yellowish hydroxyl-apatite crystals up to about 10 cm long, sometimes with a transparent core, from near Potosí; and cassiterite from the Viloco mine near La Paz, with faceted stones reaching up to 25 ct. Danburite crystals from Alto Chapare very rarely contain parallel fibers of magnesio-riebeckite (an amphibole group mineral) that can yield a strong cat's-eye effect. Phosphophyllite from Cerro Rico de Potosí can reach 75 ct. Transparent pyrargyrite crystals come from Colquechaca, southeast of Oruro, and several have been faceted. Large (up to 20 cm) siderite crystals with transparent portions recently came from the Colavi deposit near Potosí.

Ornamental stones used by ancient Indians, mostly for beads, include chalcedony with native copper inclusions, chrysocolla, malachite, blue-green fluorite, and turquoise. The chalcedony, chrysocolla, and malachite were probably from the copper deposits of Corocoro and/or Turco. Turquoise probably came from northern Chile, with the other materials mostly from Peru.

Recently exploited ornamental stones include sodalite from Cerro Sapo (figure 8) and stromatolite (a layered sedimentary-algal rock) from near the city of Potosí.

Cultured pearls from Indonesia. In this report, prepared with H. C. Zwaan, Dr. Pieter C. Zwaan of the Netherlands Gemmological Laboratory in Leiden noted that while conditions in Indonesia are generally good for the cultivation of saltwater pearls, actual production is restricted to a limited number of localities.

Earlier operations, between 1950 and 1960, produced a significant quantity of large cultured pearls, up to about 15 mm in diameter, from the Aru Islands in the Arafura Sea. Named after the most important trade center in that area, these pearls are commercially known as Dobo pearls.

Examination of a collection of these pearls, ranging from 9.2 to 15.3 mm in diameter, gave a density between 2.691 and 2.755. The nacre thickness varied from 1.0 to 2.0 mm, which by European laboratory standards is considered very good. Dobo pearls are produced by the silver-lipped mollusk *Pinctada maxima*. Recent information indicates that important pearl trade activities are now going on in that area.

Cultivation of blister pearls on *Pinctada maxima* shells started several years ago near the coast of Lombok island, in particular in Street Lombok, around the very small island Gili Air. Three shells from this area with a total of nine mabe "pearls" were examined and found to have hemispherical bead nuclei composed of artificial resin instead of mother-of-pearl or soapstone. These cultured blister pearls are sold on Lombok and Bali islands as natural pearls. At first glance, however, they resemble imitation pearls, because the relatively thin, translucent nacreous layer causes a deceiving sheen, which is produced by light reflection from the artificial nucleus. The specific gravity of these blister pearls is also extremely low, ranging from 1.815 to 1.905.

Sapphires from northern Madagascar. In the past few years, several new and important sapphire deposits have been discovered in Madagascar. Dr. Margherita Superchi, of CISGEM, Milan, Italy, described a new occurrence at Ambondromifehy, in Antsiranana Province, in the northern part of the island. The sapphires found to date were alluvial, having been weathered from basaltic rocks that were emplaced intermittently during the period from the Upper Oligocene to the Pleistocene. The sapphires are thought to be xenocryts; that is, they did not crystallize from the basaltic magma, but simply were transported by it. They are associated with zircon, spinel, pyroxene, and olivine.

Dr. Superchi and her colleagues (A. Donini, D. Muzzioli, and E. Roman) obtained detailed gemological data, chemical compositions, and optical and Raman spectra for 74 crystals (the largest being 182.59 ct) and 13 cut stones. Among the more interesting discoveries were inclusions of pyrochlore, zircon, and sodic plagioclase, which, with the chemical data (e.g., high gallium contents) confirm the "basaltic" association of these sapphires (see the earlier abstract on gem corundum).

Tunduru-Songea gem fields in southern Tanzania. Dr. Claudio Milisenda of the German Gemmological Association, using research done with Dr. Ulrich Henn and Dr. Hermann Bank, discussed the spectacular new gem occurrences that were discovered in late 1993 and early 1994 in the Tunduru-Songea area of extreme southern Tanzania. These alluvial deposits are located along tributaries of the Ruvuma River, which forms Tanzania's southern border with Mozambique. The area produces a large variety of gem materials, in particular blue and fancy-colored sapphire (including "padparadscha" and color-change stones), ruby, many colors of spinel, garnet (such as rhodolite, hessonite, and color-change), chrysoberyl (including cat's-eye, alexandrite, and cat's-eye alexandrite), various quartz and beryl varieties, tourmaline, zircon, kyanite, scapolite, peridot, and diamond.

The first gem rough appeared on the market in 1994, and included sapphire, spinel, garnet, chrysoberyl, and zircon, reportedly from an area east of Songea, where the Muhuwesi and Mtetesi rivers converge. Shortly afterwards, an even richer alluvial deposit was discovered near Tunduru, a remote area in southeast Tanzania. Because thousands of people were involved in mining and trading gemstones at the outset, it is almost impossible now to tell if some rough gems are from the Songea or the Tunduru area.

With the exception of the diamondiferous Mwadui pipe within the Tanzanian craton, all of Tanzania's known gemstone occurrences (including the Tunduru-Songea gem fields) are situated within the Proterozoic Ubendian-Usagaran System, a medium- to predominantly high-grade metamorphic unit that includes gneiss, marble, metapelite, and quartzite, which are intruded by numerous pegmatites. The Ubendian-Usagaran System forms the Tanzanian part of the Mozambique Belt. This gem-bearing complex experienced its main thermo-tectonic evolution during the Pan-African orogeny (approximately 600 million years ago), which affected the entire eastern part of the African continent as well as southern India and Sri Lanka.

Figure 8. Sodalite is one of the ornamental materials that is currently being mined in Bolivia, from the ancient deposits near Potosí. This cabochon weighs 5.05 ct. Photo by Maha DeMaggio.

Dr. Milisenda also reported on the gemological characteristics of corundum, spinel, chrysoberyl, garnet, and tourmaline from the Tunduru-Songea region, which were based on the study of hundreds of carats of rough and cut stones. A visit to the localities yielded information on the geology and recovery techniques. Iron- and titanium-oxide contents of the corundum were compared with similar gem materials from Sri Lanka and India. With the exception of the occurrence of diamond and an unusual mint-green, vanadium-colored chrysoberyl, the gem gravels of the Tunduru-Songea region strongly resemble the gem concentrates of Sri Lanka, and the two areas may be genetically related. However, the large variety of gems of contrasting genetic type suggests that the gems themselves were derived from different geologic sources in both locales.

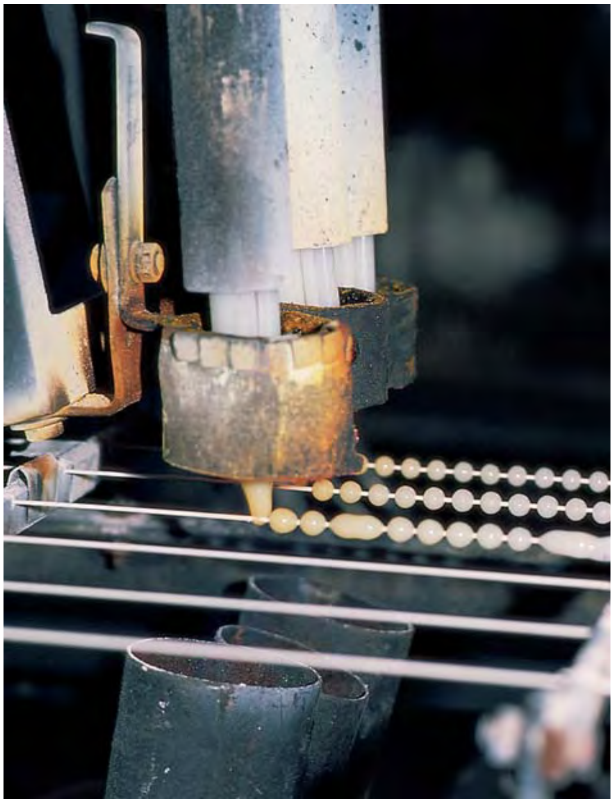
SYNTHETICS AND SIMULANTS

Imitation pearls—so-called "I Pearls" from Japan. Professor Akira Chikayama of Tokyo, Japan, discussed the modern production of imitation "I Pearls" in Japan. Although best known for its cultured pearl industry, Japan is also an important manufacturer of imitation pearls. During the production of most imitation pearls, spherical beads are given their pearly-luster coating through the application of a fish-scale extract known as *Essence d'Orient*. More recently, a lead-carbonate-based pearlescent coating material has also been used.

The least expensive manufacturing process for imitation pearls uses plastic bead centers formed by injection molding. Because of their low cost, such imitations are responsible for as much as 80% of the imitation pearl market. Their low specific gravity, however, makes them less desirable than those imitations with heavier centers. This is particularly obvious when plastic imitations are used in strands, since these bead strands do not lay evenly or move "naturally."

The most expensive imitation pearls manufactured in Japan use central beads formed from shell. They can be quite convincing in both appearance and heft, and have been variously called "shell pearls," "imitation cultured pearls," and "man-made pearls."

Figure 9. Machine manufacturing of alabaster glass beads has modernized the production of glass-based imitation pearls in Japan. Note the accidental "baroque" beads that occasionally form. Photo by Professor A. Chikayama.



The third form of imitation pearl is produced from a bead center of white alabaster glass. In the past, these bead centers were hand blown. More recently, a modern automatic bead-forming machine was invented by Mr. Satake of Izumi City. Machine manufacturing of the alabaster glass beads (figure 9) is much more efficient than the previous hand-blowing methods, so these glass-based imitation pearls are much more economical.

Because of the confusion created by numerous commercial names, the Japan Imitation Pearl & Glass Articles Association has suggested a new nomenclature to describe imitation pearls manufactured in Japan: the use of "I Pearl" together with an indication of the base material, such as shell, glass, or plastic. The letter I stands for "imitation" and also for the place of production, Izumi City. "I" (Ai) also means "love" in Japanese.

Growth-induced imperfections and inhomogeneities in single crystals. The science of crystal growth is important for distinguishing natural from synthetic single-crystal gem materials. Natural, synthetic, and treated stones have the same basic chemical composition and crystal structure, but different growth or post-growth histories. Dr. Ichiro Sunagawa, of the Yamanashi Institute of Gemmology and Jewellery Arts in Kofu, Japan, explained how imperfections and inhomogeneities are induced into a crystal during the growth process, or modified through post-growth treatment. Since growth conditions and ambient phases different from those of natural stones are required for the synthesis of many single crystals, the two materials may have different imperfections and inhomogeneities.

In the synthesis of gem crystals, growth usually takes place at the seed crystal–nutrient phase interface. The external forms of a crystal (its morphology) and surface microtopography of the crystal faces represent the final stage of a growth process, although these features are usually removed during cutting. However, features within the crystal represent earlier growth surfaces; thus, they serve as a record of the events that took place at the interface during growth. These events include: fluctuation of growth rates, incorporation of impurities, entrapment of inclusions, generation of dislocations, and the like. Solid or nutrient-phase inclusions, subgrain boundaries, and twin boundaries are macroscopic imperfections. However, growth sectors, sector boundaries, growth banding, and associated color zoning either can be detected with a microscope or require special techniques to visualize, such as X-ray topography, cathodoluminescence, or laser-beam tomography. Detection of dislocations requires special techniques. Post-growth treatments, such as heat and irradiation, may modify the growth-induced imperfections and inhomogeneities. In particular, the valence state of impurities may be detectably altered. As crystal-growth techniques become more sophisticated, gemologists may have to look to these signs more and more to make an identification.

Surface features and growth conditions of quartz crystals. The surface features of experimentally grown hydrothermal synthetic quartz were examined by Professor Takeshi Miyata, in collaboration with M. Hosaka, both also of the Yamanashi Institute. These researchers grew single crystals of synthetic quartz in sodium hydroxide solutions at 350°–515°C, and in sodium chloride solutions at 450°–490°C. They observed the morphology of the crystals and their surface microtopography using interference microscopy.

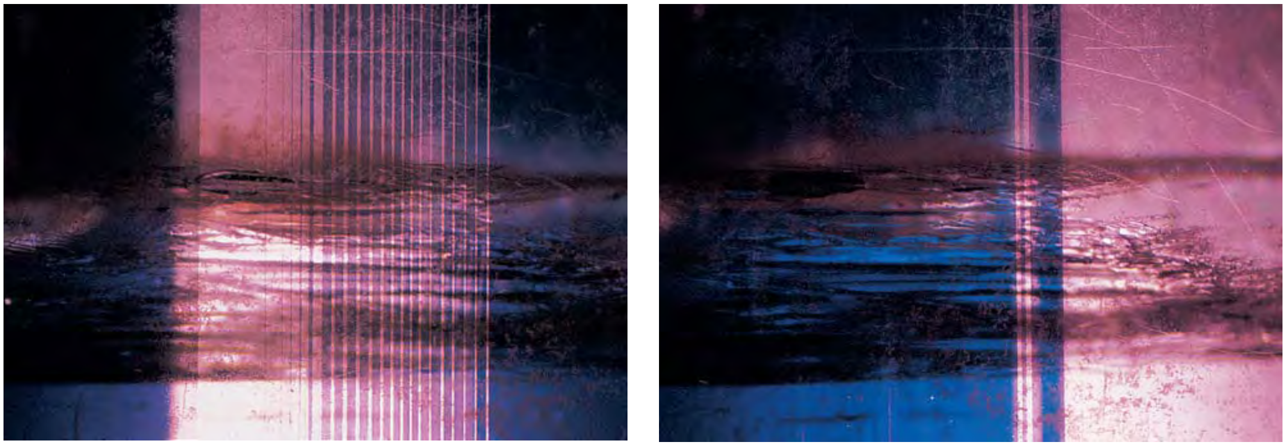
So that the shape of the seed would not influence the morphology of the grown synthetic crystal, spherical seeds of synthetic quartz were used. The growth rates were calculated by measuring the size of the seeds before growth and the size of the synthetic crystal overgrowths that formed within a specific time period. It is well known that the various shapes of natural quartz crystals from different localities are influenced by their growth conditions. So, too, are their macroscopic and microscopic surface characteristics. Comparison of shapes and surface features seen on synthetic quartz crystals grown under known, controlled conditions, to similar shapes and surface features observed on natural quartz crystals, may provide information on the growth conditions of the natural crystals.

Figure 10. Illustrated here are the largest known crystal (136.89 ct) and the only known cut sample (5.33 ct) of neodymium penta-phosphate. Photo by Maha DeMaggio.

Reversible twinning in an unusual synthetic material. Three pieces of an unusual synthetic material were loaned to Gem News editor John Koivula by Arthur T. Grant of Coast-to-Coast Rare Gems, Martville, New York. The samples constituted a well-formed 136.89 ct crystal, a 5.33 ct faceted sample (figure 10), and a 28.81 ct partially polished rectangular block. This material is transparent and an intense, slightly purplish pink.

Twelve crystals of this material were grown about 10 years ago as an experimental material for the laser industry. The experiment was terminated when it was

Figure 11. Only slight finger pressure was required to cause a shift in the twin pattern in this block of neodymium penta-phosphate. Photomicrographs by John I. Koivula; polarized light, magnified 10×.



discovered that the crystals were difficult to cut because even slight pressure would cause a reversible elastic lamellar twin structure, which shifted position as the direction of pressure was changed. Hundreds of lamellar twin planes can be seen to appear and then disappear in polarized light (figure 11) when only slight finger pressure is applied. The shift in the twin planes is often accompanied by an audible clicking or cracking sound. Mr. Grant also encountered this twinning phenomenon when he faceted the 5.33 ct modified marquise shown in figure 10. During cutting, he noticed what appeared to be a cleavage plane form across the table facet which would alternately disappear and then reappear. Because the contour of the surface also shifts slightly when this occurs, it was very difficult to get a flat, well-polished table facet.

Qualitative EDXRF chemical analysis on the faceted sample by Sam Muhlmeister at GIA Research in Carlsbad, California, showed the presence of both neodymium and phosphorus. This analysis supported the stated chemistry as being neodymium penta-phosphate, with the formula NdP_5O_{14}. Gemological testing gave refractive indices of 1.608–1.632 and a birefringence of 0.024. The specific gravity obtained hydrostatically was 3.36. A strong typical rare-earth spectrum was observed using a handheld spectroscope. The material was inert to UV radiation, there was no reaction to the "Chelsea" color filter, and the pleochroism was weak, showing a shift between pink and purplish pink hues. Numerous two-phase inclusions visible with magnification in both the crystal and the block suggest hydrothermal growth.

TREATMENTS

Heat treatment of garnets. It is generally thought that garnets are not affected by treatment processes such as heating and irradiation, and therefore are not treated. Going against this convention, Gerhard F. A. Becker, of Idar-Oberstein, reported on the results of heat-treatment experiments he carried out on uncut rhodolite garnets from Brazil.

Mr. Becker conducted his experiments using a standard muffle furnace with the stones in air. The garnets were purple (figure 12, left) prior to heat treatment, and had gemological properties typical for rhodolite. Heating was conducted in 50°C increments, with the samples cooled and inspected between steps. The first noticeable change in color was observed at 700°C (figure 12, center), and the color continued to change up to 900°C (figure 12 right). Further heating resulted in the appearance of a metallic, hematite-like coating on the garnets (figure 13) that could be polished off.

Mr. Becker's research independently confirms earlier preliminary experiments done by Dr. Kurt Nassau (see *Gemstone Enhancement*, 2nd ed., 1994). Following up on an unpublished observation by G. V. Rogers, Dr. Nassau changed purplish rhodolite into a "hessonite-type brownish color" at a temperature of "about 600°C."

The metallic coating was probably the result of iron oxidation because the stones were heated in air. This coating might be similar to that reported in the Fall 1975 issue of *Gems & Gemology* on an emerald-cut almandine garnet that was misrepresented as cuprite. However, as heat treatment of garnets is generally not suspected, the stone seen in 1975 was thought to have been "sputter" coated (that is, to have had some material deposited on it) to give it the metallic coating.

Titanium and chromium diffusion-induced star sapphires. Gao Yan, of the National Gem Testing Center in Beijing, China, described some diffusion-treated star sapphires he and his colleagues, Z. Beili and L. Jingzhi,

Figure 12. Progressively hotter treatment of the untreated starting material on the left produced the changes in color shown in the two garnets on the right, at 700°C and 900°C, respectively. Photo by Gerhard Becker.

Figure 13. The metallic coating on these Brazilian garnets was the result of heat treatment above 900°C. Photo by Gerhard Becker.

received for identification in September 1996. All of the samples had essentially the same visual appearance, and all were approximately 5 × 7 mm. In daylight, the stones were translucent to opaque and showed a dark blue color with gray tone. They exhibited distinct six-rayed stars, very similar to those typically seen in synthetic star sapphires.

Measurements yielded an R.I. of approximately 1.76 and an S.G. of 3.97. All samples showed a distinct dichroism of blue and bluish green when viewed parallel to the girdle. A weak absorption line at 450 nm was visible with a hand spectroscope. The stones were inert to both long- and short-wave UV radiation. With magnification and darkfield illumination, three characteristics were observed: distinct color zoning, fingerprint-type healing fissures with two-phase inclusions, and tiny white spots scattered throughout. With the polariscope, almost all samples showed polysynthetic twinning. When viewed with fiber-optic illumination and high magnification, the surface revealed a very thin film of cotton-like material with spectral colors. A group of intense blue lines were concentrated along surface-reaching fractures that were produced by the polysynthetic twinning. When the samples were immersed in methylene iodide, a red halo appeared on the polished surface and a high-relief red outline was concentrated around the girdle.

EDXRF data from a cross-section cut across one of the samples showed that chromium was restricted to the sapphire's rim, and the titanium content was higher in the rim than in the core, although the sample was dark blue throughout. Iron was homogeneous throughout. With deep polishing of the dome of this sample, the asterism disappeared, confirming the conclusion that the material was diffusion-induced star sapphire.

Two distinctive characteristics were noted for these sapphires. First, instead of the colorless or pale blue treated corundum typically used as a starting material, the producer used dark blue sapphire with visible color banding. Second, it appears that chromium as well as titanium was part of the diffusion process, possibly to produce a thin red film that would deepen the blue surface color. On a dark blue background, the asterism becomes sharper and the color bands are less visible. Chromium may also enhance the asterism, although this remains to be verified.

These diffusion-induced star sapphires can be easily identified. The natural origin of the precursor material can be proved by internal characteristics such as the color banding and absorption spectra. The titanium and chromium diffusion process can be readily identified by blue lines along twin planes on the surface, a red halo on the surface, and a high-relief red outline around the girdle when the stone is immersed in methylene iodide. [Editor's note: See the Summer 1996 Gem News, pp. 136–138, for more information on diffusion-induced star sapphires.]

ANNOUNCEMENTS

New hall opens at the Smithsonian Institution. The Janet Annenberg Hooker Hall of Geology, Gems & Minerals opened on September 20, 1997, at the National Museum of Natural History (Smithsonian Institution). The 20,000-square-foot exhibit features the renowned Hope Diamond along with the museum's superb collection of gemstones and jewelry (figure 14), including donations that had not previously been displayed. The hall features interactive computerized displays, animated graphics, special lighting effects, and touchable specimens. Its various galleries include the National Gem Collection; Minerals and Gems Gallery; Mine Gallery; Plate Tectonics Gallery; Moon, Meteorites and Solar

Figure 14. The famed Mackay emerald is on display in the new Janet Annenberg Hooker Hall of Geology, Gems & Minerals at the Smithsonian Insitution. The emerald weighs 168 ct and is set in an Art Deco diamond and platinum necklace. Photo courtesy of the National Museum of Natural History (Smithsonian Institution).

Figure 15. This Victorian-era brooch, mounted with two cabochon garnets, 35 rose-cut diamonds, and several pearls and half pearls, is among the pieces that will be displayed in the new Gem Room at the Cleveland Museum of Natural History, Cleveland, Ohio. Photo courtesy of the Cleveland Museum of Natural History.

System Gallery; and Rocks Gallery. For more information, visit their website at http:\\www.mnh.si.edu\collections.html. The National Museum of Natural History is located at 10th Street & Constitution Avenue Northwest, Washington, DC.

Diamonds at the American Museum of Natural History. *The Nature of Diamonds* exhibit opened on November 1, 1997, and runs through April 26, 1998. This comprehensive exhibit explores all aspects of diamond, from its geological origins to its place in history, art, adornment, and literature, including its uses in modern technology and research. A specially designed walk-in diamond vault houses some of the most dazzling objects in the exhibition. Other highlights include a hands-on model of the crystal structure of diamond, a mine tunnel leading to a re-created "diamond pipe," and a large-screen computer-animated illustration of how diamonds are formed. For more information, contact Holly Evarts, Department of Communications, American Museum of Natural History, Central Park West at 79th Street, New York, 10024–5192; or call 212-769-5099. The exhibit will be traveling to other museums after closing in New York.

New exhibits at the Cleveland Museum of Natural History. November 1 marked the opening of the Reinberger Hall of Earth and Planetary Exploration. This multi-sensory, permanent hall integrates earth science and planetary geology. Some of the thematic sections include Ores and Mining, Geology Beneath Your Feet, Rocks and Minerals, and the Gem Room. The Jeptha Homer Wade II Gem Room will open in the spring of 1998; this exhibit will showcase a permanent collection of gems, jewels (see, e.g., figure 15), and mineral specimens. The museum is at 1 Wade Oval Drive in University Circle, Cleveland, Ohio, 44106–1767. For more details, call 216-231-4600 or visit the museum's web site at http://www.cmnh.org.

***Gems & Gemology* wins ASAE award—again!** For the second year in a row—and the fourth time in the past six years—*Gems & Gemology* won first place for peer-reviewed journals in the Gold Circle competition of the prestigious American Society of Association Executives. *Gems & Gemology* Editor Alice Keller accepted the award in early December on behalf of the journal.

ERRATUM

The authors wish to make the following corrections to "Benitoite from the New Idria District, San Benito County, California," which appeared in the Fall 1997 issue of Gems & Gemology:

1. *In the geologic map in figure 7, "Blueschist" should refer to the dark blue unit, and "Altered blueschist" should refer to the light blue unit.*
2. *The reference suggesting that benitoite can be used as a standard for measuring dispersion in gemstones should be reported as: Hanneman W.W. (1992) Determination of dispersion using a refractometer.* Journal of Gemmology, *Vol. 23, No. 2, pp. 95–96.*