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COLORED STONES AND ORGANIC MATERIALS

Andradite from Erzincan, eastern Turkey. In October 2007, Alexandra Woodmansee (Rock Logic, Glencoe, Minnesota) informed GIA about a new find of demantoid in Turkey. She obtained some rough and cut samples of this material in time for the 2008 Tucson gem shows, and loaned several pieces to GIA for examination. Her supplier, Kerem Özütemiz (Truva Mining Ltd., Ankara, Turkey), also exhibited the garnet in Tucson, in both 2008 and 2009. He informed one of us (BML) that he owned the claim, located near Erzincan, 700 km east of Ankara. Due to the long and severe winters, he mines the area for only three months of the year (June through August). Using a pneumatic hammer and hand tools, he produced ~300 g of cuttable material in 2007, and ~120 g in 2008, although most was fairly small and included. To date, he has had about 20 stones cut (in Germany) that range from 0.5 to 1.2 ct, as well as an abundance of melee-sized material, totaling ~300 carats.

A gemological examination of 13 stones that Mrs. Woodmansee obtained from Mr. Özütemiz showed that six were andradite (including some demantoid) and seven were grossular (tsavorite). The presence of grossular could not be explained, but Mr. Özütemiz indicated that those stones may have been introduced into the parcel at the cutting

factory. The six andradite samples (figure 1; 0.15–0.38 ct) were characterized for this report: color—orange brown, brownish yellow, yellow-green, and yellowish green (the four yellow-green to yellowish green samples were demantoid); RI—>1.81; hydrostatic SG—3.82–3.93 (brown/yellow samples) and 4.17–4.43 (green samples); inert to both long- and short-wave UV radiation; and a 440 nm cutoff visible with the desk-model spectroscope. Microscopic examination revealed radiating curved fibrous needles with associated fractures (some of which contained a transparent filler or partially dried residue), blocky “fingerprints,” and cubic growth zoning. Except for the high SG values, these properties are typical for andradite (e.g., M. O’Donoghue, Ed., *Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 206–210). In addition, the demantoid samples had distinct brown and green cubic color zoning, similar to that seen previously in two samples of andradite from Iran (see Spring 2007 Gem News International [GNI], pp. 65–67).

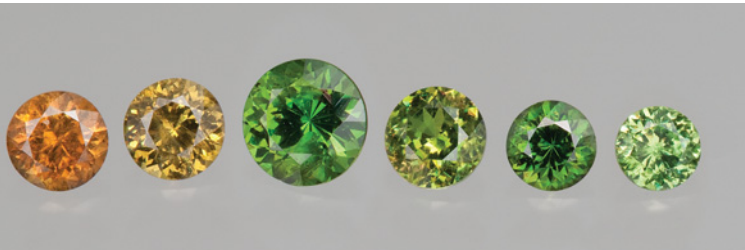
Quantitative chemical analysis of the six andradites was performed by electron microprobe at the University of Oklahoma (see details in the *G&G* Data Depository at www.gia.edu/gandg), and revealed the garnets contained 93.4–98.9 mol% andradite component. The demantoid samples contained significant levels of Cr (0.09–1.45 wt. % Cr₂O₃), while the orange brown andradite had the highest Ti content (0.13 wt. % TiO₂).

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Figure 1. These andradites (0.15–0.38 ct) were reportedly cut from rough produced in eastern Turkey in mid-2007. Photo by Kevin Schumacher.



Editor's note: Interested contributors should send information and illustrations to Brendan Laurs at blairs@gia.edu or GIA, The Robert Mouawad Campus, 5345 Armada Drive, Carlsbad, CA 92008. Original photos will be returned after consideration or publication.

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Figure 2. This 5.63 ct star apatite was sold as aquamarine. Photo by K. Sieber.

Star apatite—first occurrence in the gem world. At the 2004 Tucson gem shows, one of these contributors (MPS) purchased a few stones represented as star aquamarine from an Indian company based in Bangkok. The gems reportedly came from India or Sri Lanka.

Although chatoyant aquamarine is relatively common, aquamarine with a four- or six-rayed star is very rare (see J. Hyršl, "Some new unusual cat's-eyes and star stones," *Journal of Gemmology*, Vol. 27, No. 8, 2001, pp. 456–460). Two of the so-called star aquamarines appeared somewhat different, prompting further examination.

The two medium brownish green cabochons (5.63 and 6.65 ct) were examined at the German Gemmological Institute (EPI). Under spot illumination, they showed four distinct rays (e.g., figure 2). Standard gemological testing gave a spot RI of 1.64 and an SG of 3.18. Neither reading fit aquamarine, and the Mohs hardness of 5 (tested on the back of the cabochons) showed that they were softer than beryl. With the handheld spectroscope, a clear absorption doublet in the yellow region was visible. In the polariscope, the specimens were transparent enough to show a uniaxial optic figure. Colorless to yellowish green dichroism was fairly strong. These properties identified the two samples as apatite.

With magnification, it was apparent that a parallel network of narrow, irregularly shaped tubes and perpendicularly oriented tiny cracks were responsible for the asterism (figure 3). To further characterize these unusual apatites, energy-dispersive X-ray fluorescence spectroscopy (EDXRF) and Raman analyses were performed on both stones by the SSEF Swiss Gemmological Institute in Basel. EDXRF detected major amounts of Ca and P, with traces of Cl. This result pointed to apatite-(CaCl), formerly known as *chlorapatite*. Raman analysis confirmed the identification, with distinct peaks at 1058, 1030, 963, 579, and 446 cm^{-1} that matched the reference spectrum for apatite.

Apatite occurs in a wide range of colors, such as white, yellow, green, blue, brown, violet, and black. While cat's-eye apatite has been found in Brazil, India, Russia, Sri

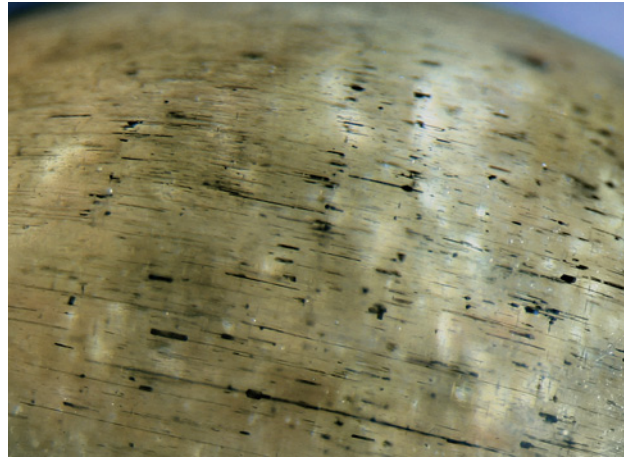


Figure 3. Parallel channel-like inclusions with irregular shapes and perpendicularly oriented tiny cracks are responsible for the asterism in the star apatite. Photomicrograph by K. Sieber; image width 8.8 mm.

Lanka, and Tanzania, to the best of our knowledge star apatite has not been previously reported.

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A chalcedony-opal cameo with remarkable inclusions. A cameo believed to be carnelian (red-orange chalcedony) was borrowed from the Dobrée Archaeological Museum in Nantes, France, for examination. The $\sim 2.7 \times 2.3$ cm gem, set in a gold tie pin, depicted the right profile of a bearded male figure with a headband (figure 4). Little is known of the cameo's history except that it appeared to be of classical Greek manufacture. The headband and background were brown in reflected light, while the rest of the carving was predominantly dark orange.

The RI, measured with some difficulty using the spot method, ranged from 1.53 to 1.55, a little low for chalcedony; the SG could not be determined because of the mounting. The cameo luminesced very weak greenish yellow to long-wave UV radiation and bright yellowish green to short-wave UV. While pure chalcedony is normally inert, this luminescence behavior is typical of uranium-bearing common opal, raising the possibility of a chalcedony-opal mixture.

To test this hypothesis, we obtained a Raman spectrum (using a Bruker RFS 100 Fourier-transform spectrometer) and compared it to that of a reference gray chalcedony. The positions of the sharp peaks were identical, but there was a broad underlying signal below the typical chalcedony peaks in the cameo spectrum. Subtracting the reference spectrum from the cameo pattern resulted in a signal with a broad band around 335 cm^{-1} and an even broader one around 3000 cm^{-1} , consistent with

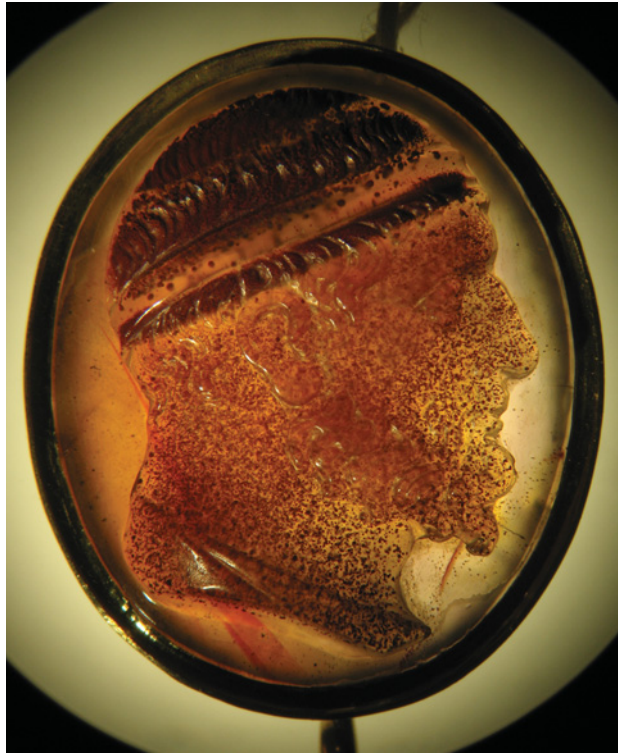


Figure 4. In transmitted light, this unusual chalcedony-opal cameo (~2.7 × 2.3 cm; Dobrée Archaeological Museum no. 927.1.1438) shows banding due to the variable density of near-spherical red-orange inclusions, probably hematite. Photomicrograph by E. Fritsch.

opal-CT. We performed additional luminescence analysis with a Jobin-Yvon Fluorolog 3 spectrometer with 315 nm excitation, and compared the cameo's emission spectrum to reference luminescence spectra for opal. The spectra had similar shape and peak positions at about 415 nm (intrinsic opal luminescence, never observed in chalcedony), 504, 524, 548, and 574 nm (uranyl emission in opal), further indication that the luminescence indeed originated from an opal component (E. Fritsch et al., "Luminescence of oxidized

porous silicon: Surface-induced emissions from disordered silica micro- to nano-textures," *Journal of Applied Physics*, Vol. 90, No. 9, 2001, pp. 4777–4782).

We therefore believe that the cameo was fashioned from a chalcedony-opal mixture, primarily the former, with the small opal component responsible for the luminescence behavior and slightly lower RI as well as the extra Raman signal. Chalcedony with similar luminescence is known from Mexico, but whether such material is actually a mixture with opal has not been determined (John I. Koivula, pers. comm., 2009).

The cameo was also remarkable for its inclusions. Although it was not apparent in reflected light, transmitted light demonstrated that the color zoning was due to variations in the density of red-orange, near-spherical inclusions (again, see figure 4). These likely consisted of hematite (see E. J. Gübelin and J. I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 2, Opinio Publishers, Basel, Switzerland, 2005, p. 360). They ranged from 0.01 to 0.4 mm in diameter, and some were striated like circled pearls. A few of the inclusions were flat with an empty core, causing them to appear crescent-shaped or circular (figure 5). Considering the size range of these inclusions, the hematite that formed them must have been quite finely divided, as shown by their red-orange (rather than metallic gray) appearance. The headband and background of the cameo contained very few inclusions, while the face and especially the hair layers were densely populated with them. A coloration by hematite inclusions is consistent with the carnelian-like appearance of the cameo.

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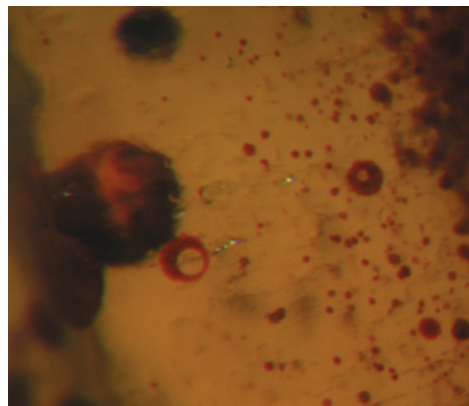
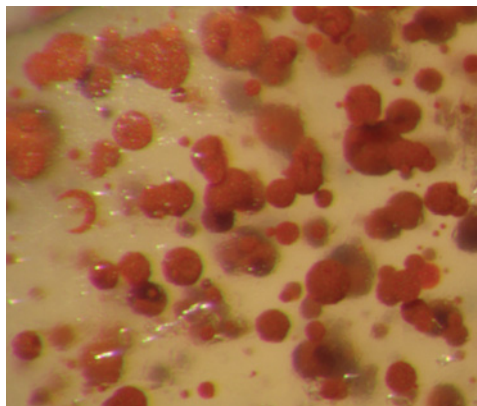


Figure 5. A few of the inclusions in the cameo are flat and lack a core, giving rise to a crescent-shaped (left) or circular appearance (right). Photomicrographs by E. Fritsch; magnified 180×.

Citrine from Andongologo, Madagascar. Deposits of natural citrine are not common, and most citrine is produced by heat treating amethyst. A new source of untreated citrine has been found in central Madagascar, at Andongologo, located 24 km southwest of Antsirabe at coordinates 19°59.510' S, 46°50.884' E. The deposit has been mined for rock crystal for a few years, but in February 2009 some new veins were found that contain citrine and smoky quartz. Using simple hand tools, 14 miners have excavated tunnels and shafts down to 15 m. So far, 300 kg of citrine have been produced.

The citrine is mined from quartz veins hosted by weathered Precambrian quartzites. The veins range up to 0.5 m wide, and locally contain cavities filled with prismatic crystals of smoky quartz and citrine. The crystals are well formed (some are doubly terminated) and range up to 30 cm long (e.g., figure 6). The crystal terminations and rims are smoky, whereas their core is brownish yellow. To this contributor's knowledge, quartz is the only mineral found in the cavities.

Much of the citrine is transparent, and this contributor is aware of faceted stones ranging from 30 to 385 ct from ~4,000 carats that have been cut. The color of the faceted stones varies from light-to-medium pale yellow to brownish yellow (e.g., figure 7). The material shows moderate dichroism, and RI measurements of 17 stones gave values of 1.544–1.553 (birefringence 0.009). No inclusions were seen in the cut samples examined.

Historically, the main source of citrine in Madagascar is located 110 km west of Antsirabe, on top of Bevitsika ("lots of ants") Mountain. The Bevitsika citrine is also hosted by quartz veins in Precambrian quartzites. For at least 20 years, large amounts of natural citrine and rock crystal have been mined there sporadically during the dry season (May to November). However, there has been no production at Bevitsika for the past two years.

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Figure 7. These faceted citrines from Andongologo weigh 83 and 138 ct. Photo by F. Danet.



Figure 6. The quartz from Andongologo (here, up to 25 cm long) typically has smoky outer zones and citrine cores. Some of the crystals are doubly terminated, as shown in the inset (30 cm long). Photos by F. Danet.

"Sugarcane Emerald" from Brazil. In 2007, some unusual beryl crystals (e.g., figure 8) were found during mining operations in northern Bahia State, Brazil, by John Papajohn and Cesar Menezes of JP International Rough Mining & Colored Gemstones Inc. (Campo Formoso, Bahia). The find occurred at 180 m depth and yielded ~1 tonne of material, including 600 kg of well-formed crystals. The company's five mines in the mountains of Serra de Jacobina at Carnaíba near Campo Formoso had previously produced mostly dark-colored emeralds and mineral specimens in mica schist. However, the material from this find was translucent bluish green, with white mottled veins and a bamboo stalk-like appearance. Many of the well-developed

Figure 8. These crystals of "Sugarcane Emerald" (104 and 77.6 g) were recovered from Bahia State, Brazil. Photo by H. Serras-Herman.





Figure 9. Some of the fashioned “Sugarcane Emerald” has been set into distinctive jewelry pieces such as this necklace, which features an 88.0 ct polished slice and 430.0 carats of beads, along with accents of black opal and fire opal. Designed, created, and photographed by H. Serras-Herman.

hexagonal crystals also showed pronounced whitish bands of hexagonal zoning. At first glance, the material resembled amazonite, but it had a higher polish luster due to beryl’s greater hardness.

JP International had most of the material fashioned into beads, as well as polished slices and carvings. Together with some crystal specimens, they debuted the gem material at the 2008 Tucson gem shows under the trade name “Sugarcane Emerald.” This contributor purchased some of the stones and incorporated them into a jewelry collection introduced at the 2009 Tucson shows (e.g., figure 9).

Although JP International has continued prospecting for similar material, so far no more of this beryl has been found. For now, the “Sugarcane Emerald” can be considered an oddity of nature, one of those rare gem occurrences perhaps never to be seen again.

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Orange kyanite from Tanzania. Kyanite derives its name from the Greek word for blue, due to its typical color. Gem-quality green kyanite has also been seen (e.g., Winter 2001 GNI, pp. 337–338), and colorless or yellow varieties have occasionally been faceted. Recently, however, orange

kyanite has appeared in the gem market. The material was mined at Loliondo, Tanzania, near the area that recently produced fine crystals of spessartine (see, e.g., Spring 2008 GNI, pp. 76–78).

Brad Payne of The Gem Trader (Surprise, Arizona) loaned GIA three faceted specimens (0.63–1.26 ct; figure 10) of this kyanite for examination. Additionally, one of these contributors (GRR) obtained two crystal fragments of orange kyanite, one from Loliondo and the other from Mautia Hill, Kongwa, also in Tanzania (again, see figure 10). The latter sample was procured in the late 1980s; both were polished on parallel sides for spectroscopy.

Examination of the cut stones gave the following properties: color—medium yellow-orange to yellowish orange; pleochroism—weak yellow-orange and yellowish orange; RI— $n_{\alpha} = 1.718$ and $n_{\gamma} = 1.734$ – 1.735 ; birefringence— 0.016 – 0.017 ; optic sign—biaxial negative; hydrostatic SG— 3.69 – 3.73 ; no UV fluorescence or Chelsea filter reaction; and a line observed at ~ 550 nm, plus a band at ~ 460 – 500 nm, seen with the desk-model spectroscope. The RI and SG values were similar to the upper ranges for blue/green kyanite given by M. O’Donoghue, Ed. (*Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, p. 422). All of the observations are also consistent with those presented by J.-M. Arlabosse for orange kyanite from Loliondo (“Kyanite orange Tanzanie,” *Gemmologie FlashData*, No. 35, www.geminterest.com/articlist.php, Dec. 9, 2008). Microscopic examination of the cut stones revealed cleavage fractures, globular-to-angular brown rutile crystals, rounded colorless high-relief zircon crystals, and globular colorless low-relief crystals of mica (probably muscovite) and quartz—all identified by Raman analysis.

The two polished fragments gave the following properties: color—light yellow-orange (Mautia Hill) and medium yellowish orange (Loliondo); and no UV fluorescence or Chelsea filter reaction. With the desk-model spectroscope,

Figure 10. These kyanites from Tanzania have a distinctive orange color. The faceted stones (0.63–1.26 ct) are from Loliondo, and the polished fragments are from Loliondo (left, no. CIT15871) and Mautia Hill (bottom center, no. GRR544). Photo by Kevin Schumacher.



a line was observed in the Loliondo sample at ~550 nm, with extinction below ~500 and above ~680 nm; no features were seen in the Mautia Hill sample. Rutile, zircon, (both confirmed by Raman analysis) and mica/quartz inclusions were also noted in the Loliondo sample.

UV-Vis-NIR spectroscopy of the polished fragments (figure 11) indicated that their orange color resulted from a transmission window with minima at approximately 645–755 nm; the adjacent absorption bands arise from Mn³⁺. The Mautia Hill sample—which displayed a lighter, yellower bodycolor—showed a similar, but lower-amplitude, absorbance trace compared to the Loliondo sample. Narrow peaks at ~380, 433, and 447 nm in the Mautia Hill spectra were due to Fe³⁺.

Laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) analysis of both slabs by GIA research scientist Dr. Mike Breeding confirmed manganese as the cause of color. The Mn concentration of the Loliondo sample (CIT15871) was ~10 times higher than that of the Mautia Hill specimen (GRR544; table 1). Iron content was similar in the two samples, but slightly greater in the one from Loliondo. A third orange kyanite—no. GNI555, a light-to-medium yellowish orange Loliondo crystal donated to GIA by Werner Radl (Mawingu Gems, Niederwörresbach, Germany)—was also analyzed. The concentrations of all elements except Fe in this specimen fell between those for Mautia Hill and the Loliondo sample.

In the mid-1970s, small crystals of orange-yellow kyanite were synthesized in experiments using Mn³⁺ in the form of Mn₂O₃ in conjunction with SiO₂ and gem-quality andalusite (a polymorph of kyanite; I. Abs-Wurbach and K. Langer, “Synthetic Mn³⁺-kyanite and viridine, [Al_{2-x}Mn_x³⁺]SiO₅, in the system Al₂O₃–MnO–MnO₂–SiO₂,” *Contributions to Mineralogy and Petrology*, Vol. 49, 1975, pp. 21–38). That research supports our observations, which indicate that Mn³⁺ is the chromophore responsible for the orange color of these Tanzanian kyanites.

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TABLE 1. Average trace-element composition by LA-ICP-MS of orange kyanite from Tanzania.^a

Sample	Locality	Mg	Ti	Cr	Mn	Fe	Zn	Ga
CIT15871	Loliondo	72.9	4.2	35.8	1893	3547	bdl	8.8
GNI555	Loliondo	62.1	8.5	22.2	655	4167	bdl	11.1
GRR544	Mautia Hill	29.4	12.4	bdl	190	3207	2.0	13.6

^a Values expressed in parts per million by weight, and collected using a Thermo X-Series II ICP-MS equipped with a New Wave 213 nm laser-ablation system. Parameters used were 40 μm spot size, 7 Hz repetition rate, and ~10 J/cm² laser fluence. The values represent the average of three spots (CIT15871 and GRR544) or two spots (GNI555). Abbreviation: bdl = below detection limit.

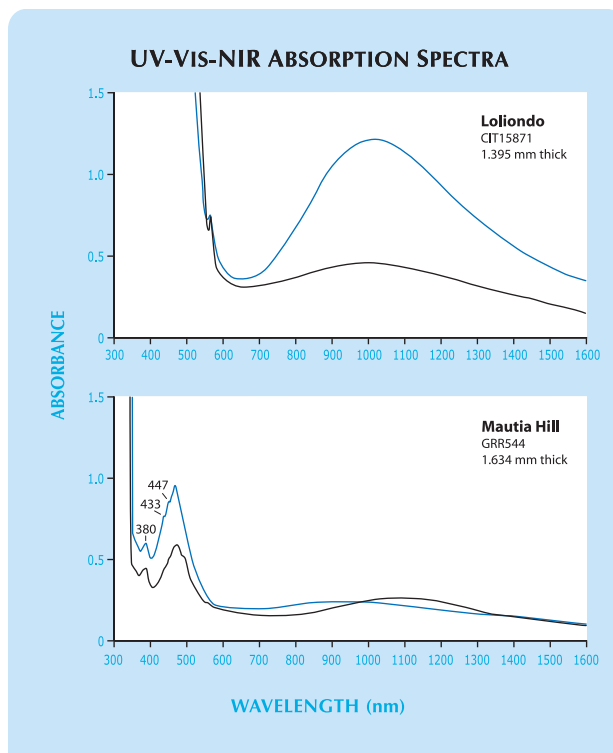


Figure 11. UV-Vis-NIR spectra of the polished fragments of orange kyanite show a transmission window at ~645–755 nm, which accounts for their orange color. The window is defined by Mn³⁺ absorption bands on either side. Also present in the Mautia Hill sample are some minor features at ~380, 433, and 447 nm due to Fe³⁺. The two spectra display two polarizations that correspond, approximately, to the Y=β (black lines) and Z=γ (blue lines) orientations.

Rare optical phenomenon in play-of-color opal. We recently examined a 4.43 ct oval cabochon of translucent white play-of-color opal provided by Francesco Mazzero (Opalinda, Paris, France). The stone came from the new Wegel Tena deposit in the Welo Province of Ethiopia (see Spring 2009 GNI, pp. 59–60). Typical play-of-color opal displays patches of pure spectral colors that result from the diffraction of visible light by the network of silica spheres (E. Fritsch and G. R. Rossman, “An update on colors in gems, part 3: Colors caused by band gaps and physical phenomena,” Summer 1988 *G&G*, pp. 81–102). This sample, however, displayed several discrete spots of spectral colors that were distributed across the entire stone (figure 12). The effect was seen most clearly when a point (e.g., fiber optic) light source was used; the colored spots moved together around the stone as the light source changed position. This phenomenon is best seen in a video, available at <http://gemnantes.fr/recherche/opale/index.php#reciproque>. Even more interesting, the color of each spot progressively changed (e.g., from yellow to red) with the position of the illumination—sometimes very slightly, sometimes noticeably. Since the cabochon was poorly cut, the spots

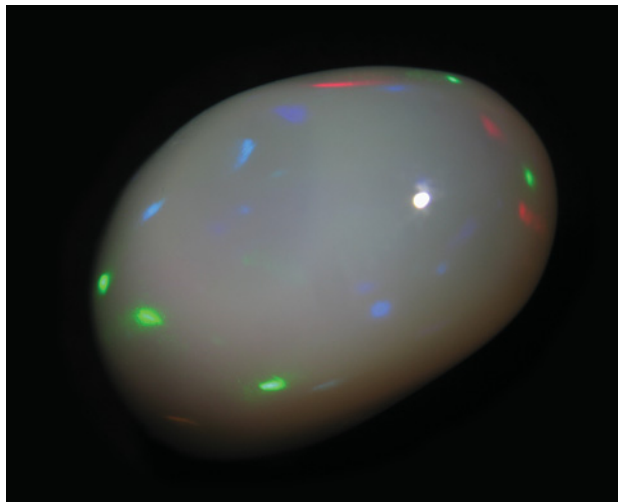


Figure 12. Rather than showing immobile patches of pure spectral colors, this unusual opal cabochon ($15 \times 7.5 \times 6$ mm) diffracts visible light as colored spots moving with the point light source (the source's reflection is visible as the white spot). Photo by B. Rondeau.

sometimes stretched into small patches over a flatter area.

According to diffraction theory, radiation diffracting on a perfect network should produce spots. Hence, for a perfect network of silica spheres constituting opal, one would expect diffraction of visible light to produce discrete colored spots—which is what we observed in this sample. For those interested in physics, this corresponds to the physical expression of the reciprocal lattice (see, e.g., http://en.wikipedia.org/wiki/reciprocal_lattice). Typically, however, the opal network is not regular enough to show this effect; instead, the spots spread out to become color patches. Each patch corresponds to small domains in which a single spot is stretched through deformation or

Figure 13. These attractive variously colored cultured pearls (up to 14.7 mm in diameter) are from Vanua Levu in Fiji. Courtesy of Gerhard Hahn Pearl AG.



irregularities in the network, and therefore represents an “average” direction of diffraction. The orientation of the network varies from one patch to the next. No matter what an opal looks like, the rules of diffraction remain the same.

The extraordinary optical phenomenon we report here is very rarely observed. It implies a perfect network extending throughout the entire stone (that is, over a centimeter), and hence a very regular stacking of spheres over a relatively large distance. This is only possible in a formation environment that is geologically very quiet.

Emmanuel Fritsch and Benjamin Rondeau

Cultured pearls from Fiji. At the BaselWorld Watch and Jewellery Show in April 2008, Gerhard Hahn Pearl AG (Düsseldorf, Germany) displayed some variously colored cultured pearls (figure 13) from a relatively new source, the South Pacific island nation of Fiji. So far, Fijian production has been limited, coming from two pearl farms located ~60 km apart on the island of Vanua Levu, in Savusavu Bay and Buca Bay. The cultured pearls are harvested from *Pinctada margaritifera* oysters, which are grown from spat collected in waters of the Savusavu area. The oysters are implanted with round bead nuclei (minimum 7.5 mm in diameter) and harvested 12–18 months later. They average 10.8 mm in diameter at first harvest (i.e., before reinsection of beads for a second harvest). They mostly range from light bluish green to the popular “chocolate” brown, and Gerhard Hahn Pearl AG indicated that their colors do not result from treatment; only standard post-harvest processing such as cleaning is performed.

Up to 65% of the production show lighter colors than those that are typical of *P. margaritifera* cultured pearls. Since some resemble bleached *P. margaritifera* products (see, e.g., Summer 2008 Lab Notes, pp. 159–160), Gerhard Hahn Pearl AG donated 20 samples to GIA for documentation purposes, and they were studied at the New York Laboratory by Akira Hyatt and Dr. Wuyi Wang.

Based on GIA’s examination over the years of many thousands of *P. margaritifera* cultured pearls, the broad range of bodycolors in this relatively small sample set was remarkable. The hues ranged from blue and green (cool hues) to orange and yellow (warm hues), with many samples showing strong saturation. *P. margaritifera* cultured pearls typically occur in the cooler hues, with darker tones showing higher saturation and lighter tones showing lower saturation. In contrast, those from the *Pinctada maxima* oyster typically show warm hues, with higher saturation in the lighter tones and lower saturation in the darker tones. The Fijian cultured pearls were split between warm and cool hues, and many of the cool hues exhibited a lighter tone, often with relatively high saturation. Some also exhibited colors generally seen in *P. maxima* cultured pearls (i.e., yellows, but with darker tone and stronger saturation), while others resembled treated “chocolate” pearls (orangy/pinkish browns) from *P. margaritifera*. (Note that in lower saturations, warm hues appear brown or brownish, while cool hues appear gray or grayish.) The

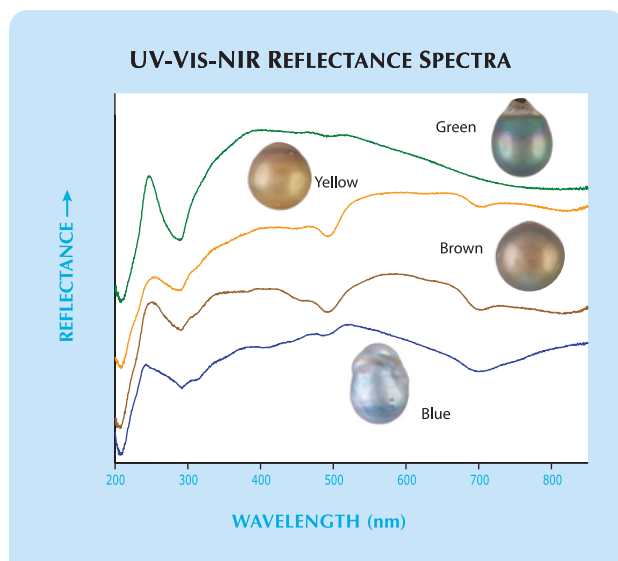


Figure 14. The shells of the *P. margaritifera* oysters that are used to produce the Fijian cultured pearls show a diversity of colors. Courtesy of J. Hunter Pearls.

diverse color range of the cultured pearls is also seen in the host *P. margaritifera* shells (e.g., figure 14).

UV-Vis-NIR reflectance spectra are given in figure 15 for four categories of the Fijian cultured pearls: brown (five samples), yellow (seven), green (five), and blue (three). The brown samples showed decreases in reflectance due to absorptions at 290, 495, and 700 nm—believed to be related to organic pigments—that were superimposed on a nearly flat background. These spectral features are similar to those of naturally colored brown Tahitian cultured pearls. The absorptions at 290, 495, and 700 nm were also distinct for the yellow samples, but the overall spectra were sloped toward lower wavelengths. The absorptions at

Figure 15. UV-Vis-NIR reflectance spectroscopy of brown, yellow, green, and blue cultured pearls from Fiji indicated that all these colors are natural. Photos by Sood Oil Chia.



495 and 700 nm were very weak in the green samples, but the 295 nm band was consistently strong. In addition, the slope of the spectra in the 400–700 nm region for the green samples was opposite that of the yellow samples. In the blue cultured pearls, the three bands related to organic pigments were clearly observed, and in general the reflectance increased with decreasing wavelength. The spectroscopic data indicate that all of the tested cultured pearls were of natural color. X-radiography showed that they were bead cultured, as represented by Gerhard Hahn Pearl AG.

The Fijian farms together produce ~40,000 cultured pearls (or 125 kg) yearly and have ~100,000 oysters under cultivation. The farms are operated by the J. Hunter Pearls Fiji Pearling Conservancy under the country's Environmental Code of Practice, to ensure that any negative environmental impact is minimized.

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Rare necklace made of natural pearls from different mollusks. The Gübelin Gem Lab recently received a necklace consisting of 29 larger pearls and numerous smaller pearls and diamonds for routine gemological identification (figure 16). Ten of the larger pearls were “cream” colored, and 19 were various shades of purple; they were near-spherical to button to baroque shaped, and they ranged from 4.6 to 20.7 mm in longest dimension. Five of the purple pearls had a nacreous appearance, while all the others were porcelainous. Ultraviolet fluorescence, Raman spectra, spot refractive index readings, EDXRF chemical data, and microscopic characteristics of all samples were consistent with saltwater pearls. The natural origin of these pearls was indicated by the fact that they originated from mollusks that are not used for cultivation.

One of the cream-colored pearls showed a flame structure, as observed in pearls produced by mollusks such as *Tridacna* species and Veneridae family bivalves, as well as by some gastropods. The nine other cream-colored pearls did not reveal any structure, as was the case for the Veneridae pearls described in the Winter 2008 GNI section (pp. 374–375), as well as for natural pearls from other mollusks.

Five of the 19 purple pearls revealed a honeycomb structure in the microscope (figure 17). Raman spectra showed aragonite peaks, along with bands at about 1520 and 1130 cm^{-1} due to a mixture of polyacetylenic pigments. To our knowledge, purple-hued pearls with these color, structure, and Raman characteristics only come from bivalves belonging to the Veneridae family. Four other purple pearls of comparable shape and color had similar Raman spectra; however, they did not show a honeycomb structure, as also documented in Veneridae pearls (see GNI entry cited above). These observations suggest that nine of the 19 colored pearls were from Veneridae family mollusks.

Five of the remaining 10 purple pearls had a nacreous structure (figure 18), but they lacked strong overtones. This is probably because the aragonite layers were thicker than is commonly observed in nacreous pearls, both natural and



Figure 16. This necklace contains 29 pearls (4.6–20.7 mm in largest dimension) that proved to be from at least two different mollusk families. Courtesy of Boghossian S.A., Geneva; photo by Evelyne Murer.

Figure 17. The honeycomb structure observed in this non-nacreous pearl can be attributed to a simple prismatic arrangement of aragonite formed by parallel and adjacent prisms that do not strongly interlock along their mutual boundaries. Photomicrograph by E. Erel; field of view ~3.0 mm high.



cultured. Raman spectra showed aragonite peaks, as well as bands at about 1490 and 1100 cm^{-1} . The positions of these bands suggest that this coloration is also due to a mixture of polyacetylenic pigments, but with a larger polyenic chain than has been documented in Veneridae pearls. To our knowledge, the only pearls with similar color, Raman spectra, and nacreous structure are those from the Mytilidae family. The other five purple pearls, which were non-nacreous, had similar Raman spectra. They also appear to originate from a mollusk of the Mytilidae family, as such pearls may have a porcelain-like appearance.

To our knowledge, this is the first time that mixed purple-hued pearls from the Veneridae and Mytilidae families have been observed in the same necklace. A combination of classical and advanced gemological analysis appears to be a promising approach for the identification of the mollusk family to which a pearl belongs.

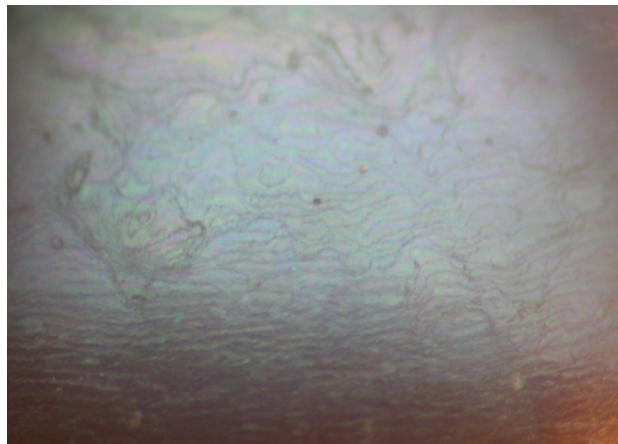
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Colorless petalite and pollucite from Laghman, Afghanistan.

Farooq Hashmi (Intimate Gems, Jamaica, New York) recently loaned GIA three colorless stones (figure 19), which he believed to be petalite (14.98 ct) and pollucite (11.30 and 12.10 ct) from Laghman Province, Afghanistan. He purchased the rough in Peshawar, Pakistan, between 2007 and 2008. The stones were reportedly byproducts of pegmatite mining for tourmaline and other gems. Mr. Hashmi said he saw several kilograms of both gem materials in the Peshawar market, but he understands from local gem dealers that neither of them is being actively mined.

Petalite and pollucite are both known to be hosted in lithium-rich granitic pegmatites, and they have a Mohs hard-

Figure 18. Nacreous structures on this pearl form a layered aragonitic structure consisting of polygonal to rounded tablets arranged in broad, regularly formed parallel sheets. Photomicrograph by E. Erel; field of view ~3.4 mm high.



ness of 6.5. Petalite (also known as castorite) is a lithium aluminum tectosilicate ($\text{LiAlSi}_4\text{O}_{10}$) and a member of the feldspathoid group. An important lithium ore, it occurs with spodumene, lepidolite, and tourmaline in tabular crystals and columnar masses that range from colorless to gray and yellow. Pollucite, $(\text{Cs},\text{Na})[\text{AlSi}_2\text{O}_6] \cdot n\text{H}_2\text{O}$, is a zeolite that forms a solid-solution series with analcime and commonly occurs with quartz, spodumene, petalite, and tourmaline, among other pegmatite minerals. Isometric crystals ranging from colorless to white and occasionally pale pink can be found, though well-formed examples are rare.

Standard gemological testing produced the following properties (with those of petalite listed first, then the 11.30 and 12.10 ct pollucites, respectively): RI—1.505–1.515, and 1.518–1.519 or 1.517–1.518; birefringence—0.010 and 0.001 (pollucite can be weakly anisotropic); SG—2.40 and 2.90; UV fluorescence—all three samples were inert to both long- and short-wave UV radiation. No bands or lines were observed with the desk-model spectroscope. Microscopic examination of the petalite only revealed two feathers. No inclusions were observed in the 12.10 ct pollucite, but the 11.30 ct stone contained colorless inclusions of pollucite (identified by Raman spectroscopy) and a plane of crystals in the pavilion (figure 20) that had a Raman pattern similar to that of muscovite.

EDXRF analyses of the petalite showed major amounts of Si and Al, and traces of Fe, Ge, Cs, and Sm. Analyses of the pollucite samples revealed major Si, Al, and Cs, low amounts of Rb, Rh, Yb, and La, and traces of Ti.

We performed infrared (see *G&G* Data Depository) and Raman spectroscopy to further characterize these unusual stones. The IR spectra for the petalite showed bands at ~ 3358 , 3270.6 , 3037 , and 2591 cm^{-1} , and broad absorption below $\sim 2390 \text{ cm}^{-1}$. The IR spectra for the pollucite samples showed a band at $\sim 4720 \text{ cm}^{-1}$ and broad absorption between ~ 5321 and 5162 , ~ 4141 and 3140 , and below $\sim 2325 \text{ cm}^{-1}$. The Raman spectra matched

Figure 20. The 11.30 ct pollucite sample contained a plane of inclusions. The larger ones gave a Raman pattern similar to that of muscovite. Photomicrograph by J. Darley; magnified 40 \times .



Figure 19. These unusual colorless gems are petalite (14.98 ct, left) and pollucite (11.30 and 12.10 ct, center and right), reportedly from Laghman Province, Afghanistan. Faceted by Robert C. Buchannan, Hendersonville, Tennessee; photo by Robert Weldon.

those of petalite and pollucite in our Raman database.

A pink cat's-eye petalite from South Africa (Winter 1986 Lab Notes, pp. 239–240) had properties similar to the colorless petalite from Afghanistan, except for its dull red fluorescence to UV radiation and its lower SG (2.34). Both the petalite and pollucite we studied had properties analogous to those reported by M. O'Donoghue (*Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 436–438), although the birefringence of petalite was slightly higher (0.013) in that publication.

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Serpentine cat's-eye. Recently, the Gem Testing Laboratory in Jaipur, India, had the opportunity to examine an unusual opaque bluish green cabochon (36.63 ct; figure 21) that had a broad but distinct chatoyant band. The color, greasy-to-dull luster, and low heft suggested it was serpentine.

Standard gemological testing gave the following results: spot RI—approximately 1.57 with no distinct birefringence blink; hydrostatic SG—2.60; fluorescence—weak yellow to long-wave UV; and absorption spectrum—weak bands in the green ($\sim 490 \text{ nm}$) and blue ($\sim 460 \text{ nm}$) regions seen with the desk-model spectroscope. In addition, the luster indicated low hardness, which was confirmed by scratching with a fluorite crystal on an inconspicuous part of the sample. These properties are consistent with those reported for serpentine (e.g., R. Webster, *Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, UK, 1994, pp. 369–372).

Serpentine is a common ornamental stone that is sometimes used as an imitation of jadeite and nephrite because of its similar aggregate structure and color appearance. It is usually seen in variable hues of blue, green, and yellow. It comprises species such as antigorite, chrysotile, and lizardite, and varieties such as bowenite, williamsite, and ricolite. Chatoyant serpentine, however, is quite rare. "Satellite," a fibrous variety exhibiting chatoyancy, has been reported from Maryland and California in the U.S. (Webster, 1994) and from Sichuan Province in China (B.-q. Lu et al., "Infrared absorption spectra of serpentine cat's eye



Figure 21. This bluish green cat's-eye cabochon (36.63 ct) proved to be serpentine. Photo by G. Choudhary.

from Sichuan Province of China," *Journal of Shanghai University*, Vol. 9, No. 4, 2005, pp. 365–368).

When the cabochon was examined with a microscope, thin parallel planes were visible. These appeared to be composed of fine films oriented perpendicular to the chatoyant band (figure 22, left), and were thus responsible for the cat's-eye effect. In addition, a few scattered brown dendritic crystals (figure 22, right) and white cloudy patches were present; this contributor has previously observed such inclusions in serpentine.

Because serpentine is a hydrous material, the FTIR spectrum in the 6000–400 cm^{-1} range exhibited complete absorption from 4500 to 400 cm^{-1} and there were two bands around 5000 and 4700 cm^{-1} . This pattern was similar to those of serpentine samples in our reference database. EDXRF analyses revealed the presence of Mg, Si, Cr, Fe, and Ni, which is consistent with the elements expected to be detected in serpentine.

This was the first time this contributor has encountered this rare variety of serpentine. The origin of this specimen is not known.

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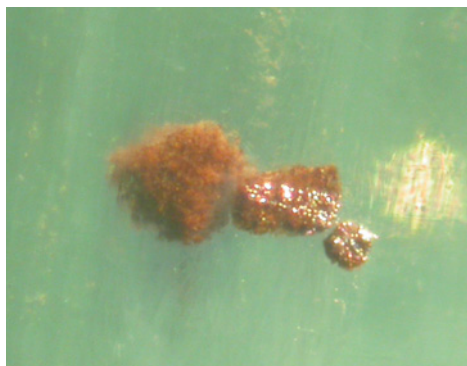
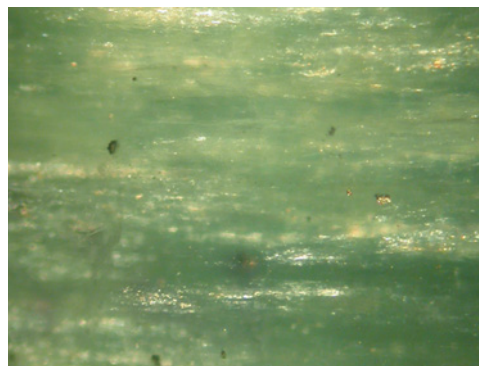


Figure 22. Parallel planes consisting of fine films were responsible for the chatoyancy of the stone in figure 21 (left). Brownish dendritic crystalline inclusions were also present (right); these are commonly seen in serpentine. Photomicrographs by G. Choudhary; magnified 30 \times and 45 \times .

Zircon mining in Cambodia. In April 2009, these contributors visited Ratanakiri (or Rattanakiri, Rotanah Kiri) Province, Cambodia, ~600 km by road northeast of Phnom Penh. Ratanakiri is the world's major source of fine heated blue zircon. Blue is not known to occur naturally in zircon, but heat treatment of brown to reddish brown material from Indochina will produce light blue stones, and many gem enthusiasts believe that the finest blue colors are produced by heating the dark brown material from Ratanakiri (e.g., figure 23). It is likely that these deposits were not exploited until the early 20th century, when the potential for this heat treatment was discovered.

The zircon is found in an area of extensive volcanism consisting of flood basalts and scattered volcanic cones. Zircon-bearing alkaline basalts are confined to the intersection of brittle crustal structures, so the occurrences are small and discontinuous. We were told by a local zircon dealer that there are more than 100 deposits in Ratanakiri, but because the gem-bearing areas are small and remote, and many are worked seasonally, it is difficult to determine the number of miners or the annual production of zircon. We saw about 70 active shafts in the four small mining areas we visited, each employing two to four people. We estimate that those four mining areas produced about 500 g of gem-grade material per day during our visit.

Mining is performed by sinking a shaft through the overburden to the zircon-bearing horizon, which lies 2–15 m below the surface (figure 24, left). In some mines, the basalt has decomposed to loose red soil, and the gems can be separated by combing through the excavated earth by hand. In others, basalt cobbles remain as gravel, and the material must be washed (figure 24, right).

In addition, since 2005, the Cambodian government has granted three large concessions—totaling 19 km^2 —in Ratanakiri: Ultra Marine Kiri Co. Ltd., Seoul Digem (Cambodia) Co. Ltd., and Ratanak Chhorpoan (Cambodia) Ltd. We visited the first two, but both were inactive.

The gems we saw during our visit consisted almost exclusively of zircon that ranged from nearly colorless to dark brown, and was occasionally reddish brown. Many crystals showed remnants of their tetragonal shape, and

most had a shiny “melted” surface (again, see figure 23) from partial resorption during transport in the basalt. A significant portion also exhibited tenebrescence: After being kept in darkness for several days, they were a bright orange to red that changed to brown with several minutes’ exposure to sunlight. This photochromism is reversible and repeatable. The rough generally weighed 0.1–5 g, although we saw non-gem-grade specimens up to 100 g. Rough that will produce clean gems in excess of 10 ct is unusual, although cut stones larger than 100 ct are known.

Most of the rough is sent to Phnom Penh or Thailand for heating and cutting, although some is processed in Ratanakiri. The stones are heated in a reducing atmosphere at 900–1000°C for ~1 hour. Almost all brown zircon from this source will turn blue with heating (e.g., figure 25); a light blue color can sometimes be produced from stones that were originally colorless.

Additional images from this expedition are available in the *G&G* Data Depository.

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Figure 23. These rough zircons were recovered from Ratanakiri Province, Cambodia. The blue rough (up to 7 g) was produced by heating brown stones such as those on the left (up to 24 g). Photo by Prasit Prachagool.



Figure 24. The best-known Cambodian zircon deposit is at Bo Keo (left), where there are ~30 active mines. The shafts in this region are typically about 15 m deep. At Bo Kalap (below), there are ~10 active pits; the excavated material contains basalt cobbles and requires washing to recover the zircon. Photos by M. H. Smith.





Figure 25. With heat treatment, most Ratanakiri zircon turns blue. The large emerald cut weighs 30.45 ct. Courtesy of Thai Lanka Trading.

CONFERENCE REPORTS

GIT 2008. After being postponed in December 2008 due to political unrest in Bangkok, the second Gem and Jewelry Institute of Thailand (GIT) conference, GIT 2008, was held March 9–12, 2009. Some 500 participants attended the two-day conference, which was followed by a two-day field trip to Kanchanaburi and the Bo Phloi sapphire mine. Parallel sessions saw 50 speakers, and there were approximately the same number of posters on display. Only selected oral presentations are mentioned in this report, since these authors were unable to attend all sessions. The conference proceedings (extended abstracts) are available in book or CD-ROM format by contacting the GIT at www.git.or.th.

After the opening ceremony, hosted by GIT Director **Dr. Wilawan Atichat** and Thai Deputy Minister of Commerce **Alongkorn Ponlaboot**, the conference started with three keynote speakers. **Vichai Assarasakorn**, president of the Thai Gem and Jewelry Traders Association, gave an impressive overview of the Thai gem and jewelry business. He was followed by **Massimo Zucchi** (Studio Zucchi Design, Milan, Italy), who discussed globalization and branding, and **Dr. Joerg Fischer-Buehner** (Legor Group SRL, Bressanvido, Italy), who lectured on palladium casting for jewelry.

Strategic marketing in emerging markets was discussed by **Dr. Kritinee Nuttavuthisit** (Chulalongkorn University, Bangkok), and the new era of jewelry design in Thailand was reviewed by **Dr. Veerawat Sirivesmas** (Silpakorn University, Bangkok). One of these contributors (**LK**) presented an overview of the Tom Lantos JADE Act, its implications for the trade, and possible alternative ruby sources.

Hyun Min Choi (Hanmi Lab, Seoul, Korea) examined photoluminescence characteristics of HPHT-processed natural type IIa diamonds. **Dr. Walter Balmer** (Chulalongkorn University) gave a presentation on behalf of Swiss gemologist **George Bosshart**, who was unable to

attend. Mr. Bosshart's research focuses on distinguishing natural from artificially colored green diamonds; the presentation introduced the properties of untreated green diamonds and the natural radiation mechanisms that produce this color.

An interesting report on rubies from Fischenæsset, Greenland, was given by **Pornsawat Wathanakul** of GIT (for **Greg Davison** of True North Gems, Vancouver, British Columbia, Canada, who could not attend). A pair of garnet lectures was given by **Dr. Karl Schmetzer** (Petershausen, Germany) and GIT's **Dr. Visut Pisutha-Arnond**. **Dr. Claudio Milisenda** (German Gemmological Association, Idar-Oberstein) reported on his study of red labradorite-andesine feldspars and offered some promising results based on FTIR data on the distinction of treated versus untreated stones. A thought-provoking talk about experimental heating of Cu-bearing tourmaline was given by **Thanong Leelawatanasuk** (GIT). **Boontawe Sripasert** (Department of Mineral Resources, Bangkok) discussed heat-treatment experiments on red spinel from Myanmar. **Dr. Chakkaphan Sutthirat** (Chulalongkorn University) gave an introduction to heat-treatment experiments on sapphire from the Awissawella deposit in Sri Lanka. **Dr. Ahmadjan Abduriyim** (Gemmological Association of All Japan—Zenhokyo, Tokyo) presented his findings on treated green amber.

The SSEF Swiss Gemmological Institute's **Dr. Michael Krzemnicki** described modern, portable instruments for advanced testing in the gemological laboratory, including UV-Vis and laser-induced breakdown spectrometers. **Dominic Mok** (AGIL Ltd., Hong Kong) gave a controversial lecture on advanced testing of jadeite jade (called *Fei Cui* by the Chinese). After describing the different colors of jadeite, he mentioned that kosmochlor and omphacite are also called *Fei Cui* in the Chinese market. This brought strong reactions from some attendees, as these two materials are considered much less valuable than true jadeite.

Dr. Henry Hänni (SSEF) delivered an overview of the different types of cultured pearls, and **Kenneth Scarratt** (GIA Thailand) discussed nautilus pearls.

After the conference, the two-day field trip took approximately 80 participants to the Bo Phloi gem field about 170 km northwest of Bangkok. The field lies within Quaternary sediments and covers an area of about 1200 km². The largest sapphire deposit in Thailand's western region, it is operated by SAP Mining Co. Ltd. as an open-pit mine. The gem-bearing layers are 1–8 m thick at depths of 6–19 m. The gravel is brought to a washing site to concentrate the gem corundum before it is hand-sorted. In addition to sapphire, miners have recovered black spinel, black pyroxene, and red garnet.

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Sinkankas Spinel Symposium. The seventh annual symposium in honor of John Sinkankas took place April 18, 2009, at GIA in Carlsbad. Co-hosted by GIA and the San Diego Mineral and Gem Society, the sold-out event was attended by 152 people.

After opening remarks by convener **Roger Merk** (Merk's Jade, San Diego, California), **Si Frazier** (El Cerrito, California) reviewed historical spinels and noted that some of them were quite large, such as the ~400 ct red spinel that was set in Catherine II's (Russian) crown. **Edward Boehm** (Joeb Enterprises, Solana Beach, California) indicated that the ~500 ct Sumerian Spinel in the Iranian crown jewels most likely came from the old mines in present-day Tajikistan. He also illustrated how most famous "rubies" in royal and ecclesiastical regalia are actually spinels. If not for spinel, ruby would not have achieved the fame it enjoys today.

Dr. William B. "Skip" Simmons (University of New Orleans) covered the mineralogy and crystallography of the spinel group. Of the 22 spinel species recognized by the International Mineralogical Association, only one (spinel *sensu stricto*) is an important gem material. **Jennifer L. Stone-Sundberg** (Saint-Gobain Crystals, Washougal, Washington) reviewed the historical and contemporary growth of synthetic spinel. Today the material produced for gem use comes mainly from China and Russia; it can be identified by its higher RI values (for Verneuil- and Czochralski-grown products), inclusions (for flux-grown as well as the flame-fusion products), chemical composition, fluorescence, and Raman spectroscopy.

Jo Ellen Cole (Cole Appraisal Services, Vista, California) examined spinel pricing, and noted that there was a sharp increase in the cost of rough/cut material during 2000–2002; prices have continued to rise since then. **Bill Larson** (Pala International, Fallbrook, California) reviewed the main sources of spinel: Tajikistan (Kukh-i-Lal), Myanmar (Mogok and Nanyaseik), Sri Lanka, Vietnam (Luc Yen), and Tanzania (Morogoro, Tunduru, and Mahenge). The rare Colored blue spinel comes from Sri Lanka and Tunduru.

Meg Berry (Mega Gem, Fallbrook, California) illustrated the recutting of spinel, in which she improved lopsided, windowed, and damaged stones by keeping the original tables and paying attention to spinel's ~40° critical angle; major improvements in appearance were attained, with a cutting yield of 56%–76%. **Robert Weldon** (GIA, Carlsbad) provided suggestions for photographing spinel—applicable to other gems as well—that include using shallow depth-of-field to highlight interesting inclusions, positioning a reflector to help eliminate a "bow-tie" effect in problematic cuts, and, in asteriated stones, placing the reflection from a pinpoint light source in the center of the stars.

John Koivula (GIA, Carlsbad) reviewed the variety of internal features found in spinel, including mineral inclusions (e.g., rutile, carbonates, graphite, hematite, högbomite, Fe-sulfides, sphene, uraninite, and zircon) and fluid inclusions (both secondary and primary). He also noted that spinel forms inclusions in other gems, such as in sapphire and

grossular (hessonite) from Sri Lanka. **Dr. George Rossman** (California Institute of Technology, Pasadena) reviewed the primary causes of color in spinel: Cr³⁺ (pink-to-red), Co²⁺ (blue), and Fe³⁺ (usually with Fe²⁺; blue to green to lavender). Also, the following colorants have been used in synthetic spinel: Mn³⁺ (yellow), Cu²⁺ (blue), and Ti³⁺ (blue-green).

The theme of next year's Sinkankas Symposium (date to be determined) will be feldspar.

Brendan M. Laurs

ANNOUNCEMENTS

Gems issue of *Elements*. The June 2009 issue of the earth sciences magazine *Elements* focuses on key aspects of gemology: how gems occur in nature, the role of geochemistry in characterizing them, the challenge of non-destructively identifying faceted samples, the detection of treatments and synthetics, and the use of pearls and corals as organic gem materials. The issue's guest editors are *G&G* contributors Emmanuel Fritsch and Benjamin Rondeau. Visit www.elementsmagazine.org.

Responsible Jewellery Council announces Code of Practice. The Responsible Jewellery Council (RJC; formerly the Committee for Responsible Jewellery Practices) outlined its supply chain Code of Practice certification system at a March 25 news conference at the BaselWorld Fair. The RJC certifies mine-to-market activities in areas of sustainable mining practices, including fair wages, benefits to local communities, health and safety standards, ethical trading, and environmental respect. During the second half of 2009, the RJC will make independent auditors available to verify each member firm's adherence to Code of Practice standards and issue the appropriate certificate. The RJC has 85 members (including GIA) in the diamond and gold mining, manufacturing, and retailing sectors. More information can be obtained at www.responsiblejewellery.com.

ERRATA

The Spring 2009 article by F. Farges et al., "The French Blue and the Hope: New data from the discovery of a historical lead cast," contained the following errors.

1. The estimated error of the density of the lead cast on p. 13 should have been given as $11.2 \pm 0.1 \text{ g/cm}^3$.
2. The entries for footnotes *a* and *b* in table 1 on p. 10 were inadvertently switched, and the entry for footnote *b* is incorrect. Footnote *a* should read 1 grain, poids de marc $\approx 0.0531147 \text{ g} \approx 0.2655735 \text{ ct}$ (Lionet, 1820). Footnote *b* should read 1 *ligne* = 2.2558 mm (Morel, 1988).
3. The name of the company that performed the scanning, Matrix Diamond Technology, was incorrect.

Gem & Gemology regrets the errors.