COLORED STONES AND ORGANIC MATERIALS

Chondrodite from Mahenge, Tanzania. At the 2011 Tucson gem shows, Dudley Blauwet [Dudley Blauwet Gems, Louisville, Colorado] showed GIA some samples of chondrodite that were found near Mahenge, Tanzania, in early 2010. Chondrodite, \((\text{Mg,Fe}^{2+})_5\text{SiO}_4\text{F,OH})_2\), is a fairly rare monoclinic silicate mineral that typically occurs as small grains ranging from yellow to red and brown; well-formed crystals and gem-quality material are rare. Faceted chondrodite was previously reported from Tanzania, though from a different locality, Sumbawanga (see Winter 2007 Gem News International [GNI], pp. 377–378).

Mr. Blauwet was aware of ~100 g of rough material being produced at Mahenge, which consisted of small waterworn pebbles and larger broken fragments. He bought a few small samples in 2010, and the cut stones from this parcel yielded 121 pieces totaling 19.06 carats. Later, during the 2011 Tucson shows, he purchased about 50 g of clean rough. This parcel produced 99 cut stones totaling 55.57 carats. It included five gems weighing >1.5 ct; the largest one was ~2.0 ct.

Gemological examination by GIA in Tucson yielded the following properties from a 0.34 ct faceted sample (figure 1, left): RI—\(n_\alpha = 1.594\), \(n_\beta = 1.602\), \(n_\gamma = 1.621\); birefringence—0.027; optic character—biaxial positive; pleochroism—weak yellow to near colorless; UV fluorescence—inert to long-wave, and slightly chalky yellow to short-wave UV; and no lines visible with the desk-model spectroscope. Inclusions consisted of numerous transparent reflective particles and fine oriented short needles, some appearing rusty orange. Compared to the Sumbawanga chondrodite, the Mahenge material had a slightly higher RI, but the same birefringence. The needle-like inclusions were not seen in the Sumbawanga material.

Mr. Blauwet reported that, to his knowledge, no additional gem-quality chondrodite has been produced from Mahenge since 2010.

Blue dolomite from Colombia. Dolomite, a calcium-magnesium carbonate \([\text{CaMg(CO}_3\text{)}_2]\), is the second most important carbonate mineral after calcite. Although dolomite is sometimes used as an ornamental stone, it is rarely seen as a gem due to its low hardness [Mohs 3½–4] and lack of transparency. However, in late 2010, GIA was informed by Farooq Hashmi [Intimate Gems, Glen Cove, New York] about a new find of gem-quality blue dolomite from the famous Muzo emerald mine in Colombia. The
material was reportedly produced in mid-2010 from veins in black shale. Less than 2 kg of gem-quality rough were found, as crystals up to 2.5 cm across (mostly ~1 cm). Mr. Hashmi arranged for some of the rough material to be donated to GIA by Greg Turner (Sacred Earth Minerals, Asheville, North Carolina), and Brad Payne (The Gem Trader, Surprise, Arizona) also loaned a 1.13 ct oval brilliant (figure 2) for examination.

All of the samples were transparent light blue without any color zoning. Their gemological properties were consistent with dolomite, which was confirmed by Raman analysis. Microscopic observation revealed two- and three-phase inclusions with jagged edges (figure 3, left), along with other fluid and transparent crystalline inclusions. Healed feathers containing tiny crystals were found in most samples. A wavy strain pattern was observed with cross-polarized light. Dolomite’s high birefringence [0.180] was evident from the strong doubling. An albite inclusion, identified by Raman and LA-ICP-MS analysis, broke the surface of one rough sample (figure 3, right). Pyrite, commonly associated with dolomite at Muzo, was also seen on the surface of a few rough samples, all of which were rhombohedral twinned aggregates with reentrant corners. The surfaces also showed numerous etch features. One crystal contained three large, flat fractures parallel to rhombic faces, consistent with the perfect rhombohedral cleavage of dolomite.

A UV-Vis spectrum of the cut stone revealed Fe$^{3+}$ absorption bands at 450, 460, and 470 nm, along with a large broad band centered at ~580 nm. Qualitative EDXRF spectroscopy detected Ca and Mg, as well as traces of Fe and Mn. LA-ICP-MS analysis revealed many additional trace elements, including Sc, Ti, V, Cr, Ni, Zn, Sr, Y, and rare-earth elements. A pure dolomite crystal is expected to be colorless, and the blue color shown by this Colombian material may be due to natural radiation. Blue color in carbonate minerals (i.e., calcite) that contain twinning and dislocations is thought to be related to natural radiation (T. Calderon et al., “Relationship between blue color and radiation damage in calcite,” Radiation Effects, Vol. 76, 1983, pp. 187–191, http://dx.doi.org/10.1080/01422448308209660).


Figure 2. This 1.13 ct oval brilliant is a rare blue dolomite from the Muzo mine, Colombia. Photo by Brad Payne.

Figure 3. The dolomite contained tiny jagged three-phase inclusions associated with other fluid inclusions (left, magnified 110×). An albite inclusion broke the surface of one rough dolomite sample (right, magnified 80×). Photomicrographs by K. S. Moe.
we believe this is the first report of blue dolomite being used as a gemstone.

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Fluorite from Namibia. The Klein Spitzkoppe area in Namibia is known as a source of attractive crystals of topaz, aquamarine, and other minerals from miarolitic cavities [see, e.g., B. Cairncross et al., “Topaz, aquamarine, and other beryls from Klein Spitzkoppe, Namibia,” Summer 1998 G&G, pp. 114–125]. In mid-2011, GIA was informed by Jo-Hannes Brunner (Pangolin Trading, Windhoek, Namibia) about a new find of fluorite located several kilometers from Klein Spitzkoppe toward the Khan River. The material shows distinctive color zoning and inclusions, and Mr. Brunner reported that only a small amount has been mined so far. He indicated that a few dozen polished slabs have been produced in sizes up to 10 cm in longest dimension, and some of them have been set in silver pendants [e.g., figure 4]. Mr. Brunner donated to GIA one polished slab (89.47 ct, or 37.05 × 39.75 × 5.60 mm) and seven rough pieces of this fluorite (9.83 to 45.97 g) for examination.

Gemological examination of the slab revealed the following properties: RI—1.434; hydrostatic SG—3.12; Chelsea filter reaction—none; fluorescence—inert to long-wave UV radiation, and weak yellow to short-wave UV in the yellow to orangy yellow portions; and no clear absorption lines visible with the desk-model spectroscope. These properties are consistent with fluorite, and the identity of all the samples was confirmed by Raman spectroscopy.

The fluorite was distinctly color zoned, with cubic violet zones inside yellow to orangy yellow areas. Whitish, prismatic inclusions with generally square cross-sections (figure 5) appeared opaque in transmitted light and were predominantly hosted by the violet areas of the fluorite. These inclusions were identified by Raman spectroscopy as dickite, a clay mineral with the formula Al₂Si₂O₅(OH)₄. Many of them consisted of partially hollow tubes, apparently created when some of the soft dickite weathered away or was removed during the polishing of the slab. A few yellow areas within the dickite inclusions were identified as sulfur, and Raman analysis also detected quartz inclusions in the fluorite. In addition, microscopic examination revealed reflective, iridescent fluid inclusions with geometric patterns.

LA-ICP-MS analysis of both the yellow and violet portions of the fluorite showed trace amounts of Ti, Sr, La, and Ce. The violet area tended to show higher concentra-

Figure 4. This unusual pendant, measuring ~3 × 8 cm, contains a slab of Namibian fluorite that is surrounded by a piece of brushed silver. It is shown in reflected light (left) and transmitted light (right). Courtesy of Goldideas, Windhoek; photos by Jo-Hannes Brunner.

Figure 5. Color zoning and several prismatic inclusions containing dickite are visible in this Namibian fluorite slab (gift of Jo-Hannes Brunner; GIA Collection no. 38388). Photomicrograph by C. Ito; magnified 16×.
ions of these elements, as well as trace amounts of additional rare-earth elements.

UV-Vis-NIR spectroscopy of a yellow portion of the slab showed a broad band at 434 nm, while a violet section displayed a 306 nm peak with broad bands at approximately 410 and 570 nm. The band in the yellow region is consistent with the “yellow center” attributed to an $O_3^-$ ion replacing two adjacent $F^-$ ions (H. Bill and G. Calas, “Color centers, associated rare-earth ions and the origin of coloration in natural fluorites,” Physics and Chemistry of Minerals, Vol. 3, 1978, pp. 117–131). The violet portion showed an absorption spectrum similar to those of purple fluorites in that article, with a 570–580 nm band (possibly attributed to colloidal calcium) and other possible Y- or Ce-associated F-center features.

Absorption spectra of the fluorite and Raman spectra of the inclusions are available in the *G&G* Data Depository at gia.edu/gandg. The delicate color patterns and interesting inclusion scene displayed by this fluorite makes it an attractive option for jewelry use when cut as slabs.

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Common opal from Laverton, Western Australia. In early 2011, Peter Piromanski from Holdfast Exploration Pty. Ltd., Wanneroo, Western Australia, showed this contributor some attractive potch opals (e.g., figure 6), to be marketed as Piroman Opal, that were reportedly from a new deposit 31 km north of the town of Laverton, near the Great Central Road at coordinates 28°22′10″ S, 122°35′59″ E. According to local geologic maps, this region consists mainly of weathered biotite monzogranite or kaolinized granites. The opal seam appears to be associated with a fault trending northeast/southwest. In September 2008, Holdfast Exploration was granted a five-year exploration license, and prospecting has been carried out since November 2008. Pits were excavated up to about 1.5 m deep in six different areas using mainly hand tools, a jackhammer, and an excavator.

Samples of opal in host rock, loose pieces of rough, and faceted stones were donated to GIA in December 2010. Eight samples weighing 0.49–4.39 ct studied for this report represented the color range of the Laverton material: two rough specimens (yellow and brownish orange) and six faceted stones (two colorless, two yellow, and two brownish orange). Some of the matrix specimens contained colorless, yellow, and brownish orange opal within the same piece. Most of the opal in matrix showed some unhealed surface-reaching fissures that were present before the stones were brought to GIA. Observations over an 11-month period showed some evidence of crazing in one of them, the colorless round brilliant shown in figure 6.

Gemological properties of the opal are summarized in table 1. Most of the samples showed some turbidity and flow patterns. One of the two colorless pieces contained clusters of minute crystals (figure 7, top left). In most of the yellow material, small spheres were seen individually (figure 7, top right) or in groups (figure 7, bottom left). In the
brownish orange opal, the most common inclusions were tiny angular, often reddish crystals associated with randomly oriented reflective (sometimes iridescent) discoid tension fissures, reminiscent of the “lily pads” seen in peridot (figure 7, bottom right). We have been unable to identify any of these inclusions with Raman microspectroscopy.

EDXRF analysis of five opals (colorless, yellow, and brownish orange) showed traces of Cu and Zr in all samples, while Ca, Fe, and Sr were detected in all but the colorless pieces. The three darker brownish orange stones contained the highest Fe contents, as expected from the literature (E. Fritsch et al., “Découvertes récentes sur l’opale,” Revue de Gemmologie, No. 138–139, 1999, pp. 34–40).

Raman spectroscopy of the same five samples showed a rather broad asymmetric band centered at about 350 cm$^{-1}$ with smaller bands at 1220, 1075, 965, and 780 cm$^{-1}$. Such spectra are typical of opal-CT (M. Ostrooumov et al., “Spectres Raman des opales: Aspect diagnostique et aide à la classification,” European Journal of Mineralogy, Vol. 11, 1999, pp. 899–908), which is usually found in a volcanic setting.

The discovery of fire opal in Western Australia, a part of the country not usually associated with opal, is an interesting development. Prospecting is ongoing, and updates and additional information on this opal will be posted at www.piromanopal.com.au. These attractive gems could make a welcome addition to Australian opal production.

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<table>
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<th>TABLE 1. Properties of opal from Laverton, Western Australia.</th>
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<td><strong>Color</strong></td>
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A bicolor, bi-pattern hydrophane opal. The Laboratoire Français de Gemmologie in Paris recently examined an unusual 17.15 ct opal cabochon, measuring approximately 20.95 × 15.96 × 11.69 mm. Play-of-color in the full rainbow of hues was visible throughout the stone (figure 8, left), but the bodycolor was not even. One end of the cabochon was medium brown, while the rest of the gem had a translucent whitish color (figure 8, right). The color boundary formed a well-defined line along the base of the stone. Such a zoning pattern has been occasionally seen in common opal but is unusual for play-of-color opal.

To better characterize the opal, we weighed it after 12 hours of drying at 100°C and recorded its weight. The weight of the opal was 17.15 ct, and its density was calculated to be 1.99 g/cm$^3$. The refractive index was determined to be 1.40–1.44, and its Mohs hardness was measured to be 5–6. The opal fluoresced yellow and brownish orange under short-wave UV light, and the color boundary was clearly visible.

**Figure 7. Inclusions seen in the Laverton opals included a cluster of minute unknown crystals (top left) and tiny spherical inclusions (top right), which sometimes occurred in clusters (bottom left). Randomly oriented crystals associated with lily pad–like tension fissures were also seen (bottom right). Photomicrographs by V. Pardieu, magnified ~40×.**
hours of drying in air in the laboratory, and again after immersion in water. Water fills the pores of opals that show hydrophane character. After immersion the stone weighed 17.99 ct, which clearly indicated a hydrophane character, but its appearance remained unaltered.

To avoid introducing foreign substances into the porous opal, we did not test for RI or SG. The gem emitted a weak whitish fluorescence to long-wave UV radiation, with a slightly less intense reaction to short-wave UV. The emission was zoned, with the brown portion nearly inert. The cap of the white zone at the top of the cabochon had a stronger fluorescence than the rest of the opal.

Another peculiarity was that the two color zones showed different patterns in their play-of-color. The brown zone had fairly large patches and a striated appearance, sometimes referred to as a “straw” or “chaff” pattern [figure 9]. This feature is due to polysynthetic twinning of the network of silica spheres found in many opals, particularly those from Ethiopia. This pattern was absent from the light-colored portion, which had smaller patches, less-visible borders, and somewhat “rolling” color flashes.

The base of the cabochon showed a cellular pattern of

Figure 9. The “straw” or “chaff” pattern in the brown zone is due to polysynthetic twinning of the network of silica spheres constituting the opal. Photomicrograph by A. Droux; magnified 55×.
well-formed “digits” that is typical of some opals from Wollo, Ethiopia, along with the abundance of twinning in the brown portion of the stone. Whitish play-of-color opal is common from Wollo but not from Ethiopia’s Shewa area. We concluded that this gem is likely from the Wollo deposits.

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chatoyant quartz with cinnabar inclusions. While on a buying trip to Jaipur, India, one of these contributors (TP) purchased a 4.56 ct cabochon of what appeared to be quartz with iron oxide inclusions, such as those seen in “strawberry” quartz from Kazakhstan. The cabochon measured 10.4 × 8.7 × 6.8 mm and had a vitreous luster (figure 10). Its spot RI of ~1.54, SG of 2.64, and inert reaction to long- and short-wave UV were all consistent with quartz. The gem was vivid red under reflected light except for a narrow linear near-colorless band. Most interestingly, it displayed chatoyancy in fiber-optic light, appearing as a four-rayed star in some positions. Microscopic examination revealed that the phenomenon was due to numerous red inclusions. These were short (<1 mm) acicular crystals oriented mainly along four directions (figure 11). When viewed with a scanning electron microscope (SEM), they showed a euhedral shape, with six-fold symmetry in cross-section, and were about 3 µm wide in narrowest dimension (figure 12). Since their morphology did not resemble that of iron oxide, we investigated them further.

Chemical analysis of surface-reaching inclusions using a JEOL 5800 SEM equipped with an energy-dispersive spectrometer detected only mercury and sulfur, a composition consistent with cinnabar. This identification is also consistent with their hexagonal symmetry. Cinnabar inclusions in quartz have been documented previously, especially in material from China [J. Hyršl and G. Niedermayr, Magic World: Inclusions in Quartz, Bode Verlag, Haltern, Germany, 2003, p. 53; E. J. Gübelin and J. I. Koivula, Photoatlas of Inclusions in Gemstones, Vol. 3, Opinio Verlag, Basel, Switzerland, 2005, pp. 592, 627]. To the best of our
knowledge, however, cinnabar has not been reported as oriented inclusions responsible for chatoyancy or a star effect, which makes this an unusual and attractive specimen.

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Quartz with acicular emerald inclusions. Quartz with randomly distributed tourmaline or rutile needles is widely available in the market. These gems are often described as “tourmalinated” or “rutilated” quartz, respectively. Recently, the Gem Testing Laboratory in Jaipur examined a quartz specimen that contained eye-visible emerald crystals (figure 13). Although intergrowths of emerald and quartz and a notable emerald-in-quartz specimen have been reported previously (e.g., Lab Notes: Summer 2000, pp. 164–165; Fall 2008, p. 258), this was quite different.

The slightly smoky 45.85 ct marquise-shaped cabochon measured 37.60 × 18.26 × 11.57 mm. The prominent green inclusions displayed an acicular habit (figure 14, left). Their green color and hexagonal profile (figure 14, right) strongly suggested emerald, but their acicular habit raised some doubts, as emeralds typically show a more columnar form. Most of the crystals also displayed basal parting planes, reminiscent of the actinolite blades found in emeralds from the Ural Mountains of Russia. Some also displayed color zones following the prism faces, while others contained rain-like inclusions.

To conclusively identify the inclusions, we examined the sample under a desk-model spectroscope. It revealed a spectrum consistent with emerald, featuring a doublet in the red region and an absorption band in the yellow-green region. Further confirmation was obtained by FTIR, which displayed a typical emerald spectrum. IR spectroscopy also confirmed the host material as quartz, which was supported by a spot RI of 1.54 and a hydrostatic SG of 2.65.

Textural relationships indicated that the emerald crystals formed before the host quartz (i.e., they are protogenetic). Emerald is known to occur within quartz, but this sample was quite unusual for the crystals’ acicular habit and their occurrence as inclusions, not merely in association with the quartz or as an intergrowth.

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Figure 13. This 45.85 ct quartz cabochon was unusual for its eye-visible inclusions of elongated emerald crystals. Photo by G. Choudhary.

Figure 14. The inclusions displayed an acicular habit (left, magnified 32×), which is usually not associated with emeralds. However, their green color and hexagonal profile (right, magnified 48×) helped identify them as emerald. (The green material in some quartz fractures is polishing powder.) Photomicrographs by G. Choudhary.
Quartz carving with inclusions of izoklakeite. These contributors recently examined a life-size quartz skull (figure 15) carved by noted gem photographer and lapidary Harold Van Pelt (Los Angeles). The hollowed skull contained two articulated pieces and a jaw hinge that opened and closed. Starting with a 250 lb. colorless quartz crystal, Mr. Van Pelt produced this 6.5 lb. (2.9 kg) sculpture.

One of the carving’s interesting features was its abundance of conspicuous submetallic silver-gray inclusions (e.g., figure 16). These were initially believed to be jamesonite, a lead-iron-antimony sulfide mineral often found in fibrous form. Initial analyses with a scanning electron microscope (SEM) quickly determined otherwise. No iron was detected, which meant the fibers consisted of a different material.

A more detailed SEM and electron microprobe investigation at Caltech revealed a lead-antimony-bismuth sulfide with a minor amount of copper. Its formula was initially determined as \( \text{Pb}_2.65\text{Cu}_{0.25}\text{Sb}_{1.14}\text{Bi}_{0.95}\text{S}_6 \). Areas of some of the fibers also consisted of several alteration products: galena (\( \text{PbS} \)), bismuthinite (\( \text{Bi}_2\text{S}_3 \)), some CuPb(Sb,Bi)\( \text{S}_3 \) minerals, and small amounts of native bismuth.

To identify the original lead-antimony-bismuth sulfide, we obtained a \( \sim 1 \text{ cm}^3 \) piece of the quartz from which the skull was originally carved. It was cooled in liquid nitrogen to make it brittle and immediately shattered in a percussion mortar. This freed numerous fragments of the silver-gray included crystals. Powder X-ray diffraction analysis at the Natural History Museum of Los Angeles County pointed to either izoklakeite or giessenite, and an electron back-scattered diffraction pattern done at Caltech,
together with the chemical analyses, confirmed that the phase was izoklakeite.

Izoklakeite is the antimony member of a solid-solution series with giessenite, the bismuth-dominant member. It was first described from a sulfide body near Izok Lake, Canada (D. C. Harris et al., “Izoklakeite, a new mineral species from Izok Lake, Northwest Territories,” *Canadian Mineralologist*, Vol. 24, 1986, pp. 1–5). The mineral was later found in Sweden and as inclusions in quartz crystals from Switzerland. Its ideal chemical formula is $\text{Cu}_4\text{Pb}_{34}\text{Sb}_{38}\text{S}_{114}$.

The quartz skull, named “Izok” in honor of its unusual inclusions, is part of an exhibit of Harold Van Pelt’s carvings on display at the Houston Museum of Natural Science through October 2012.

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**Update on ruby and sapphire mining in Pakistan.** In August and September 2011, these contributors visited Pakistan to collect reference samples for GIA’s laboratory. With the support of gem merchant Syed Iftikhar Hussein (Syed Trading Co., Peshawar, Pakistan), we traveled first to northern Pakistan to visit ruby deposits near Hunza and Bisil. Author VP, with assistance from Zulfiqar Ali Abbas (Kashmir Gems Ltd., Abbottabad, Pakistan), then proceeded to the ruby and sapphire deposits in the Kaghan Valley near Batakundi. This report provides an update on the mining and production at some of the Pakistani deposits described in the Fall 2007 (pp. 263–264) and Winter 2010 (pp. 319–320) GNI entries.

About 100 miners and local dealers were involved with ruby mining and trading around the Hunza Valley, at several deposits that initially started producing in the 1960s and 1980s. The rubies are found in marbles, sometimes associated with mica and blue and pink spinel. The deposits are located north of the valley, from Datumbaresho (figure 17) in the northwest to the Aliabad and Karimabad areas (Bajoring, Gharei Chhar, Phudan Daar, Gafinas), Altit, Ahmedabad, and Dong-e-Das (also known as Ganesh) in the east. Most of the workings are located 500–1,000 m above the villages at an elevation around 3,000 m (nearly 10,000 feet), and they are difficult to access because of the steep terrain. The color of the ruby generally ranges from deep red at Datumbaresho to pinkish red at Aliabad/Karimabad to pinkish and bluish red around Dong-e-Das. The size of the stones appears to

![Figure 17. A Pakistani miner breaks marble to collect rubies at Datumbaresho, in the Hunza Valley. Photo by V. Pardieu.](image)
increase in that same direction, from <0.4 g to 20+ g. Most Hunza ruby is cabochon quality at best, though mineral specimens are also important. Much of the region’s production is apparently exported to China.

The Bisil ruby deposit is located near 35°52′53″ N, 75°23′52″ E, in the Basha Valley north of Skardu. It was discovered in 2003 by a local prospector. Rubies from Bisil (figure 18) are also found in marble, within veins or pods, typically in association with diopside and mica. We saw about 10 mining pits, up to 20 m deep. The deposits appear to extend from just above Bisil village [elevation ~2,800 m] to the top of the mountains at an elevation above 3,500 m, and may extend more than 10 km in an east-west direction. About 15 miners were working the area using simple tools, jackhammers, and dynamite. Small stones ranging from pink to deep red are mined year-round, but production is very limited.

The Batakundi ruby deposit is located in the Kaghan Valley at 34°52′41″ N, 73°48′05″ E, at an elevation of 4,190 m. Marble-hosted rubies, most of them small and deep red, have been recovered there since 2000. Rough stones larger than 0.6 g are very rare, with most of the production smaller than 0.2 g. A group of seven miners led by Haider Ali have been working in the current area since 2006. As at Bisil, the miners use a jackhammer, dynamite, and hand tools; production is extremely limited.

Also in the Batakundi area, the Besar [also known as Basil or Besel] sapphire mines were being worked by about 50 miners using jackhammers and explosives at two sites, located at 35°02′41″ N, 73°52′56″ E, and 35°02′58″ N, 73°53′19″ E [e.g., figure 19]. The elevation of these sites is 4,020 m and 3,780 m, respectively. Several kilograms of pink to purple sapphires were being extracted from the graphite-rich veins on a daily basis, less than 5% was of gem quality.

The overall ruby production from Pakistan is very low compared to other primary-type deposits in Asia and Africa. Most of the ruby production in Central Asia comes from the Murgab area in eastern Tajikistan and from Jegdalek, Afghanistan. Pakistani rubies are typically more included and smaller. Although Pakistan’s ruby mines are rarely affected by the political instability and security issues present elsewhere in the country, the deposits are located high in mountainous areas that are difficult to access.

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Figure 18. These rubies are from the Bisil area, in the Basha Valley of Pakistan. The largest piece, on the far right, is ~1 cm long. Photo by V. Pardieu.

Figure 19. At the Besar deposits, in the Batakundi area of Pakistan’s Kaghan Valley, several miners use jackhammers and explosives to break the hard rock in search of sapphires. Photo by V. Pardieu.
Vanadium-bearing color-change sphene from Pakistan/Afghanistan. Recently seen in the Carlsbad laboratory was a parcel of rough and cut sphene (e.g., figure 20) loaned for examination by Eric Braunwart (Columbia Gem House, Vancouver, Washington). According to him, the sphene originated near the Pakistan/Afghanistan border. The most interesting feature of this material was that many of the stones showed a slight to moderate color change. In daylight-equivalent lighting, the sphene was dominantly vivid green to yellowish green, changing to brownish orange or brown under incandescent light (again, see figure 20). However, strong pleochroism was responsible for the multiple colors seen in the faceted stones.

The rough consisted of well-formed blade-like crystals, so it is apparent that the material was mined from a primary deposit. Rough production as of July 2011 was estimated by Mr. Braunwart to be around 600 g, from which approximately 200 carats of finished material have been produced. The cut stones ranged from calibrated sizes as small as 3 mm in diameter up to larger stones weighing several carats. The largest faceted stone from the production so far was a 5.45 ct oval brilliant.

Gemological properties of the material were consistent with sphene. The RI was over-the-limit of the refractometer, and the average SG (measured hydrostatically) was 3.54. A strong red reaction was observed with a Chelsea filter. Microscopic observation revealed strong doubling and numerous included crystals. These were identified by Raman microspectroscopy as transparent near-colorless apatite and dark elongated needle-like crystals of an amphibole mineral (figure 21). Several stones also contained fluid “fingerprints.” A few rough pieces showed prominent zoning, and the color change was less apparent across these zoned areas.

EDXRF spectroscopy of all samples showed major amounts of Ca, Ti, and Si that are expected for sphene, as well as traces of V, but no Cr. LA-ICP-MS measurements of several spots on a faceted sample detected an average of more than 2400 ppmw V (and no Cr), which is presumably the cause of the color change. The visible spectrum showed a broad absorption feature centered at approximately 603 nm (figure 22). Transmission windows on either side of this broad band are consistent with the spectrum expected for a color-change gem.

The coloration of this sphene is much different from the typically “golden” orange material previously described from Pakistan’s North West Frontier Province (Spring 2006 GNI, pp. 68–69), and also from the yellow sphene known from Badakhshan, Afghanistan (Summer 2006 GNI, pp. 180–182).

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Cobalt blue–colored spinel from Khuoi Ngan, Vietnam.

Blue spinel has been reported from several localities in the An Phu–Luc Yen area of northern Vietnam, though highly saturated material is quite rare (e.g., C. P. Smith et al., “A closer look at Vietnamese spinel,” InColor, Spring 2008, pp. 11–13; J. B. Senoble, “Beauty and rarity—A quest for Vietnamese blue spinel,” InColor, Summer 2010, pp. 18–23; Spring 2011 GNI, pp. 60–61). Testing has shown that the blue color is due to various amounts of cobalt and iron impurities (Smith et al., 2008).

Gem and mineral dealer Dudley Blauwet recently visited one of the Vietnamese blue spinel deposits and provided some information on the mining and production of this material. The site was located just east of the village of Khuoi Ngan and approximately 2.5 km southeast of An Phu, where a few local villagers were mining secondary deposits in shallow pits along the edges of rice paddies (figure 23). Work at the site began in 2008, and a number of pits were excavated with hand tools to a depth of 2–3 m. The gem-bearing material was taken to a nearby area for washing and hand picking (figure 24).

The spinel rough was quite small but intensely colored. Mr. Blauwet obtained four small parcels ranging from 0.4 to 5 g over the course of four days in Luc Yen. In addition, he purchased a fifth lot of rough in An Phu on the day that he visited Khuoi Ngan. The individual pieces of rough were mostly <0.2 ct but suitable for cutting melee because of the high color saturation. All of the lots were said to be from Khuoi Ngan, except one that was reportedly from Bai Ruong (which may be an alternative name for Khuoi Ngan, as it refers to the same area of rice fields). The largest piece of rough Mr. Blauwet purchased yielded a faceted oval weighing 0.80 ct (figure 25). During his latest visit to Vietnam, in November 2011, he reported very limited production of the intense blue spinel from Khuoi Ngan, in small sizes that would cut stones expected to weigh <0.15 ct.

Mr. Blauwet mentioned that buyers continue to see glass and synthetics in rough and cut gem parcels in Vietnam. After receiving his first shipment of blue spinels from the cutting factory, a 0.26 ct sample was found to be glass. Such imitations can be difficult to identify in the field since the rough material commonly has been tumbled to give the appearance of alluvial pebbles, which also disguises any obvious bubbles or swirl marks. He reported that a Chelsea filter is helpful in such situations: Co-bearing spinel appears pink to red, while glass shows no reaction.

Three faceted samples of Mr. Blauwet’s intense blue
Khuoi Ngan spinel (0.24–0.80 ct) were examined at GIA’s Carlsbad laboratory. SG values ranged from 3.50 to 3.57, and the RI of the largest stone was 1.716. LA-ICP-MS analyses showed 60–290 ppmw Co. Iron was 7,400–10,500 ppmw, and significant traces of Zn, Ga, Ni, Mn, V, and Li also were recorded. As expected, all three samples appeared red in the Chelsea filter.

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Trapiche spinel from Mogok, Myanmar. Trapiche growth structure, most commonly observed in emerald, has also been seen in ruby, sapphire, tourmaline, quartz, and andalusite. In January 2011, Bill Larson (Palagems.com, Fallbrook, California) loaned five samples to GIA that were represented as trapiche spinel from Mogok, Myanmar. They were polished into round tablets that ranged from 1.2 to 3.0 cm, and all showed a subtle radiating texture that was more visible with transmitted light. Two pieces (3.64 and 6.76 ct) were characterized by this contributor for this report.

The samples were translucent and ranged from pinkish orange to red with “arms” that were dark gray (e.g., figure 26). Gemological properties of both samples were consistent with spinel, except for an inert reaction to UV radiation. Raman spectroscopy confirmed the spinel identification. Six arms were easily recognized in each tablet, though the trapiche structure was not well defined. Rather than a core, the 3.64 ct sample contained a point where the arms intersected. The 6.76 ct tablet had an...
indistinct core that was cloudy and full of cracks. The arms were created by concentrations of gray wispy clouds and a denser network of cracks than in the surrounding material.

In both tablets, tiny black graphite inclusions (identified by Raman analysis) were visible throughout with a gemological microscope. In the 3.64 ct tablet, minute inclusions of molybdenite, magnesite, goethite, and hematite were detected in the arms (e.g., figure 27; see the G&G Data Depository for more images). Hematite crystals were found between the arms, and hematite, magnesite, molybdenite, and calcite were found along the outer rim of the samples. In the 6.76 ct tablet, dolomite crystals were detected in the core and the arms; goethite crystals were identified between the arms and in the rim. Notably, Cr³⁺ photoluminescence bands at 692 and 694 nm, which are characteristic of ruby, were detected in one tiny included crystal along the rim of this sample (figure 28).

Numerous cracks and cavities were observed throughout the tablets. DiamondView images revealed bright blue and purple zones in the cracks, while the host spinel showed a faint blue color. In the 3.69 ct tablet, orange-red stains were seen with the microscope inside the fractures between the arms. Qualitative EDXRF analysis revealed Mg, Al, Ti, V, Cr, Fe, Zn, Ga, Ca, and Mn in both samples. The spinels had not been exposed to heat treatment, as confirmed by their PL spectrum, which featured a sharp band at 685 nm.

Similar samples of trapiche spinel from Myanmar were characterized by M. Okano and A. Abduriyim (“Trapiche spinel,” Gemmology, Vol. 41, No. 485, Issue 2, 2010, pp. 14–15 [in Japanese]), who suggested that the trapiche structure formed during the growth of tabular spinel crystals. A pseudomorphic origin of this trapiche spinel after ruby is also possible, and is supported by the remnant ruby inclusion detected in one of the samples.

Editor’s note: Consistent with its mission, GIA has a vital role in conducting research, characterizing gemstones, and gaining knowledge that leads to the determination of gemstone origins. The samples studied in this report are not subject to the Tom Lantos Block Burmese JADE Act of 2008, and their import was in accordance with U.S. law.

Kyaw Soe Moe

SYNTHETICS AND SIMULANTS

“Cat’s-eye pearls”: Unusual non-nacreous calcitic pearl imitations. Imitations of non-nacreous pearls are abundant in the market. They can be made of just about any materi-

Figure 26. This 6.76 ct tablet of trapiche spinel, reportedly from Mogok, may represent a spinel pseudomorph after ruby. The trapiche structure is not well defined, but the arms are easily recognized, particularly in transmitted light (left). Photos by Robert Weldon.

Figure 27. Micro-inclusions in the trapiche spinel identified using Raman spectroscopy included a molybdenite crystal along the rim (left), a rhombohedral magnesite crystal in an arm (center), and a dark-appearing calcite crystal along the rim (right). Raman microscope photomicrographs by K. S. Moe.
al but are usually sculpted from shell. Shells thick enough to yield such pearl imitations are rather common, though generally they are restricted to aragonitic mollusks such as *Strombus sp.*, *Tridacna sp.*, and *Cassis sp.* Calcitic shells, including those of *Pinna sp.* and *Atrina sp.*, tend to be thin and are therefore not suitable. Shell imitations show a layered structure when viewed with strong transmitted light, making them easy to identify.

This contributor recently received for testing six unusual black “pearls” (figure 29) from two different clients. Represented as non-nacreous natural pearls, the pieces weighed between 2.52 and 10.26 ct and exhibited chatoyancy when illuminated with an intense light source. The chatoyancy was displayed all around the...
samples when they were rotated about an axis perpendicular to the band, but it was not visible along this axis. The phenomenon was caused by light reflections from their fibrous structure (figure 30, left). Viewed from the side, no fibrous structure was visible, but hexagonal outlines of the fibers could be seen. These parallel layers of very fine hexagonal prisms are characteristic of calcitic pearls and shell. As expected, reflectance infrared spectroscopy identified the samples as calcite. Distinct concentrations of Sr, detected by EDXRF chemical analysis, confirmed that they were of marine origin.

The surface of the samples showed obvious polishing lines, a common feature in polished and worked non-nacreous natural pearls. The telltale layered structure of sculpted shell was not visible since the samples were practically opaque to strong fiber-optic light. X-ray photographs did not reveal any structure, which is very unusual for brown to black calcitic natural pearls; those from Pinnidae mollusks typically show distinct concentric structures.

Because the orientation of the prismatic fibers and the resulting chatoyancy clearly indicated a layered structure, and none of the properties were consistent with natural pearls, these objects could only be sculpted shell. To more closely examine the layered structure of these “cat’s-eye pearls,” we were granted permission to grind down one of the smaller samples until it was transparent. This section displayed a distinct layered structure perpendicular to the direction of the fibrous prismatic calcite crystals (figure 30, right), as expected for shell.

Having confirmed that these “cat’s-eye pearls” were sculpted from calcitic shell, the question remained: Which mollusk could form a dark brown to black shell thick enough to cut a 10 mm pearl imitation? After some research, we found a private collection with a few massive shells from *Atrina vexillum* (a pen shell) that were thick enough to cut pearl imitations such as the ones described in this report.

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**Large synthetic quartz.** Recently, the Gübelin Gem Lab received four large gems (figure 31) submitted for analysis by Erwin Walti (Oetwil am See, Switzerland). They were represented as amethyst (surprising for a dark green gem), aquamarine (greenish blue and light blue concave cuts), and citrine (yellow oval cut), and they weighed 162.00, 33.20, 36.30, and 38.40 ct, respectively. To improve workflow, the laboratory occasionally puts stones through more advanced analyses, such as FTIR and EDXRF spectroscopy, prior to gemological testing. Such was the case with these samples.

We noticed immediately that the analytical data did not match either natural quartz or aquamarine. All four FTIR spectra showed total absorption below approximately 3600 cm⁻¹ and only a weak, broad absorption band at 5196 cm⁻¹ (e.g., figure 32). These IR features are consistent with those reported for some synthetic quartz (e.g., P. Zecchini and M. Smaali, “Identification de l'origine naturelle ou artificielle des quartz,” *Revue de Gemmologie a.f.g.*, Vol. 138–139, 1999, pp. 74–83). EDXRF spectroscopy of all four stones showed major amounts of Si with traces of Fe. The dark green sample also contained small but significant amounts of cobalt (0.005 wt.% Co₃O₄), indicative of synthetic origin, while the yellow sample showed traces of calcium (0.068 wt.% CaO). All other measured elements were below the detection limit.

Microscopic examination of the dark green gem showed a colorless seed plate with fine particles on each side (figure 33) and parallel green banding. The other gems were very clean, with only the light blue one showing reflective breadcrumb-like particles. No growth or color zoning was observed in those stones. Refractive indices were 1.54–1.55, consistent with quartz, and Raman analysis of the light blue and the yellow samples confirmed this identification. We therefore identified all four samples as synthetic quartz. While synthetic citrine is well known, dark green synthetic quartz is less common, and the aquamarine-like color varieties reported here are not often seen in the market.

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TREATMENTS

Sugar-acid treatment of opal from Wollo, Ethiopia. Several gemological laboratories have recently identified “black” opals from Ethiopia’s Wollo Province as smoke treated (e.g., www.stonegrouplabs.com/SmokeTreatmentinWolloOpal.pdf). The effectiveness of the smoke treatment is probably related to the hydrophane character that is commonly shown by Wollo opal. The porosity allows the smoke to penetrate the opal structure deep enough to create a dark bodycolor. Accordingly, one of us (FM) investigated the possibility of treating Wollo opal using a sugar-acid process similar to that used for matrix opal from Andamooka, Australia.

For this experiment, we chose 12 mostly low-grade...
opals tumbled as irregular pebbles, with a white to yellowish white bodycolor typical for opals from Wollo (figure 34, left). The samples were first heated at 90°C for 2 hours in a solution containing 25% sugar by weight. Next they were heated at 100°C for 3 hours in a 60% solution of hydrochloric acid. All the opals turned a darker color (figure 34, right). Some acquired a homogeneous, opaque, black bodycolor, while others darkened unevenly from grayish brown to gray. The play-of-color became more intense in some samples and less vivid in others. Two of the opals were broken open, revealing that the dark coloration penetrated only a few millimeters into the stones. The samples with the greatest hydrophane character (as indicated by their ability to stick to the tongue) showed the darkest colors after treatment. Conversely, the more transparent and least hydrophane-like opals were least affected by the treatment (e.g., inner portion of the upper-right sample in figure 34). As expected, the hydrophane character appears to have facilitated the penetration of the sugar and acid solutions into the opal.

Even darker coloration in hydrophane opal may be attainable by varying the carbon source and its concentration, the nature of the acid and its concentration, and finally the temperature and duration of heating in both solutions. Such experiments are in progress, and the results will give gemologists a better idea of what to expect for future treatments of this prolific type of opal.

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CONFERENCE REPORTS
32nd International Gemmological Conference. The biennial IGC was held July 13–17, 2011, in Interlaken, Switzerland. More than 70 gemologists from 31 countries gathered to discuss developments in the field. The organizing committee was led by Dr. Michael Krzemnicki, in collaboration with colleagues at the Swiss Gemmological Institute SSEF, the Swiss Gemmological Society, George and Anne Bosshart, and Dr. Henry A. Hänni. The conference featured 12 sessions on topics ranging from colored stones to pearls and diamonds, analytical methods and gem treatments, and special sessions on Canadian gems, rare stones, and organic materials. The 48 talks and 14 interactive poster presentations covered a wide range of topics and regions. The conference proceedings and excursion guides are available at www.igc2011.org; some of the presentations are summarized below.

Dr. Thomas Armbruster (University of Bern, Switzerland) delivered the opening keynote address on gemology’s position at the interface of mineralogy and crystallography. Using the beryl group as an example, he demonstrated the similarities and differences in the crystal structures within this group of minerals. Dr. Karl Schmetzer (Petershausen, Germany) described chemical zoning in trapiche tourmaline from Zambia, which is characterized by a strong negative correlation between Ca and Na. Dr. Jürgen Schnellrath (Centro de Tecnologia Mineral, Rio de Janeiro) discussed unusual fiber distribution patterns in Brazilian cat’s-eye quartz. Dr. Shang-i Liu (Hong Kong Institute of Gemmology) presented results of a study on Cs- and Li-rich beryl from Madagascar, using electron microprobe, LA-ICP-MS, FTIR, Raman analysis, and electron paramagnetic resonance spectroscopy.

The pearl session included presentations by Dr. Michael S. Krzemnicki on formation models for Tokki cultured pearls, which form as attachments to larger bead-ed cultured pearls; Nick Sturman (GIA, Bangkok) on separating natural from cultured Queen conch pearls (Strombus gigas); and Federico Bärlocher (Farlang, Cernobbio, Italy) on the production and trade of Melo pearls from Myanmar.
Walter Balmer [Department of Geology, Chulalongkorn University, Bangkok] addressed the characterization of rubies from marble deposits in Myanmar (Mogok), Vietnam (Luc Yen) and Tanzania (Morogoro and Uluguru Mountains) using UV-Vis spectroscopy. John Koivula [GIA, Carlsbad] showed how high-temperature fusion of corundum mimics residues in heat-treated rubies and sapphires. Terry Coldham [Sapphex, Sydney] advocated greater cooperation between researchers and producers in shedding light on the genesis of basaltic sapphires. Edward Boehm [RareSource, Chattanooga, Tennessee] offered insight into current colored stone market trends, and Brad Wilson [Alpine Gems, Kingston, Canada] described a wide variety of recent finds on Baffin Island, Canada.

Dr. Thomas Pettke [University of Bern] gave the conference’s second keynote talk, in which he reviewed LA-ICP-MS applications and offered an outlook on the potential of this method in gemology. The poster sessions gave insights into current research, including presentations on jadeite trading in China [Elizabeth Su, DuaSun Collection, Shanghai] and rare-earth coloration in bastnäsite [Dr. Franz Herzog, Swiss Gemmological Institute SSEF, Basel].

The conference was preceded by excursions to the Natural History Museum in Bern and mineral localities in the Ticino Alps. A three-day trip to the Binn Valley and Zermatt immediately followed the conference. Both tours took participants to areas of mineralogical and geological interest in Switzerland. Adopting Dr. Nguyen Ngoc Khoi’s proposal, the delegates unanimously decided to hold the 2013 IGC in Vietnam.

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2011 NAG Institute of Registered Valuers Conference.
The National Association of Goldsmiths IRV 23rd annual conference took place September 24–26 at its usual venue, Loughborough University, Leicestershire, UK. Approximately 150 delegates attended the various presentations, including hands-on workshop sessions.

Market trends and industry issues were discussed by Richard Drucker of Gemworld International [Glenview, Illinois]. He explained how the market is changing locally and internationally with China and India now becoming the predominant buyers, and how these global influences are pushing some diamond and gem prices to new heights. A round-up of the auction market, including information on commissions and insurance, as well as recommendations on how to best work in the auction world, was presented by Stephen Whittaker of Fellows & Sons [Birmingham, UK]. He also explained the use and costs of technology in the auction business.

The focal point of the conference was introducing a new valuation qualification, CAT (Certificate of Appraisal Theory), which was presented by Heather McPherson, a Fellow of the NAG Institute of Registered Valuers [Coalville, UK]. This training program is intended to replace the JET (Jewellery Education & Training) valuation course and will be launched by spring 2012 as a new requirement to become an Institute Registered Valuer.

Harry Levy, president of the London Diamond Bourse, explained the valuation of diamonds and colored stones, with information on nomenclature, treatments, and origins. The importance of treatment disclosure was the main theme of his presentation. Steve Bennett of GemsTV [Worcestershire, UK] described how education, training, and vertical integration have been the key factors in his family-run business.

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ERRATA
1. For figure 1 of the Fall 2011 CVD synthetic diamond article by B. Willems et al. (pp. 202–207), the correct photographer of the images in this composite photo was Jian Xin [Jae] Liao.
2. Figure 18 of the Fall 2011 Vietnamese corundum article by N. N. Khoi et al. (pp. 182–195) shows the absorption spectrum of a sapphire, rather than a ruby. G&G thanks Nathan Renfro for this correction.
3. The Fall 2011 GNI entry by D. Beaton (pp. 247–248) should have indicated that the strong absorption peaks at 376 and 386 nm were attributed to Fe^{3+} pairs (376 nm) and Fe^{2+} (386 nm). G&G apologizes for introducing errors in the peak assignments, and thanks Nathan Renfro for the correction.