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Contributing Editors
Emmanuel Fritsch, *University of Nantes, CNRS, Team 6502, Institut des Matériaux Jean Rouxel (IMN), Nantes, France* (fritsch@cnrs imn.fr)
Gagan Choudhary, *Gem Testing Laboratory, Jaipur, India* (gagan@gjepcindia.com)
Christopher M. Breeding, *GIA, Carlsbad* (christopher.breeding@gia.edu)

COLORED STONES AND ORGANIC MATERIALS

Aquamarine from a new primary deposit in Mexico. Scientists still have not adequately surveyed Mexico from a mineralogical or gemological point of view. But recent finds of amazonite, jadeite, topazolite, demantoid, and labradorite demonstrate the importance of systematic research of the Mexican subsoil, which may lead to the discovery of other gemstones and gem localities (M. Ostrooumov, "Gemstones from Mexico—A review," Summer 2011 *G&G*, p. 141).

Recently, the author discovered transparent blue crystals with hexagonal-prismatic habit in a granitic pluton in the hills of Guadalcázar municipality, San Luis Potosí State, in north-central Mexico. These crystals, the largest of which measured 12.04 × 5.68 × 4.57 mm, were embedded in a single quartz vein in association with muscovite (figure 1). All observed aquamarine crystals were generally characterized by a lighter blue tone, lacking visible inclusions. The samples were submitted for identification at the Institute of Earth Sciences at the University of Michoacan in Morelia, Mexico.

Standard gemological testing yielded the following properties: refractive index (RI)—n_o=1.582–1.587 and n_e=1.575–1.580; pleochroism—strong blue and near-colorless; birefringence—0.007, with a uniaxial negative optic sign; hydrostatic specific gravity (SG)—2.70–2.71; fluorescence—inert to both long- and short-wave UV radiation. These properties suggested beryl, which we later confirmed with UV-Vis-NIR and infrared reflection spectroscopy and Raman microprobe.

Editors' note: Interested contributors should send information and illustrations to Stuart Overlin at soverlin@gia.edu or GIA, The Robert Mouawad Campus, 5345 Armada Drive, Carlsbad, CA 92008.

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UV-Vis-NIR spectroscopy showed absorption bands at 428, 452, 575, 630, and 805–815 nm. Narrow, weak absorption lines at 428 and 452 nm are attributed to the spin-forbidden transition of six-coordinated Fe^{3+}. A broad intense band at 575 nm and a much weaker line at 630 nm, which are responsible for the aquamarine color, are assigned to an Fe^{2+}-O-Fe^{3+} intervalence charge transfer transition (A.S. Marfunin, *Advanced Mineralogy*, Vol. 2, Springer-Verlag, Berlin, 1995, pp. 113–114). Finally, an intense broad band at approximately 805–815 nm is attributed to spin-allowed transitions of Fe^{2+}.

Infrared reflection spectroscopy and Raman microprobe are methods of "fingerprinting," and a combination of

Figure 1. Aquamarine was recently discovered in San Luis Potosí State in north-central Mexico. Here the aquamarine is shown in association with muscovite and quartz. The approximate size of the visible aquamarine crystal is 12.04 × 5.68 × 4.57 mm. Photo by M. Ostrooumov.

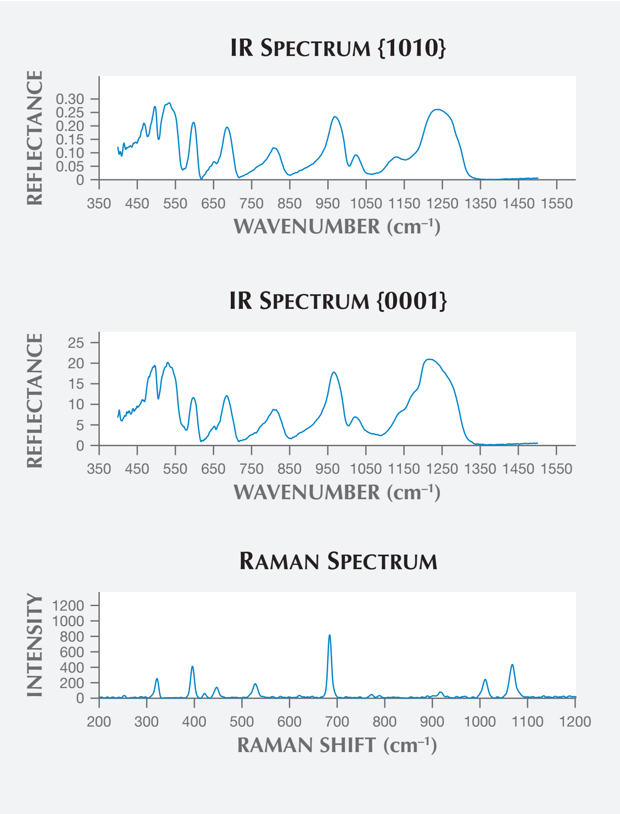


Figure 2. Infrared reflection spectra and Raman microprobe results of the samples confirm their aquamarine identity. The IR spectrum at the top is from the {1010} orientation, while the middle spectrum shows the {0001} orientation. The bottom plot shows the unoriented Raman microprobe results, with principal peaks at 322, 396, 447, 528, 684, 773, 916, 1011, and 1068 cm^{-1}.

these techniques permits the user to identify a wide range of mineralogical, gemological, and archaeological objects (M. Ostrooumov, "Infrared reflection spectrometry analysis as a non-destructive method of characterizing minerals and stone materials in geoarchaeological and archaeometric applications," *Geoarchaeology*, Vol. 24, No. 5, 2009, pp. 619–637).

This study confirmed that the crystals belonged to the beryl group (http://rruff.info). The infrared reflection spectra were obtained on oriented crystal faces {0001} and {1010} in order to take into account the effect of orientation (figure 2, top and middle). These results indicate the presence of the typical Be-O band vibrations at 743–807 cm^{-1} and 1215–1276 cm^{-1}. The infrared absorption spectra showed the presence of hydroxyl groups with a prominent band at 3450 cm^{-1} and a secondary band at about 3558 cm^{-1} due to the fundamental OH stretching vibration of water molecules, as well as the water-bending vibration at approximately 1630 cm^{-1}. The Raman microprobe spectra (figure 2, bottom) showed excellent agreement with a reference spectrum for aquamarine from Ilmen, Russia, in the author's FT-Raman database (http://www.mineralog.net). The Raman spectra of aquamarine in the water range from 3700 to 3500 cm^{-1} using 532 nm excitation wavelength showed two Raman bands at 3608 and 3598 cm^{-1} with different intensities. Water molecules in the channels are classified as type I or type II according to their orientation to the beryl structure. The Raman band at 3608 cm^{-1} is assigned to the vibration of type I water, and the Raman band at 3598 cm^{-1} is ascribed to the vibration of type II water molecules. UV-Vis-NIR, infrared reflection, and Raman microprobe techniques, as well as standard gemological testing, confirmed the discovery of aquamarine in the Guadalcázar granitoid deposits of San Luis Potosí State.

The recent discovery of *in situ* aquamarine in Mexico has renewed interest in the geology and mineralogy of gem deposits in that country. More discoveries are anticipated with further exploration in the region.

Mikhail Ostrooumov (ostroum@ umich.mx)
University of Michoacan, Institute of Earth Sciences
Morelia, Michoacan, Mexico

Update on colored gemstone mining in Tanzania. A team of GIA field gemologists visited Tanzanian mines in the summer of 2016 to collect ruby and sapphire for GIA's reference collection and explore new sources of colored stones. The field expedition, led by these authors, visited many known Tanzanian gem localities as well as new deposits at Loolera, Kibuko (figure 3), Lutela, Amani Makoro, and Ngapa. The trip was made possible by the support of Mark Saul of Swala Gem Traders (Arusha, Tanzania), Tanzanian gem broker Justin Mmbaga, and several regional mining officers. We found that the most active colored gemstone mining area is still Merelani, which produces tanzanite and green grossular garnet. Ruby and sapphire output has been relatively low since the 2009 discovery of the ruby deposit in Montepuez, Mozambique, as confirmed by our Tanzanian sources.

Tanzanian miners supply stones to licensed brokers, who are allowed to buy and transport gems within the country. These brokers sell to licensed master dealers, who are allowed to export internationally. These master dealers are mainly located in Dar es Salaam and Arusha. While we met Thai and Sri Lankan buyers in Mahenge, Songea, and Tunduru, foreigners must have approval from regional mining officers and possess a proper business visa to visit the deposits. This is particularly enforced in southern Tanzania; around Songea, we met immigration officers who were "hunting for foreigners."

Our journey started in Longido, where rubies were discovered about 100 years ago (D. Dirlam et al., "Gem wealth of Tanzania," Summer 1992 *G&G*, pp. 80–102). The main operation in the Longido area is the Mundarara ruby mine, currently Tanzania's largest, with a workforce of 78 people. The gems are extracted from an underground tunnel about 200 meters deep crossed by several horizontal tunnels that

Figure 3. A view of the pink sapphire mining pit at Kibuko, in the Uluguru Mountains of Tanzania. Photo by Vincent Pardieu/GIA.

host most of the production. The mine yields ruby in zoisite (suitable for carving), as well as some cabochon- and facet-grade material of a very deep red color. The color is reminiscent of rubies from Mozambique.

We continued to the Umba River, where Tanzanian sapphire production began after World War II and a ruby-bearing area was discovered by Georges "Papas" Papaeliopoulos in the 1950s (again, see Dirlam et al., 1992). The situation has changed significantly since author VP visited in 2005 and 2009. At the time there was a dispute between the company working the deposit, called "Amazon," and local communities. The dispute ended with the government revoking Amazon's license. During our 2016 expedition, we witnessed about 40 small-scale local miners using hand tools to work the primary deposit discovered by Papaeliopoulos, as well as secondary deposits scattered along the banks of the Umba. Most of the production is traded each evening around the Mississippi Hotel in Umba.

In the Kilindi area, about halfway between Umba and Winza, a new ruby deposit has been discovered near the Maasai village of Loolera. This site, located atop a hill, produces gems very similar to those found near Winza in 2007. We visited the area with the support of the village leader, who said the first rubies were found about 10 years ago, but the quality of the stones was low. A few miners were working the deposit sporadically using hand tools. But in April 2016, some good-quality material was found in amphibole matrix, attracting considerable interest. About 25 mining licenses were issued during the summer of 2016, but there is a sense that the area is under the control of a few major players.

The deposit where the first rubies at Loolera were found is owned by a miner called Dr. Ozu. The mining pit appeared to be about 90 meters deep, but we could not inspect the tunnel as Dr. Ozu was not present. We studied the entrance and looked through the tailings near the pit. In these rejects we found many small fragments of rubies associated with garnets, amphibole, mica, and feldspar. Although the material we saw resembled Winza ruby, the stones contained minute particles that gave them a milky aspect.

Our next stop was Winza, where an important gem rush occurred in 2007–2008 (D. Schwarz et al., "Rubies and sapphires from Winza, central Tanzania," Winter 2008 *G&G*, pp. 322–347; V. Pardieu, "The Winza ruby and sapphire mining area, Mpwapwa district, Dodoma province, Tanzania," www.fieldgemology.org, 2009). The main mining area at Mtakanini was nearly deserted. An old rusted washing plant was visible, but due to mechanical problems it had not washed any stones in more than a year. We estimated that a handful of people were still mining around Mtakanini, mainly at primary deposits in underground tunnels, some of which were over 100 meters deep. Working conditions are difficult, as the rock is hard and the tunnels are prone to flooding. We learned that several brief ruby rushes occurred nearby at Godegode, Makutop, Magaseni, Singonali, and Berega. In Morogoro Province, two ruby and spinel mining areas have been exploited since the 1980s. One is located just east of Morogoro in the Uluguru Mountains, and the second is about 150 km south near Mahenge. Most of the gem trade in the Uluguru Mountain region is in Mkuyuni, while the mining takes place near Matombo, Ngongolo, Mwaraze, and Kibuko. In Matombo we witnessed about 30 people retrieving pink spinel and rubies from a secondary deposit near Kiswila. Near Ngongolo, we visited four small-scale operations where locals with hand tools were mining small rubies in marble associated with pyrite, graphite, and mica.

Figure 4. Pink sapphires from the new deposit near Kibuko. Photo by Vincent Pardieu/GIA.

Figure 5. This garnet was mined from the new deposit in Lutela, Tanzania. Photo by Vincent Pardieu/GIA.

Near Kibuko, a new pink sapphire deposit was worked by about 10 miners on a site owned by Luciano Kipanzi, who took over the area in 2015. Pink sapphires up to 100 carats are associated with carbonates and pyrite in a primary deposit (figure 4). Most of the stones were the milky "geuda" type, but there was some transparent facet-grade material with very fine crystallization. The mine had evidently yielded about 20 kg of sapphire, from cabochon- to facet-grade, during the previous six months. Nearby, three groups of small-scale miners were uncovering a limited amount of similar stones from secondary deposits.

The Mahenge district, known for spinel and ruby, is the second most active gemstone mining area in Tanzania. Recent discoveries of graphite near Ipanko and garnet near Lutela (the latter in February 2016) have kindled interest in the area. The new alluvial deposit produces an interesting range of attractive garnets (figure 5), from light "champagne" to deeper saturated rhodolite, including some color-shifting stones. We saw some clean stones weighing up to 20 ct and heard about others as large as 60 ct. About 100 miners were still working the alluvial deposit. Activity was already slowing; we were told that a few months earlier, up to 300 miners were in the valley. This secondary deposit is rapidly depleting, and so far no primary deposit has been located.

Ipanko is still the main spinel deposit in the region. Author VP noticed that the pits were much larger than in 2012, meaning that the area had been mined since then. Nevertheless, the activity seemed slow compared to 2012: Several excavators were working secondary deposits, whereas small-scale miners once worked individual plots, called "boxes" by the locals. The nearby primary spinel deposit was still active, with about 400 people mining red spinel and only a few working on rubies. We then visited several small-scale ruby deposits along the Lukande River, including three operations working either primary or sec-

Figure 6. This blue sapphire rough, weighing about 7 ct, is from the new deposit at Ngapa, near Tunduru. Photo by Vincent Pardieu/GIA.

ondary deposits. As in the Uluguru Mountains, the rubies from these areas come from marble-type deposits. We saw about 50 miners working around Lukande, Kwam Somali, Mayote, Chipa, Ibogoma, Gombe, and Kitonga during the dry season, retrieving cabochon-grade rubies along with smaller facet-grade material. During the rainy season, these workers focus on gold mining or farming.

Our last visit was the region around Songea and Tunduru, where sapphire production began in the 1990s. The Songea deposit, discovered in 1992, was quite productive until the discovery of fine blue, yellow, and pink sapphires near Tunduru in 1994. The deposit was nearly inactive until the early 2000s, when the newly developed beryllium diffusion treatment was able to turn Songea's muddy green and brownish purple stones into attractive yellow to orange sapphires. In Songea, we heard of a new discovery at Amani Makoro, close to the old diggings around Ngembambili and Masuguru. In Amani Makoro, we witnessed about 200 miners in a swampy area using hand tools. The aspect and quality of the stones was similar to those from Ngembambili and Masuguru. Overall, about 300 people are still mining or trading gems around Songea. According to the regional mining officer, nine Thai merchants are registered buyers here. Songea still seems to be Tanzania's most active sapphire mining area.

The region east of Tunduru, located along the Muhuwesi, Lumesule, and Ruvuma rivers and up through Ngapa and Kitowelo, is known to produce blue, yellow, green, pink, and purple sapphires, and rarely rubies. The deposits, discovered by Swiss gem merchant Werner Spaltenstein in 1994, were very active until 1999, when buyers left Tunduru for the newly discovered sapphire deposits of Ilakaka, Madagascar.

A paved road linking Tunduru to the coast and then Songea should be finished in 2017, making these areas much less isolated. Around Tunduru, a new environmental law that forbids mining within 60 meters of a stream or a river is creating issues, as most of the mining there takes place in riverbeds. Last year Mr. Spaltenstein had to stop his mechanized operation because of that law, though local authorities seem to be more tolerant of small-scale miners. While the area is much less active than when VP visited in 2005 and 2008, we estimate that about 400 to 500 miners are working around Tunduru. In the town, we found 10 Sri Lankan and three Thai buying offices. In the main gem-producing area there was a small rush in Ngapa, near Kitowelo and the area known as the "DSM Box" (figure 6). We were told the area produces some good blue, pink, and purple sapphire rough weighing up to 50 ct; fine sapphire of this size was previously unknown in Tunduru. The second most active place was Muhuwesi, where several groups of small-scale miners are reportedly working.

The post-2009 downturn of Tanzania's ruby and sapphire mining was not unexpected, because many of the corundum discoveries triggered rushes that were exploited for short-term gain. Tanzania also faces competition from the world-class ruby deposit in Montepuez. Nevertheless, recent colored stone discoveries point to the vast potential of gem mining in Tanzania.

Vincent Pardieu and Wim Vertriest
GIA, Bangkok

Purple pyrope-almandine garnet from Mozambique. In early 2016, attractive purple garnets from East Africa started to appear in the Bangkok market (T. Sripoonjan and T. Leelawatanasuk, "Preliminary investigation of purple garnet from a new deposit in Mozambique," *GIT Gemstone Update*, 2016, pp. 1–6). Author VP purchased 17 samples (figure 7) at the Bangkok Gem Fair and inquired about their origin. Mark Saul of Swala Gem Traders (Arusha, Tanzania) informed him that the source was a very unstable area of Manica Province in central

Figure 7. These purple pyrope-almandine garnets are from Manica Province of Mozambique. The rough specimens weigh (clockwise from left) 1.49, 1.14, 1.11, and 1.77 ct, while the faceted stone in the center weighs 2.34 ct. Photo by Lhapsin Nillapat.

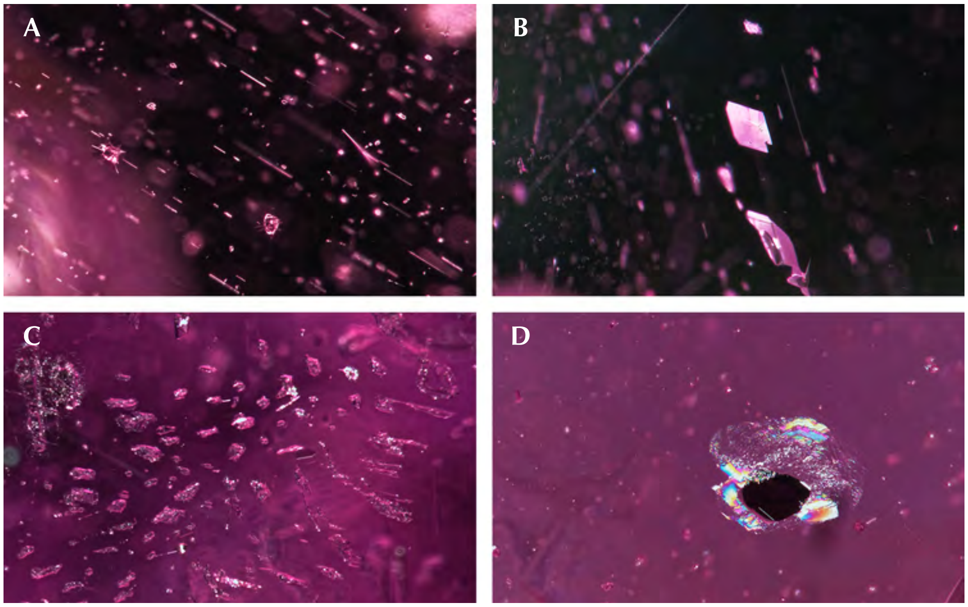


Figure 8. Magnification of the pyrope-almandine garnets revealed several internal features: (A) zircon inclusions with stress halos and needles, field of view 1.4 mm; (B) thin films, field of view 3.5 mm; (C) groups of colorless quartz, field of view 1.8 mm; and (D) a platelet of black graphite, field of view 1.8 mm. Photomicrographs by Victoria Raynaud.

Mozambique. Ameen Ikram, a gem merchant from Sri Lanka, confirmed this after managing to visit the mining site in June 2016. The deposit is located about 60 km northeast of Chimoio, near Gorongosa National Park. The area is under the control of the Mozambican National Resistance (RENAMO), an armed rebel group.

The stones exhibited a vitreous luster. Standard gemological testing yielded an isotropic RI reading of 1.767 ± 0.003 and an SG value of 3.87 ± 0.02. An isotropic reaction with anomalous double refraction (ADR) was observed through the polariscope. The samples were inert when exposed to both long-wave and short-wave UV radiation. Examination with a gemological microscope revealed several internal features (figure 8), including individual and clustered zircon crystals, zircons with stress halos, black platelets of graphite, groups of colorless quartz crystals, thin films, needles, tubes, and iron stains in tubes. Raman spectroscopy was used to identify the mineral inclusions.

Advanced analytical techniques, including UV-Vis-NIR and Fourier-transform infrared (FTIR) spectroscopy and laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS), were used to collect additional information. The UV-Vis-NIR spectrum (figure 9, left) indicated electronic transitions of specific Fe and very weak Mn transition metal ions, as described in the literature (K. Krambrock et al., "Purplish-red almandine garnets with alexandrite-like effect: Causes of colors and color-enhancing treatments," *Physics and Chemistry of Minerals*, Vol. 40, No. 7, 2013, pp.

Figure 9. Left: The purple garnet's UV-Vis-NIR spectrum shows weak absorption bands attributed to Fe^{3+} (337, 367, and 424 nm) and Mn^{2+} (408 nm). The remaining peaks in the visible region (400, 461, 504, 523, 575, 619, and 698 nm) can be assigned to Fe^{2+}. Right: The FTIR spectrum reveals Fe^{2+} bands at 5820 and 4450 cm^{-1}, hydroxyl group features at 3552 and 3525 cm^{-1}, and CO_2 peaks at 2360 and 2341 cm^{-1}. The very small peak at 2627 cm^{-1} may be caused by the samples' numerous inclusions.

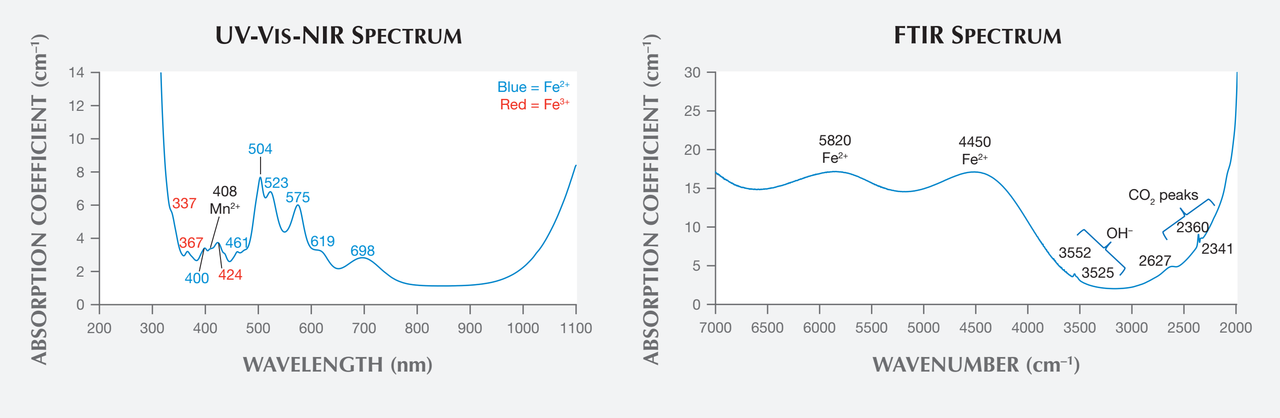


TABLE 1. LA-ICP-MS analyses of pyrope-almandine garnets from Mozambique.

Oxide	Weight (%) ± SD (n = 5)
SiO_2	42.34 ± 0.33
Al_2O_3	25.41 ± 0.22
FeO	17.93 ± 1.31
MgO	13.16 ± 1.19
CaO	0.94 ± 0.20
MnO	0.22 ± 0.02
V_2O_3	0.002 ± 0.001
Cr_2O_3	bdl
TiO_2	bdl

n: number of studied samples
bdl: below detection limit
SD: standard deviation

555–562). All of the samples showed an iron spectrum including Fe^{2+} and Fe^{3+}, and a weak absorption peak at 408 nm was assigned to Mn^{2+}. The FTIR spectrum (figure 9, right) showed Fe^{2+} peaks at 4450 and 5820 cm^{-1} (R.G. Burns, *Mineralogical Applications of Crystal Field Theory*, Vol. 5, Cambridge University Press, Cambridge, UK, 1993, pp. 155–158), hydroxyl group features at around 3500–3600 cm^{-1} (G.R. Rossman et al., "Quantitative analysis of trace OH in garnet and pyroxenes," *American Mineralogist*, Vol. 80, No. 5–6, 1995, pp. 465–474), and CO_2 peaks at 2340–2360 cm^{-1}. A minor FTIR peak at 2627 cm^{-1} might have resulted from the numerous inclusions in the samples. LA-ICP-MS analysis (table 1) revealed major amounts of Si, Al, Fe, and Mg, as well as minor amounts of Ca and Mn. Vanadium was also detected in very low concentrations, while titanium and chromium were below the detection limits. The LA-ICP-MS data confirmed the material's identification as pyrope-almandine garnet with the following chemical components: 48.8–59.5% pyrope, 37.9–47.6% almandine, 2.0–3.5% grossular, and 0.5–0.6% spessartine.

The UV-Vis-NIR spectrum explains the purple color of the samples. Since the main absorption bands dominate the green-yellow regions of the visible spectrum, two strong blue and red transmission regions combine to produce an eye-visible purple color. These samples can be classified as pyrope-almandine garnet, commonly referred to as "rhodolite" garnet.

Supharart Sangsawong, Victoria Raynaud, and
Vincent Pardieu
GIA, Bangkok

Trapiche rhodochrosite. It is not often that a very old locality produces a gem material previously unrecorded in the literature. Yet the Capillitas mine in Argentina's Catamarca Province, once mined by the Incas and long known for its fine rhodochrosite stalactites, has yielded two trapiche-like rhodochrosite gemstones, first observed by the author in August 2014.

The stalactite that produced these two slices was reportedly found in the 1980s. The smaller of the two specimens, a 30 mm round weighing 35 ct (figure 10, left), is a symmetrical example of this rhodochrosite's cogwheel habit. The 40 mm oval, which weighs 56 ct (figure 10, right), was cut from the same stalactite; it is the only other example of this formation the author could locate.

Rhodochrosite from the Capillitas mine typically consists of minute crystalline grains. These two examples, however, are very coarsely crystalline and are quite possibly twinned, which would explain both the unusually large size of these crystals and their obvious symmetry.

Dr. Carl Francis, former curator of the Mineralogical Museum of Harvard University, points out that stalactites of calcite, which are chemically and structurally similar to rhodochrosite, rarely exhibit this type of growth (pers. comm., 2014). The floral pattern of these red gemstones makes them beautiful and incredibly rare.

Russell E. Behnke
Meriden, Connecticut

Figure 10. The trapiche-like rhodochrosite "flower" on the left, measuring 30 mm across and weighing 35 ct, is from Argentina's Capillitas mine. This piece appears to be formed by the intersection of three crystals, with 60° of separation. The 56 ct rhodochrosite specimen on the right, also from the Capillitas mine, measures 40 mm across. Photos by Russell E. Behnke; from the author's collection.

Preliminary study on rubies reportedly from Pokot, Kenya. In July 2016, Christine Muthama and David Pkosing from Pokot Gems Ltd. in Nairobi submitted eight faceted rubies (figure 11) to GIA's Bangkok laboratory. The material came from a new operation in the Pokot area, a marble-type deposit in western Kenya that has been largely inactive since the 1960s. This new production could prove to be an interesting source of cabochon- and facet-grade rubies from East Africa.

The submitted rubies ranged from 0.36 to 4.38 ct and were semitransparent to translucent, with a very fine, milky appearance. Their gemological properties were consistent with ruby from marble-type deposits. The samples displayed strong red fluorescence under long-wave UV radiation and a medium red reaction under short-wave UV. They contained unhealed fractures, planes of negative crystals, fingerprints, and different mineral inclusions such as apatite, calcite, orange and black rutile, chlorite, pyrite, zircon, and amphibole (figure 12), the last of which is uncommon in marble-hosted rubies. Short needles, boehmite, and clouds of reflective particles were also observed.

Since the samples had inclusion features similar to those seen in marble-hosted rubies from Myanmar or Luc Yen, Vietnam, this interesting new Kenyan material could present a challenge in future origin determination studies. Nevertheless, spectroscopy and chemical composition analysis can be used to separate rubies from these deposits. FTIR spectroscopy of all eight samples from Pokot showed the presence of boehmite. LA-ICP-MS analysis revealed a distinguishing trace element composition. The rubies from Pokot had low Fe content (60–252 ppma), along with the following trace element contents: V: 6–11 ppma; Ga: 5–10 ppma; Ti: 29–135 ppma; and Cr: 678–1773 ppma. This combination is quite different from that of known Vietnamese rubies, showing once again that trace element composition is a useful tool for determining the origin of rubies.

Figure 11. These eight rubies (0.36–4.38 ct) are reportedly from Pokot, Kenya. Photo by Lhapsin Nillapat.

Sudarat Saeseaw, Charuwan Khowpong, and Vincent Pardieu
GIA, Bangkok

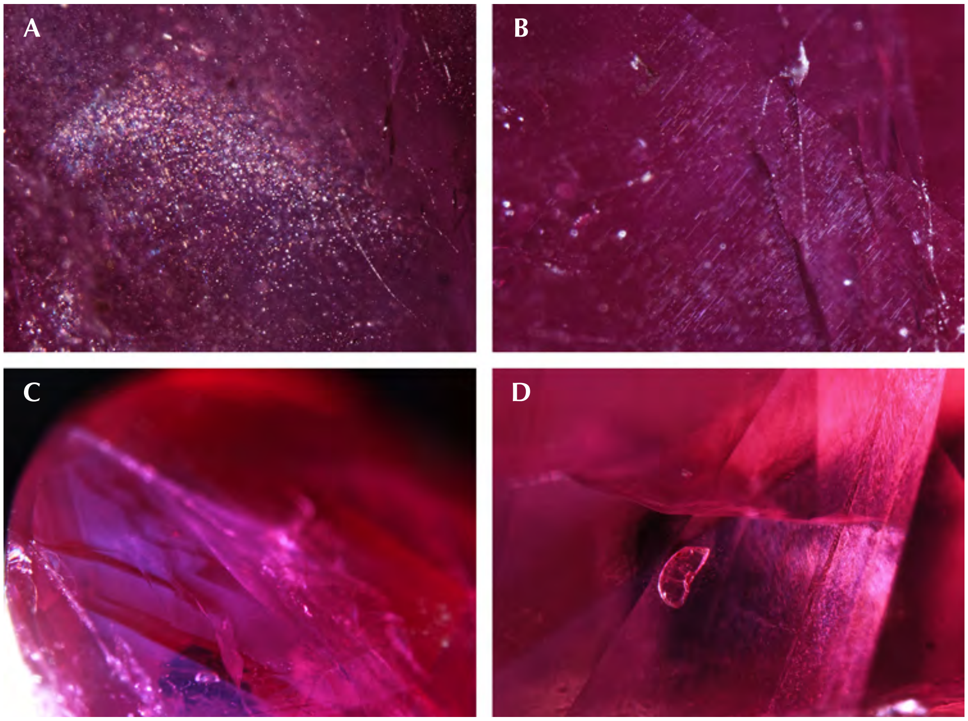


Figure 12. The rubies reportedly from Pokot contained a variety of internal features, including (A) reflective particles, field of view 2.4 mm; (B) very fine short needles, field of view 1.3 mm; (C) very fine milky bands, field of view 4 mm; and (D) an amphibole crystal, field of view 1.3 mm. Photomicrographs by Charuwan Khowpong.

Blue sapphire reportedly from Badakhshan, Afghanistan. Recently, Habib Khan (Royal Gems Stone, Bangkok) donated a parcel of more than 40 rough sapphires to the GIA laboratory in Bangkok. Mr. Khan reported that they were mined from a new deposit in Badakhshan Province of northeastern Afghanistan. A few days later, Kamran Wahidy from the city of Fayzabad informed author VP of a new sapphire deposit near Khash in Badakhshan. This site produces material similar to the stones presented by Mr. Khan. Previous discoveries of corundum around Khash have been reported (Fall 2007 GNI, pp. 263–265; Winter 2010 GNI, pp. 319–320).

The samples (see figure 13) were blue, purplish, or near-colorless. The rough sapphires ranged from 0.9 to 19.6 ct and were transparent to translucent. Standard gemological testing revealed an RI of 1.760–1.768 and an SG of 3.71–3.98. The wide range in SG can be explained by the large pieces of lighter matrix attached to some of the corundum samples. The stones displayed weak orange to inert fluorescence under long-wave UV and were inert under short-wave UV.

All samples were originally covered with a thick, dark greenish black skin that was removed to reveal the blue sapphire inside. Most samples still had some of this skin attached. The skin contained dark green spinel, phlogopite, chlorite, feldspar, amphibole, and tourmaline, which were identified by Raman spectroscopy.

Flat negative crystal fingerprints were commonly seen; some contained CO_2 bubbles and diaspore fibers that became visible at 60× magnification. The samples displayed ladder- or dust-like inclusions similar to those seen in sapphires from Kashmir (figure 14; see H.A. Hänni, "A contribution to distinguishing characteristics of sapphire from Kashmir," *Journal of Gemmology*, Vol. 22, No. 2, 1990, pp. 67–75).

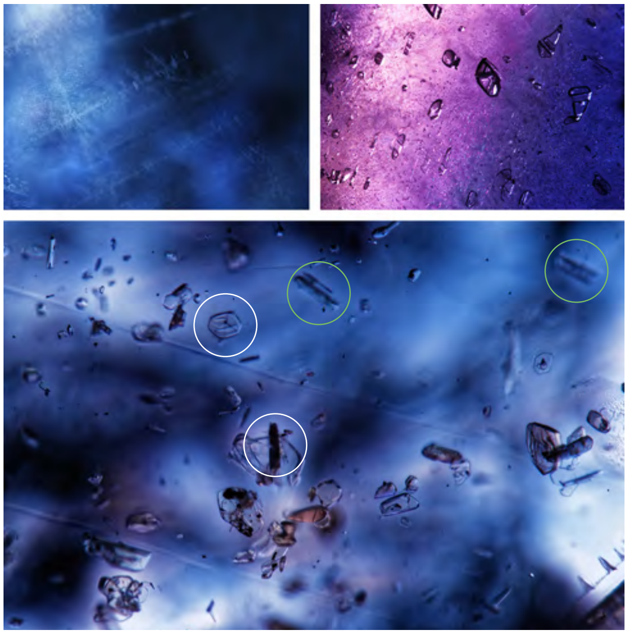


Figure 14. Inclusion scenes in the Badakhshan sapphire. Left: Ladder-like inclusions under darkfield illumination; field of view 2.7 mm. Right: Negative crystals with CO_2 bubbles; field of view 1.8 mm. Bottom: Crystal inclusions of amphibole (green circles) and mica (white circles); field of view 2.4 mm. Photomicrographs by Charuwan Khowpong (left) and Victoria Raynaud (right and bottom).

Figure 13. These blue and purplish sapphires are reportedly from a new deposit near Khash in Badakhshan Province, Afghanistan. The largest stone weighs 19.6 ct and measures 19.2 × 13.9 mm. Photo by Lhapsin Nillapat.

Crystal inclusions were identified (using Raman spectroscopy and the RRUFF reference database) as apatite, amphibole, mica, diaspore, chlorite, tourmaline, feldspar, and spinel. We also observed unidentified clusters of tiny black crystals and crystals that might have been epidote or allanite. FTIR spectroscopy revealed the presence of boehmite, kaolinite, and a peak at 3161 cm^{-1}. LA-ICP-MS showed an iron content between 154 and 402 ppma, while gallium ranged from 7 to 11 ppma.

If confirmed, the discovery of a new blue sapphire deposit near Khash could be interesting for the gem trade in Afghanistan. However, this new material represents a true challenge for gemologists working on origin determination, as its inclusion scene is, in some aspects, very similar to those in sapphires from Kashmir.

Wim Vertriest, Ungkhana Atikarnsakul, Victoria Raynaud,
Charuwan Khowpong, and Vincent Pardieu
GIA, Bangkok

"Punsiri"-type FTIR spectral features in natural yellow sapphires. Recently, a yellow sapphire from Chanthaburi, Thailand, showed a spectrum associated with "Punsiri" high-temperature heat treatment of blue sapphire. In response, GIA's Bangkok lab performed FTIR spectroscopy

Figure 15. Ten of the 38 basalt-related yellow sapphires from this study. The specimens on the left, weighing 0.22–0.41 ct, are from the Anakie area in Queensland, Australia. The material on the right, ranging from 0.41 to 1.40 ct, comes from the Khao Ploi Waen area of Chanthaburi, Thailand. Photo by Nuttapol Kitdee.

on 38 untreated natural basalt-related yellow sapphires (figure 15). Twenty-two of the samples were from the Anakie Gem Fields area in Queensland, Australia, and the remaining 16 from the Khao Ploi Waen area of Chanthaburi. All were collected from the mines by GIA field gemologists.

Standard gemological testing of the Australian sapphires showed RI (n_ω) = 1.774 ± 0.001 and RI (n_ε) = 1.765 ± 0.001, with a birefringence of 0.009 ± 0.001. For the Thai sapphires, RI (n_ω) = 1.773 ± 0.001 and RI (n_ε) = 1.764 ± 0.001, with a birefringence of 0.009 ± 0.001. All the stones were inert under long-wave and short-wave UV radiation due to their very high iron content.

Most of the Australian sapphires were yellow, whereas the Thai sapphires appeared greenish yellow. Only homogeneous yellow areas were analyzed by FTIR. Many of the stones (about 45% of the Australian stones and about 38% of the Thai stones) showed a characteristic Punsiri FTIR spectrum, consisting of a multiple band structure positioned around 2000–3300 cm^{-1} with peaks at 2025, 2137, 2258, 2413, 2463, 2627, 2990, 3032, and 3220 cm^{-1} (figure 16). These features have traditionally been considered indicative of heat treatment, since this pattern has only been observed in Punsiri-type heated blue sapphires (G. DuToit et al., "Beryllium treated blue sapphires: continuing market observations and update including the emergence of larger size stones," *GIA Research News*, June 2009) that display multiband FTIR spectra around 3000 cm^{-1}. This FTIR feature is attributed to the stretching vibration of the OH bond formed by the incorporation of hydrogen and host oxide ion in a publication about "magnesium-doped α-alumina" grown by the Verneuil method, where the IR absorption results are affected by the incorporation of hydrogen into a Mg-doped α-alumina (N. Fukatsu et al., "Incorporation of hydrogen into magnesium-doped α-alumina," *Solid State Ionics*, Vol. 162, 2003, pp. 147–159). Since the samples were all collected in the field, it is extremely interesting to document that Punsiri-type FTIR spectra may be found in natural unheated yellow sapphires.

LA-ICP-MS showed trace elements of Mg, Ti, V, and Ga, with very high ppm levels of Fe (3000 ppma on average). Mg content (about 23 ppma) was higher than Ti content (approximately 16 ppma); thus, blue coloration is not seen in these stones. Since Be was not detected, there are no concerns about beryllium diffusion treatment, which is not surprising since these specimens were collected in the field.

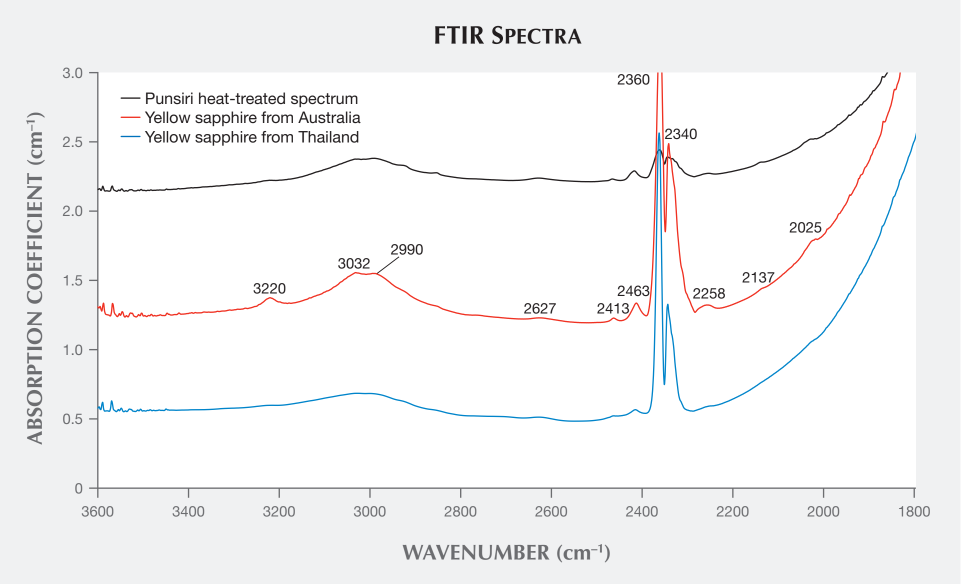


Figure 16. FTIR spectra of natural yellow sapphires from Australia and Thailand in the 1800–3600 cm^{-1} range. The peaks shown here are similar to those observed in Punsiri heat-treated blue sapphire (black spectrum). Peaks at 2360 and 2340 cm^{-1} are related to CO_2. Please note that the absorption coefficient of the Punsiri heat-treated blue sapphire (black spectrum) at the y-axis was divided by two.

Figure 17. This 15.54 ct triangular modified brilliant faceted amethyst (left) features a large aqueous primary fluid inclusion (right; field of view 7.19 mm). Photos by Jonathan Muyal.

It appears as though the incorporation of hydrogen in corundum may form characteristic Punsiri-like FTIR features. Since these features were observed in natural basalt-related yellow sapphires from Australia and Thailand, careful consideration must be exercised when using FTIR to identify heat treatment in corundum.

Supharart Sangsawong, Vincent Pardieu, Victoria Raynaud, and Sasithorn Engniwat
GIA, Bangkok

Large aqueous primary fluid inclusion in amethyst. A triangular modified brilliant was submitted to GIA's Carlsbad laboratory by L. Allen Brown (All That Glitters, Methuen, Massachusetts) for scientific examination. The 15.54 ct stone (figure 17, left) was presented as a Moroccan amethyst. Standard gemological testing established the following properties: RI—1.544–1.553; birefringence—0.009; optic sign—uniaxial positive; pleochroism—moderate purplish blue to purple; SG—2.65; fluorescence reaction—inert to long- and short-wave UV radiation. All of these properties were consistent with amethyst. What made this example notable was a strikingly large primary fluid inclusion under the table facet, which is easily seen with the unaided eye and confirms the natural origin of this stone (figure 17, right). The gas bubble in the fluid inclusion moves freely when the stone is turned slightly. No magnification is needed to reveal the beauty of this interactive inclusion, which can be easily enjoyed by rocking and tilting the stone.

Ziyin Sun and Jonathan Muyal
GIA, Carlsbad

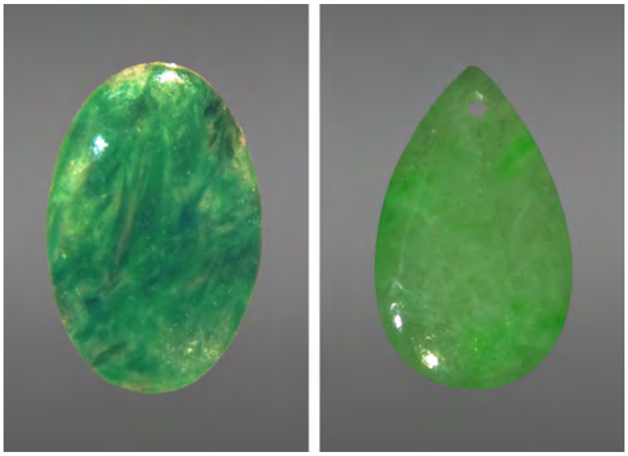
TREATMENTS

Application of the DiamondView in separating impregnated jadeite. Infrared and Raman spectroscopy are frequently used to separate impregnated jadeite jade from untreated material. Recent trials show that the DiamondView instrument provides reliable results in detecting impregnated material, offering gemologists a new identification method.

The Lai Tai-An Gem Lab in Taipei analyzed two client-submitted jadeite samples (figure 18): a 4.91 ct oval measuring approximately 19.64 × 11.78 × 2.62 mm and a 0.32 ct pear-shaped drop measuring 7.77 × 5.91 × 0.95 mm. The oval possessed a mottled dark and light green bodycolor, while the pear shape exhibited a more uniform, lighter green bodycolor. Both pieces were translucent. Standard gemological testing showed spot RIs of 1.66 and SGs of 3.30 for the oval and 3.24 for the pear. A handheld spectroscope revealed lines at 630, 655, and 691 nm, indicative of naturally colored jadeite; both samples were inert to long-wave and short-wave UV fluorescence. Microscopic observation revealed fine surface-reaching networks of cracks and uncovered the "cobweb-like" features characteristic of bleached jadeite. However, DiamondView imaging produced striking blue reactions (figure 19), clearly indicating that both jadeites had been impregnated.

We confirmed that the samples were impregnated jadeite using the advanced methods commonly applied in such cases. FTIR spectroscopy revealed absorptions at 3061, 3037, 2965, 2925, and 2874 cm^{-1} (figure 20), while Raman spectroscopy using a 532 nm laser showed peaks at 638, 1112, 1608, and 3066 cm^{-1}. Both offered proof that an epoxy was used as the impregnation material.

Figure 18. The two jadeite samples exhibited a mottled dark and light green bodycolor (left, 4.91 ct oval) and a uniform lighter green bodycolor (right, 0.32 ct pear). Photos by Lai Tai-An Gem Lab.



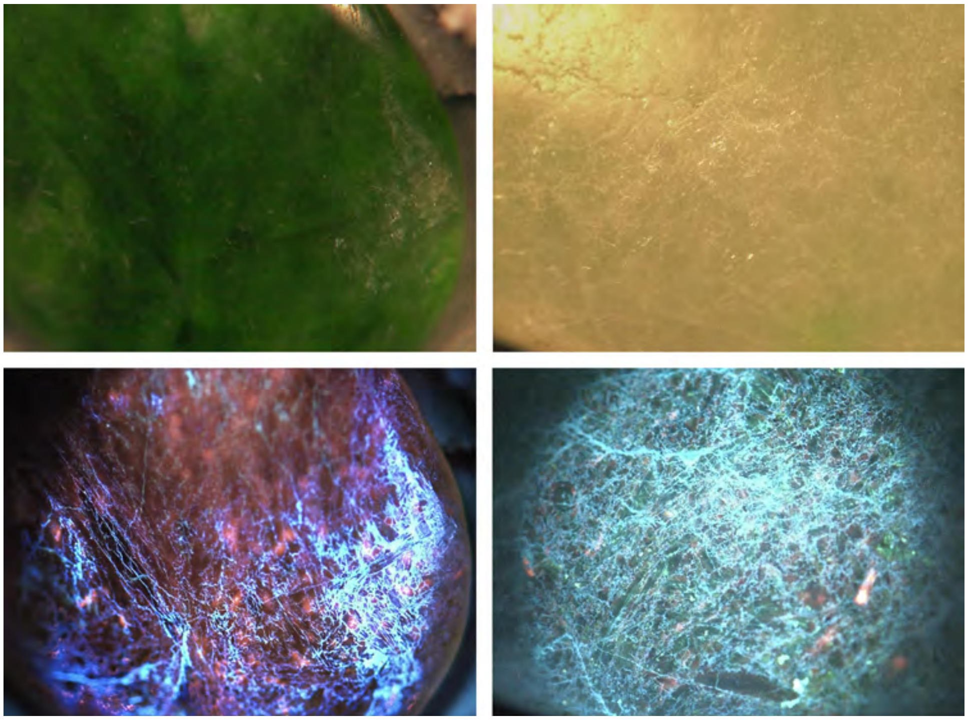
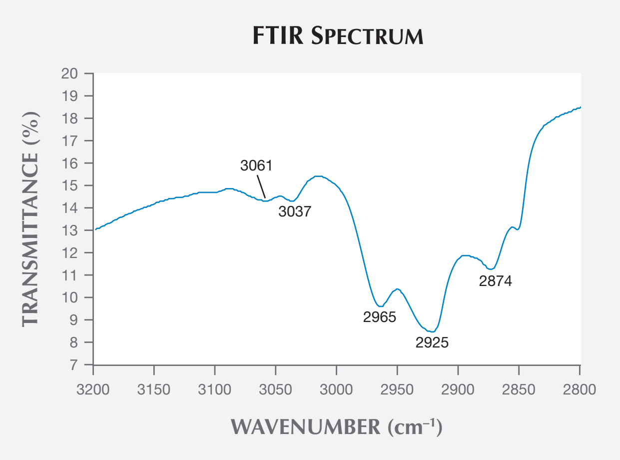


Figure 19. DiamondView imaging of the jadeite samples. Top: Both the oval (left) and the pear shape (right) displayed the "cobweb" feature under visible light. Bottom: The DiamondView's UV light produced striking blue reactions in the cobweb structure, indicating impregnation in both jadeites. Images by Lai Tai-An Gem Lab.

DiamondView imaging is effective in alerting gemologists to possible impregnation in jadeite. While more samples need to be examined, this technique could be a simple and effective way to identify impregnation treatment.

Larry Tai-An Lai (service@laitaian.com.tw)
Lai Tai-An Gem Laboratory, Taipei

Figure 20. Peaks in the jadeite sample's FTIR spectrum at 3061, 3037, 2965, 2925, and 2874 cm^{-1} proved that an epoxy was used as the impregnation material.



CONFERENCE REPORTS

Gem Materials at the Second European Mineralogical Conference (emc2016). The European Mineralogical Conference, organized by the Italian Society of Mineralogy and Petrology (SIMP) and the Universities of Ferrara and Padova, was held in Rimini, Italy, September 11–15. Among the event's 28 sessions was "Gem Materials," chaired by **this contributor**, **Lee Groat** (University of British Columbia, Vancouver, Canada), **Federico Pezzotta** (Museum of Natural History, Milan), and **David Turner** (University of British Columbia). "Gem Materials" yielded both an oral and a poster session.

The poster session, held September 13, covered topics such as worldwide emerald sources; red beryl; demantoid from Madagascar; turquoise from the collections of the Royal Mineralogical Museum of Naples; epidote from Val Malenco, Italy; and rhodonite from the Swiss Alps. There was also a review of colored gems in art and gemology, as well as experimental work applied to gems from miarolitic pegmatites.

The September 15 oral session featured 14 presentations. **Dan Marshall** (Simon Fraser University, Burnaby, Canada) opened with a keynote address on a reclassification of emerald deposit formation models based on tectonic and metamorphic conditions. **Emmanuel Fritsch** (Institut des Matériaux, Jean Rouxel, University of Nantes, France) posed the question of why some minerals are gem quality, using crystal growth as a consideration.

Peter Bačik (Comenius University, Bratislava, Slovakia) began the presentations on Cr- and V-bearing minerals with spectrometric characterizations of ruby, spinel, chrysoberyl, diopside, garnet, zoisite, emerald, and tourmaline. **Isabella**

Pignatelli (French National Center of Research, Vandœuvre) studied the Cr- and V-bearing euclase from the Gachala mining district of Colombia, focusing on atypical texture formed by solid inclusions trapped along crystallographic axes. Her presentation opened a discussion of trapiche vs. trapiche-like textures. **Dan Marshall** spoke again, this time on fluid inclusions and stable isotope data from emerald in Western Australia's Poona deposit, showing multiple generations of emerald combined with metamorphic and magmatic fluid circulations. **This contributor** demonstrated that it was possible to decipher the geographic origin of pink and red spinel through oxygen isotopes and trace-element data on pink and red spinels in marble, with a special focus on the Kul-i-Lal mine in Tajikistan. **Stefanos Karampelas** (GemResearch Swisslab, Adligenswil, Switzerland) offered new insights on detection of heat treatment of tanzanite, indicating that this form of treatment can only be identified under very specific circumstances.

Aaron C. Palke (University of Queensland and Queensland Museum, Brisbane, Australia) presented on melt inclusions in sapphires from Montana's Yogo deposit, which are similar in composition and mineralogy to the ocelli observed in the Yogo lamprophyres. **David Turner** offered new mineralogical insights from near-field hyperspectral imaging of sapphire-bearing marble at Baffin Island, Canada.

The silica family was covered in three presentations. **Benjamin Rondeau** (University of Nantes) related the presence of numerous minerals (including an unknown type) from the lazulite-bearing blue quartzite from Itremo, Madagascar. **Ilaria Adamo** (Italian Gemological Institute, Milan) characterized blue and white banded chalcedony (agate) from Yozgat Province in Turkey. The agate formed from mixture of quartz and moganite, but the origin of the blue color is unknown, since iron content at approximately 10 ppm is constant in all the banding. **Boris Chauviré** (University of Nantes) explained a model for the formation of precious opal from Wegel Tena, Ethiopia. The model suggests a paleotopographic control on the location of the deposits and the repetition of the soil formation process in space and time.

Special topics related to gem museums and historical writings were also covered. **William B. "Skip" Simmons** (Maine Mineral and Gem Museum, Bethel) retraced the state's recent and historical gem production and the museum's acquisitions from Maine pegmatites. **Ann C. Pizzorusso** (Naples, Italy) tackled the gems of Dante's *Divine Comedy*, discussing the gemological knowledge of the late Middle Ages and the meanings associated with precious metals, pearls, rubies, diamonds, and other gems.

Details from the European Mineralogical Conference are available at http://emc2016.socminpet.it.The next conference will take place in 2020 at a site to be determined.

Gaston Giuliani
Institute for Research and Development
Toulouse, France
French National Center of Research, Vandœuvre

GSA 2016 annual meeting. The Geological Society of America (GSA) held its annual meeting September 25–28 in Denver, Colorado. This was the fourth meeting in which GIA hosted gemological technical sessions. In the oral and poster sessions, gemologists, geoscientists, and students from all over the world came together to present their research and discuss advanced topics.

Invited speaker **Jeffrey Post** (Smithsonian Institution, Washington DC) presented detailed studies on a selection of significant fancy-color diamonds, including blue, pink, and chameleon stones. Among these, the researchers applied time-of-flight secondary ion mass spectrometry (ToF-SIMS) analysis to the Hope diamond, which allowed the measurement of total boron concentration; the results revealed strong zoning from this chromophore in many blue diamonds. **Graham Pearson** (University of Alberta, Canada) reported on his study of the saline fluid inclusions preserved in some diamonds from the Ekati and Diavik mines and pointed out that alkali- and Cl-rich fluids play a key role in diamond formation. Invited speaker **Emmanuel Fritsch** (University of Nantes, France) discussed the state of synthetic diamond identification. He also noted the advantages and limitations of some of the most commonly used sorting methods.

GIA researchers shared their results on several diamond-related projects. **Christopher M. Breeding** showed the fluorescence colors and patterns that diamonds can display when exposed to ultraviolet light. In addition to their beauty, these colors and patterns are important in diamond formation studies and the identification of natural, treated, and synthetic material. **Karen Smit** presented new data on a suite of canary diamonds from Sierra Leone. This will allow researchers to further specify the source fluids and color-forming defects of these yellow diamonds and better correlate their features to the unusual geological formation history of the Zimmi diamond deposit. **Evan Smith** reported his findings on inclusions in thousands of high-quality type II polished diamonds and trimmed-off portions. The recurring set of inclusions in many stones includes a metallic multi-phase assemblage and retrogressed former perovskite phases. Together, the two inclusion types revealed a unique paragenesis for these large, top-quality diamonds.

Presentations on colored gemstone research revealed a variety of studies on important gem species and collector stones. **Mandy Krebs** (University of Alberta) reported on Pb-Pb geochronology of rubies and the first-ever radiometric age determination of ruby. This new method allows dating to be done directly on the ruby itself rather than on inclusions such as zircon. This dramatically broadens the application of geochronology in ruby provenance determination. **Jullieta Lum** (University of Johannesburg) presented major and trace element composition of emerald and aquamarine collected from central Namibia and South Africa. **Peter Heaney** (Penn State University) revealed the cause of iridescence in metamorphic hematite from Minas Gerais, Brazil. The study by Dr. Heaney and his former student Xiayang Lin found that this phenomenon is caused by a framework of well-oriented hematite nanorods. **Raquel Alonso-Perez** (Harvard University) presented preliminary results on the geochemistry of emeralds from the Irondro deposit in Madagascar.

Important research on gemstone formation was also delivered. **Yury Klyukin** (Virginia Tech) addressed the valuable information that fluid and melt inclusion studies can provide in solving gem formation problems, using diamond, emerald, and corundum as examples. Invited speaker **David London** (University of Oklahoma) discussed the different mechanisms that caused zonation within pegmatites. Understanding of mineral segregation within pegmatites is critical for gem exploration.

The poster session presenters included two graduate students from the China University of Geosciences (Wuhan). **Chengsi Wang** proved the robustness of photoluminescence (PL) spectroscopy in treated and synthetic spinel identification through a series of heating and annealing experiments. **Yuan Zheng** applied linear discriminant analysis (LDA) in separating hundreds of turquoise samples from three different sources after analyzing their trace elements using ICP-MS.

GIA staff also presented interesting discoveries in the poster session. **Wuyi Wang** studied the distribution of the SiV^- defect and found that it has a dramatically different correlation with Ni_i^+ between natural and HPHT synthetic diamonds. **Paul Johnson** demonstrated that hydrogen-rich diamonds with intensive inclusions and fractures can be heated to generate a more uniform black color. Based on his experience, microscopic observation remains the most powerful tool in identifying this treatment. **Troy Ardon** and **Sally Eaton-Magaña** conducted a series of annealing experiments at different temperatures with two hydrogen-rich Zimbabwe diamond plates. They evaluated the effect of high temperature on the diamonds' spectroscopic features and inclusions. **Rose Tozer** examined one of the rarest publications in the GIA library collection: *Russia's Treasure of Diamonds and Precious Stones*. Edited by the well-known mineralogist A.E. Fersman, this book documents Russia's regalia and crown jewels at the time of the February Revolution in 1917. The volume has been digitized as part of GIA's project to digitize items from its rare book collection and can be accessed free of charge at https://archive.org/details/gialibrary.

Abstracts from the two gemological sessions can be found at https://gsa.confex.com/gsa/2016AM/webprogram/Session40327.html (oral) and https://gsa.confex.com/gsa/2016AM/webprogram/Session41331.html (poster). The 2017 meeting will be held October 22–25 in Seattle.

Tao Hsu, Jim Shigley, and Dona Dirlam
GIA, Carlsbad

IN MEMORIAM

Fred Ward (1935–2016). *Gems & Gemology* mourns the loss of acclaimed photographer and gemologist Fred Ward, who died July 19 at the age of 81. Mr. Ward was known for capturing iconic images of celebrities and for his work with *National Geographic* magazine, which sparked his gemological pursuits.

Mr. Ward was born in Huntsville, Alabama, and grew up in Miami. His passion for photography blossomed in high school, when he decided to turn his extracurricular activity into a career. He earned a master's degree in journalism from the University of Florida in 1959.

Well known for his shots of President John F. Kennedy's funeral in November 1963 and the Beatles' first American performance (1964), he photographed Gerald Ford for *Portrait of a President* (1975). Mr. Ward's work can be found in collections owned by the Metropolitan Museum of Art and the Library of Congress, among others. Mr. Ward became interested in gemology as a freelance photographer for *National Geographic*, where he worked on several assignments related to gems. He went on to publish the highly influential nine-volume Fred Ward Gem Book Series. He earned his Graduate Gemologist diploma from GIA in 1990 and was a member of the Washington, DC chapter of the GIA Alumni Association. He was a coauthor of *G&G*'s Spring 2000 article "Burmese Jade: The Inscrutable Gem."

Fred Ward is survived by his wife of 58 years and frequent collaborator Charlotte Mayes Ward, four children, and four grandchildren. We extend our deepest condolences to his family and friends.

ERRATA

1. In the Summer 2016 field report retracing Peter Rainier's time in Chivor, Colombia, the publication date of Fritz Klein's *Smaragde unter dem Urwald* was incorrectly listed as 1925 (p. 175). The correct date for the first edition is 1941.

2. The Summer 2016 Chivor field report also stated that Klein first returned to Germany from Colombia in 1914 (p. 176). However, Klein's own book states that he left Colombia in January 1915. It was impossible for him to have worked for Francisco Restrepo on his return from Germany after World War I in 1919, as Restrepo had died in 1914 at the mine. The authors thank Dr. Karl Schmetzer for bringing these errata to our attention.