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Brendan M. Laurs

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Franck Notari, GGTL GemLab–GemTechLab, Geneva, Switzerland (franck.notari@gemtechlab.ch)

Kenneth Scarratt, GIA, Bangkok, Thailand (ken.scarratt@gia.edu)

**COLORED STONES AND ORGANIC MATERIALS**

**Beryl from Kaduna State, Nigeria.** In April 2011, Dudley Blauwet (Dudley Blauwet Gems, Louisville, Colorado) informed GIA about new production of blue-gray, blue-green, and green (including emerald green) beryl from previously known deposits near Gwantu, in the Kaduna State of north-central Nigeria (D. Schwarz et al., “Emerald and green beryl from central Nigeria,” *Journal of Gemmology*, Vol. 25, No. 2, 1996, pp. 117–141). He obtained the rough material from Nigerian suppliers at the February 2011 Tucson gem shows. From 69.9 grams of rough, he cut 63 faceted stones totaling 78.27 carats and three cabochons with a combined weight of 32.78 carats. Mr. Blauwet noted that despite the saturation of the green stones, none of them exhibited any pink or red reaction when viewed with the Chelsea filter. He loaned 11 samples (nine faceted stones [figure 1] and two cabochons) to GIA, and these were examined for comparison with the properties listed by Schwarz et al. (1996) and by T. Lind et al. (“Blue and green beryls [aquamarines and emeralds] of gem quality from Nigeria,” *Journal of Gemmology*, Vol. 20, No. 1, 1986, pp. 40–48).

The nine faceted stones were separated by hue into three groups, and standard gemological properties were determined. **Group 1** (3.03 and 3.89 ct) samples were light blue, and showed: pleochroism—strong blue and near colorless; RI— $n_o = 1.575\text{--}1.573$ ,  $n_e = 1.568\text{--}1.570$ ; birefringence—0.005; hydrostatic SG—2.68 and 2.71; and an absorption line



Figure 1. The recently produced beryls from Kaduna State, Nigeria, range from aquamarine (top two stones, 3.03 and 3.89 ct) to emerald (bottom, 0.87 ct). Photo by Robert Weldon.

at ~427 nm visible with the desk-model spectroscope. **Group 2** (0.84, 0.97, 1.52, and 1.74 ct) samples were light bluish green and greenish blue, and showed: pleochroism—strong yellow and green, except for strong blue and near colorless in the 1.52 ct sample; RI— $n_o = 1.574\text{--}1.575$ ,  $n_e = 1.568\text{--}1.570$ ; birefringence—0.005–0.006; hydrostatic SG—2.63–2.69; and an absorption line at ~427 nm and weak lines near 700 nm visible with the desk-model spectroscope. **Group 3** (0.87, 3.36, and 3.50 ct) samples were emerald green and showed: pleochroism—strong yellowish green and bluish green; RI— $n_o = 1.573\text{--}1.575$ ,  $n_e = 1.568\text{--}1.569$ ; birefringence—0.005–0.007; hydrostatic SG—2.62–2.65; and absorption lines near 700 nm visible with the desk-model spectroscope. All of the samples were inert to long- and

*Editor's note: Interested contributors should send information and illustrations to Justin Hunter at [justin.hunter@gia.edu](mailto:justin.hunter@gia.edu) or GIA, The Robert Mouawad Campus, 5345 Armada Drive, Carlsbad, CA 92008.*

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Figure 2. The Kaduna beryls contained fluid inclusions with various morphologies, as shown by these jagged (A, magnified 112 $\times$ ), and elongate (B, 112 $\times$ ) three-phase inclusions. The aquamarines also showed angular growth structures (C, 30 $\times$ ). Photomicrographs by P. Cevallos.

short-wave UV radiation. Microscopic examination of samples from all three groups revealed equidimensional to elongate two- and three-phase fluid inclusions (figures 2A and 2B) and partially healed fractures. In addition, the two Group 1 stones (aquamarines) contained transparent crystals and well-defined angular growth structures (figure 2C). The gemological properties shown by all three groups are con-

sistent with those reported by Lind et al. (1986) and Schwarz et al. (1996).

Electron microprobe analysis of the faceted samples (table 1) was performed at the University of New Orleans. Beryls from Groups 1 and 2 contained variable Fe, and no Cr or V except for one sample (0.97 ct). Group 3 samples contained a similar range of Fe contents in addition to

**TABLE 1.** Average electron microprobe analyses of beryls from Kaduna, Nigeria.<sup>a</sup>

Group	1		2				3		
	Blue	Blue	Greenish blue	Bluish green	Bluish green	Bluish green	Green	Green	Green
Color	Blue	Blue	Greenish blue	Bluish green	Bluish green	Bluish green	Green	Green	Green
Weight (ct)	3.03	3.89	1.52	0.84	0.97	1.74	0.87	3.36	3.50
Oxides (Weight %)									
SiO <sub>2</sub>	65.90	65.95	65.87	65.76	65.96	65.86	65.62	65.86	65.77
Al <sub>2</sub> O <sub>3</sub>	18.56	18.58	17.86	18.47	18.66	17.79	17.17	18.63	18.30
Cr <sub>2</sub> O <sub>3</sub>	bdl	bdl	bdl	bdl	0.02	bdl	0.02	0.02	0.03
V <sub>2</sub> O <sub>3</sub>	bdl	bdl	bdl	bdl	0.05	bdl	0.01	0.01	0.04
BeO	13.77	13.80	13.63	13.73	13.77	13.63	13.51	13.80	13.70
FeO <sup>b</sup>	0.83	1.19	0.20	0.86	0.29	0.49	0.20	0.94	0.59
MnO	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.01	bdl
MgO	bdl	bdl	0.02	bdl	bdl	0.01	0.31	0.04	0.04
CaO	bdl	bdl	bdl	0.03	bdl	bdl	0.01	bdl	bdl
Na <sub>2</sub> O	0.06	0.05	0.16	0.05	0.11	0.16	0.03	0.16	0.03
K <sub>2</sub> O	0.02	0.03	0.05	0.03	0.03	0.03	0.04	0.02	0.02
Total <sup>c</sup>	99.15	99.62	97.80	98.93	98.87	97.96	96.93	99.49	98.52
Ions per 18 oxygens									
Si	5.976	5.965	6.035	5.978	5.983	6.032	6.063	5.961	5.994
Al	1.985	1.982	1.930	1.979	1.996	1.921	1.870	1.988	1.967
Cr	bdl	bdl	bdl	bdl	0.001	bdl	0.002	0.001	0.002
V	bdl	bdl	bdl	bdl	0.003	bdl	0.001	0.001	0.003
Be	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000	3.000
Fe <sup>2+</sup>	0.063	0.090	0.015	0.065	0.022	0.037	0.016	0.071	0.045
Mn	bdl	bdl	bdl	bdl	bdl	bdl	bdl	0.001	bdl
Mg	bdl	bdl	0.003	bdl	bdl	0.001	0.043	0.005	0.006
Ca	bdl	bdl	bdl	0.003	bdl	bdl	0.001	bdl	bdl
Na	0.011	0.010	0.028	0.009	0.019	0.028	0.006	0.029	0.005
K	0.002	0.004	0.006	0.003	0.003	0.004	0.005	0.003	0.002

<sup>a</sup> BeO was calculated based on an assumed stoichiometry of 3 Be atoms per formula unit. Analytical standards included both natural and synthetic materials: sillimanite (Si and Al), clinopyroxene (Mg, Ca, Fe, and Ti), rhodonite (Mn), chromite (Cr), V<sub>2</sub>O<sub>5</sub> (V), albite (Na), and adularia (K). MAN standards in addition to the above standards were MgO, hematite, and rutile. Abbreviation: bdl = below detection limit. Detection limits (in wt.%): Cr<sub>2</sub>O<sub>3</sub> = 0.012, V<sub>2</sub>O<sub>3</sub> = 0.009, MnO = 0.005, MgO = 0.009, and CaO = 0.007; TiO<sub>2</sub> was below the detection limit (0.009) in all analyses.

<sup>b</sup> All Fe is reported as FeO.

<sup>c</sup> Analyses do not include H<sub>2</sub>O.

traces of Cr and V. The levels of Fe reported here are similar to those listed by Lind et al. (1986) and Schwarz et al. (1996), but those authors documented higher amounts of Cr and V in some of their samples.

UV-Vis-NIR spectroscopy (figure 3) of all the beryls showed broad Fe<sup>2+</sup> absorption at 817–820 nm and bands at approximately 373 and 427 nm that corresponded to Fe<sup>3+</sup>. In addition, Group 2 samples also had very weak to moderate peaks due to superimposed Cr<sup>3+</sup> and V<sup>3+</sup> absorptions near 683 nm, while Group 3 stones displayed well-defined Cr<sup>3+</sup> and V<sup>3+</sup> absorptions from ~630 to 683 nm. These spectral features are comparable to those given by Lind et al. (1986) and Schwarz et al. (1996).

Infrared spectroscopy recorded a weak band at 2358 cm<sup>-1</sup> (related to CO<sub>2</sub> in the structural channels) and a stronger absorption at 2328 cm<sup>-1</sup> in all samples. In addition, Group 3 samples showed a weak band at 2290 cm<sup>-1</sup>.

As documented in previous studies, this suite of recently produced beryls shows a complete gradation from aquamarine to emerald, with the greener colors due to Cr<sup>3+</sup> and V<sup>3+</sup>.

*Pamela Cevallos (pcevallo@gia.edu)  
GIA, New York*

*William B. (Skip) Simmons and Alexander U. Falster  
University of New Orleans, Louisiana*

**Green and orangy yellow calcite from Pakistan.** Mehul Durlabhji, co-convener of the Gem Testing Laboratory of Jaipur, India, recently brought two cabochons to this contributor for identification (figure 4). The specimens, one green and one orangy yellow, were obtained from a dealer who said that large quantities were being mined from a marble quarry in the Pakistani province of Baluchistan. At first glance, both resembled opal or chalcedony, but gemological and spectroscopic testing proved otherwise.

The 16.77 ct green cabochon measured 20.51 × 13.87 × 7.57 mm, while the 32.06 ct orangy yellow stone was 20.91 × 17.37 × 12.35 mm. Both had a spot RI of ~1.56, with the large birefringence blink typically seen in carbonate minerals, and a hydrostatic SG of 2.72. The orangy yellow cabochon fluoresced yellow to long- and short-wave UV radiation, while the green sample was inert. No absorption features were seen in either stone with a desk-model spectroscope. While observing the stones in various directions under a lamp, banding was seen along their length (e.g., figure 5), indicating a layered growth. These bands were quite prominent and widely spaced, unlike those seen in chalcedony. At higher magnification, fine acicular to fibrous inclusions oriented perpendicular to the direction of banding were visible (figure 6). Such an inclusion pattern is a common feature in minerals showing botryoidal growth, such as malachite or chalcedony; however, this structure was not visible in these two samples. The growth features indicated that the specimens were not single crystals but compact masses of fine acicular crystals, similar to those in “satin-spar,” the term used for a variety of gypsum with parallel fibrous crystals

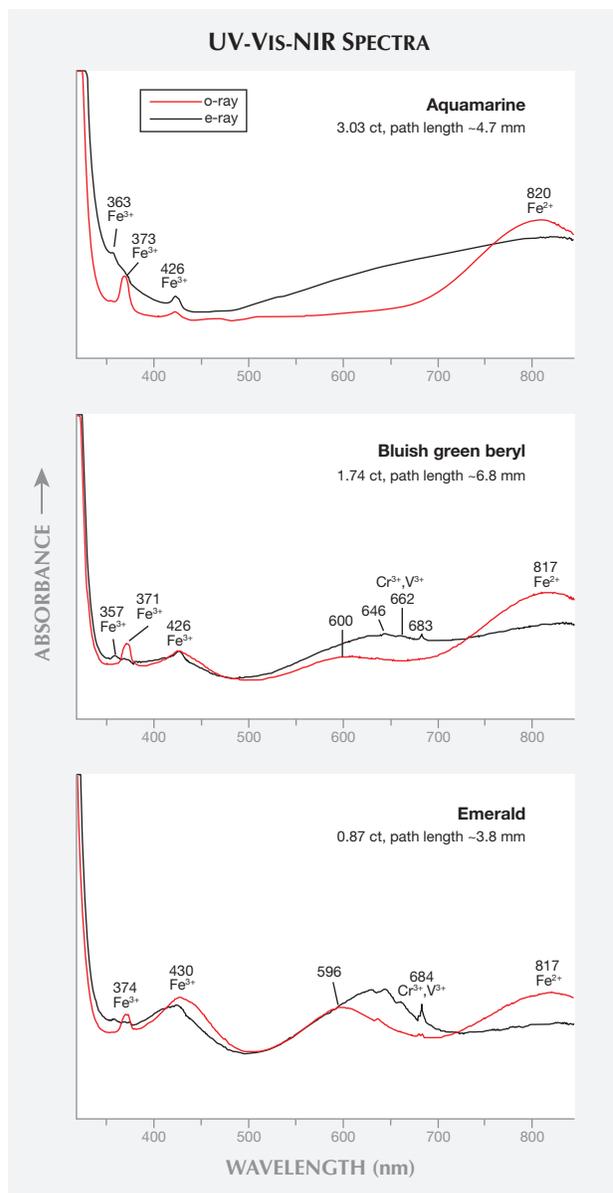


Figure 3. Polarized UV-Vis-NIR spectroscopy of the beryls showed features due to Fe<sup>2+</sup> and Fe<sup>3+</sup>, as well as Cr<sup>3+</sup> and V<sup>3+</sup> in the greener samples.

(see, e.g., R. Webster, *Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, UK, 1994, pp. 307–308 and 310).

FTIR spectroscopy revealed two bands at around 4520–4200 cm<sup>-1</sup> and 4150–3870 cm<sup>-1</sup>, as well as complete absorption to 3750 cm<sup>-1</sup>. These features are characteristic of carbonate minerals such as calcite. Qualitative energy-dispersive X-ray fluorescence (EDXRF) spectroscopy of both cabochons revealed the presence of Ca (as expected for calcite), as well as traces of Cu and Mn in the green sample and traces of Sr in the orangy yellow one.

Identification of these calcite varieties is straightfor-



Figure 4. These green and orangy yellow cabochons (16.77 and 32.06 ct, respectively) proved to be calcite, reportedly mined from Pakistan's Baluchistan province. Photo by G. Choudhary.

ward using standard gemological techniques. Despite their low hardness, they add to Pakistan's wide range of available gem materials.

Gagan Choudhary (gagan@gjepcindia.com)  
Gem Testing Laboratory, Jaipur, India

**Citrine from Zambia.** In September 2011, GIA was informed by gem and mineral dealer Dudley Blauwet about a new find of citrine, which was represented to him as natural-color material from the Kitwe area of Zambia. He obtained ~1 kg of the rough at the 2011 Tucson gem shows from a regular supplier of African rough. Faceting of 208.5 grams of rough yielded 29 stones totaling 268.08 carats. Four of the stones were concave cut, and the largest one weighed 48.69 ct.

Mr. Blauwet loaned seven of the cut citrines to GIA for examination, ranging from 3.38 to 43.86 ct (figure 7). Concave facets on the three largest pieces accentuated their brilliance. The color of the citrine ranged from pale slightly brownish yellow to brownish orangy yellow, and the seven stones showed the following gemological properties: RI— $n_o = 1.542$ ,  $n_e = 1.552$ ; birefringence—0.010; hydrostatic

SG—2.65–2.66; UV fluorescence—inert to both long- and short-wave UV radiation, except for one pale yellow sample that fluoresced very weak white to long-wave UV; and no features seen with the desk-model spectroscope. Microscopic examination revealed straight and angular color zones, as well as a general haziness and bands of hazy particles (figure 8), which proved natural origin and were similar to those described in citrine from Sri Lanka (E. J. Gübelin and J. I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 2, Opinio Publishers, Basel, Switzerland, 2005, p. 573). The 3.38 ct stone also contained a plane of parallel tubules and two-phase inclusions (figure 9). Viewed with cross-polarized light, minor areas of Brazil-law twinning were seen in only the two smallest samples.

FTIR spectroscopy revealed the absence of a  $3595\text{ cm}^{-1}$  band. This feature is sometimes used as confirmation of natural quartz, especially amethyst, when it is well resolved and there are no diagnostic natural inclusions (S. Karampelas et al., "Infrared spectroscopy of natural vs. synthetic amethyst: An update," Fall 2011 *G&G*, pp. 196–201). In citrine this feature is often absent, so proper identification must rely on inclusion observation, or the analysis of trace elements (C. M. Breeding, "Using LA-ICP-MS analysis for

Figure 5. In certain directions, the calcites displayed banding along their length, indicating layered growth. The pattern was readily apparent in the green sample but more subtle in the orangy yellow stone. Photo by G. Choudhary.

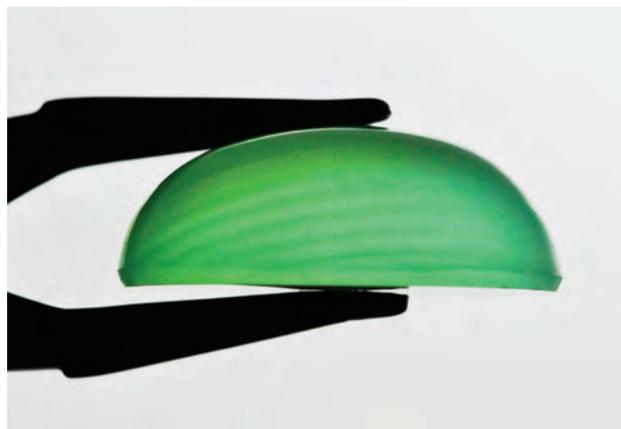


Figure 6. At higher magnification, both calcites displayed fine acicular to fibrous inclusions oriented perpendicular to the direction of banding. Photomicrograph by G. Choudhary; magnified 64x.

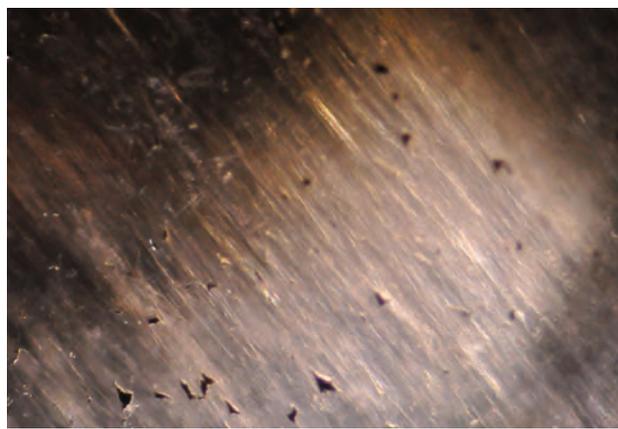




Figure 7. These citrines (3.38–43.86 ct) showing the range of color from the new Zambian deposit are reportedly untreated. Photo by Robert Weldon.

the separation of natural and synthetic amethyst and citrine," [www.gia.edu/research-resources/news-from-research/LA-ICP-MS-quartz.pdf](http://www.gia.edu/research-resources/news-from-research/LA-ICP-MS-quartz.pdf)).

Natural-color citrine is less common than other quartz varieties such as amethyst and smoky quartz. Assuming that the coloration of this citrine is natural—as represented by the supplier—this large, clean material makes a nice addition to the gem market.

*Donna Beaton (donna.beaton@gia.edu)  
GIA, New York*

Figure 8. Hazy clouds and bands are common features in the Zambian citrine. Photomicrograph by D. Beaton; image width 2.7 mm.

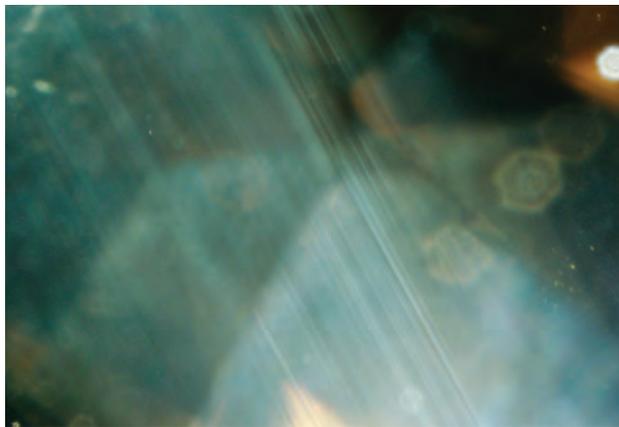


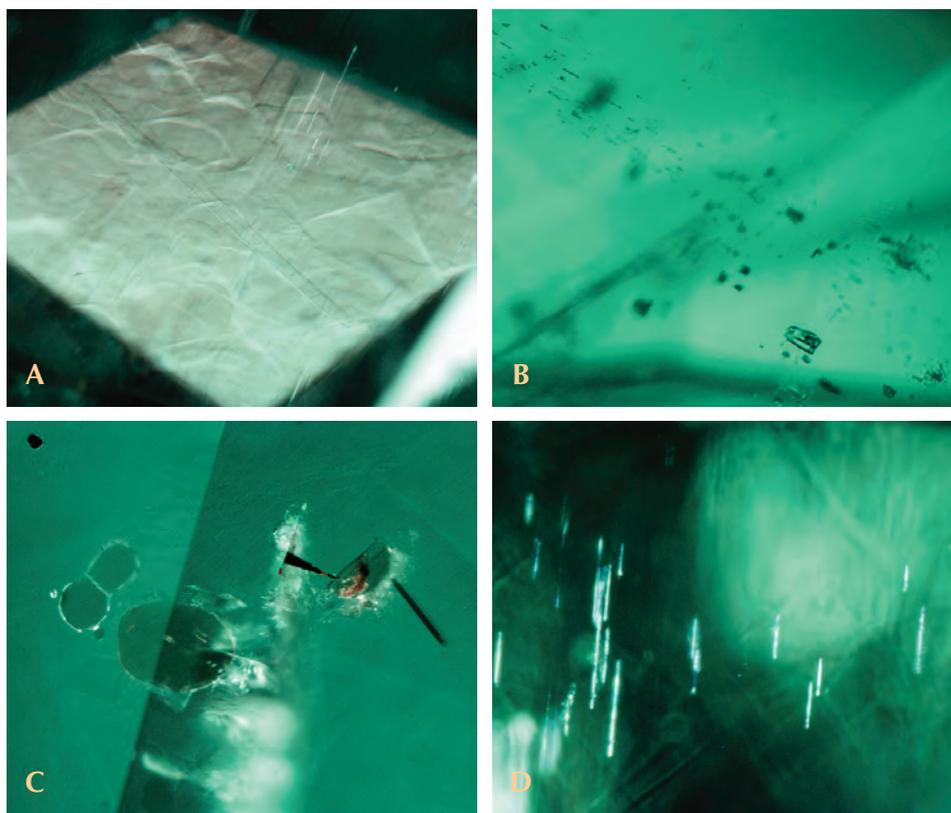
Figure 9. The 3.38 ct triangular modified brilliant in figure 7 contains a plane of elongated tubules and two-phase inclusions. Photomicrograph by D. Beaton; image width 1.5 mm.

**Emerald from Ethiopia.** At the 2011 Tucson gem shows, Farooq Hashmi (Intimate Gems, Glen Cove, New York), loaned GIA a 1.36 ct emerald from southern Ethiopia for examination (figure 10). It reportedly came from near the town of Dubuluk', which is located ~80 km north of the Kenyan border. Mr. Hashmi was told that the area has produced emeralds for a few years, and he saw several hundred grams of rough material while on a buying trip to Ethiopia in 2011. Although some of the pieces were quite large (up to several centimeters in dimension), gem-quality areas tended to be small (a few grams at most).

Figure 10. Weighing 1.36 ct, this emerald (cut by Hassan Z. Hamza, Noble Gems Enterprises, Dar es Salaam, Tanzania) is reportedly from southern Ethiopia. Photo by Robert Weldon.



Figure 11. The Ethiopian emerald shows distinct growth structures (A, magnified 40×), two-phase fluid inclusions (B, 112×), flat pale brown crystals with the appearance of biotite (C, 100×), and short needles (D, 112×). Photomicrographs by P. Cevallos.



Examination of the 1.36 ct trilliant yielded the following properties: color—green; pleochroism—weak yellowish green and bluish green; RI— $n_o = 1.585$ ,  $n_e = 1.578$ ; birefringence—0.007; hydrostatic SG—2.72; fluorescence—weak red to long-wave UV radiation and inert to short-wave UV; and strong absorption lines near 700 nm visible with the desk-model spectroscope. These properties are consistent with those reported for emerald (e.g., M. O'Donoghue, Ed., *Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 150–161). Microscopic examination (figure 11) revealed strong roiled and jagged growth structures, blocky two-phase fluid inclusions, pale brown plates, short needles, and a pale brown elongated inclusion.

Electron microprobe analysis of the stone was performed at the University of New Orleans. An average of five points showed 0.05 wt.%  $\text{Cr}_2\text{O}_3$  and 0.10 wt.%  $\text{FeO}$ ; vanadium was below the detection limit (<0.009 wt.%  $\text{V}_2\text{O}_5$ ). Polarized UV-Vis-NIR spectroscopy showed a broad absorption in the near infrared with a maximum at ~826 nm due to  $\text{Fe}^{2+}$ , as well as several well-defined  $\text{Cr}^{3+}$  bands at ~426, 633, 659, 669, and 687 nm (e-ray) and at 435, 596, and 636 nm (o-ray). The infrared spectrum (figure 12) showed bands at  $2358\text{ cm}^{-1}$  (related to  $\text{CO}_2$  in the structural channels) and  $2290\text{ cm}^{-1}$  (of unknown origin, but seen in natural and Tairus synthetic emeralds).

In the future, Ethiopia may be able to add emerald to its growing list of commercially significant gems.

Pamela Cevallos, William B. (Skip) Simmons, and Alexander U. Falster

**Emerald from Sumbawanga, Tanzania.** Sumbawanga, in western Tanzania, is known as a source of emerald from weathered rock of unclear genesis (I. Moroz et al., "Mineral and fluid inclusion study of emeralds from the Lake Man'yara and Sumbawanga deposits, Tanzania," *Journal of African Earth Sciences*, Vol. 33, No. 2, 2001, pp. 377–390). However, gem-quality material is rare from this deposit. While on a 2011 buying trip in Dar es Salaam, Tanzania, gem dealer Farooq Hashmi was told that some better-quality emerald was recently produced from Sumbawanga. From a parcel weighing 50–100 grams, he picked two of the better pieces of rough and had one cut into a 2.29 ct faceted octagon (figure 13). A 1.21 g piece of rough was retained for reference, and Mr. Hashmi loaned both stones to GIA for examination.

Characterization of the faceted stone yielded the following gemological properties: color—green; pleochroism—moderate yellowish green and green; RI— $n_o = 1.575$ ,  $n_e = 1.568$ ; birefringence—0.007; hydrostatic SG—2.69; fluorescence—faint red to long-wave UV radiation and weak red to short-wave UV; and a pair of absorption lines near 700 nm visible with the desk-model spectroscope. The rough sample showed: color—green; pleochroism—moderate yellowish green and bluish green; RI—1.58 (spot reading); SG—2.68; fluorescence—faint red to long-wave UV radiation and weak red to short-wave UV. These properties are consistent with those reported for emerald (e.g., M. O'Donoghue, Ed., *Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 150–161). Microscopic examination of both stones revealed sim-

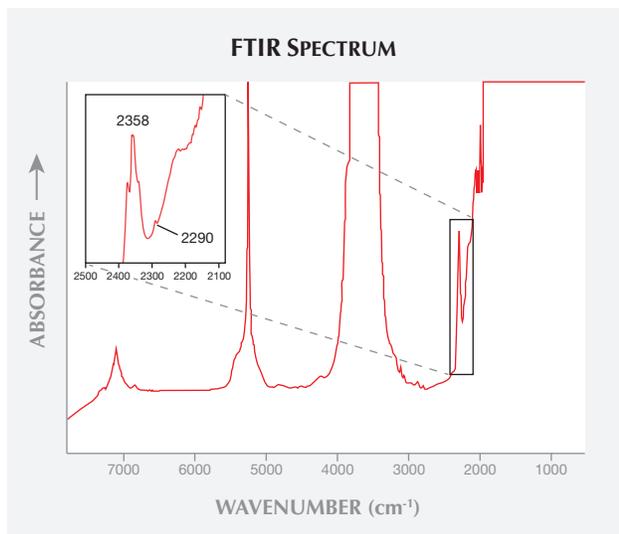


Figure 12. Infrared spectroscopy of the Ethiopian emerald shows bands at 2358  $\text{cm}^{-1}$  and 2290  $\text{cm}^{-1}$ .

ilar internal features, consisting of flat iridescent platelets, primary fluid inclusions, and distinct parallel green bands (figure 14). Although none of the mineral inclusions in this sample could be identified by Raman spectroscopy, Moroz et al. (2001) reported phenakite, euclase, helvite, bertrandite, quartz, mica, illite, and anhydrite in Sumbawanga emeralds; the phase relations and fluid inclusions suggested that they formed at low temperatures (220–300°C) and pressures of 0.7–3.0 kbar.

Electron microprobe analyses of the faceted stone at the University of New Orleans showed an average (from five points) of 0.09 wt.%  $\text{Cr}_2\text{O}_3$  and 0.23 wt.%  $\text{FeO}$ , while vanadium was below detection limit (<0.009 wt.%  $\text{V}_2\text{O}_5$ ). By comparison, Moroz et al. (2001) reported 0.07–0.44 wt.%  $\text{Cr}_2\text{O}_3$ , 0.20–0.41 wt.%  $\text{FeO}$ , and up to 0.06 wt.%  $\text{V}_2\text{O}_5$ . UV-Vis-NIR spectroscopy showed absorptions due to  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$ , in addition to well-defined  $\text{Cr}^{3+}$  bands. Infrared spectra of both samples revealed a band of unknown origin at 2290  $\text{cm}^{-1}$  (seen in natural and Taurus synthetic emeralds). The rough sample also showed bands at 2358  $\text{cm}^{-1}$  (related to



Figure 13. This 2.29 ct emerald (cut by Hassan Z. Hamza of Noble Gems Enterprises, Dar es Salaam) is reportedly from Sumbawanga, Tanzania. Photo by Robert Weldon.

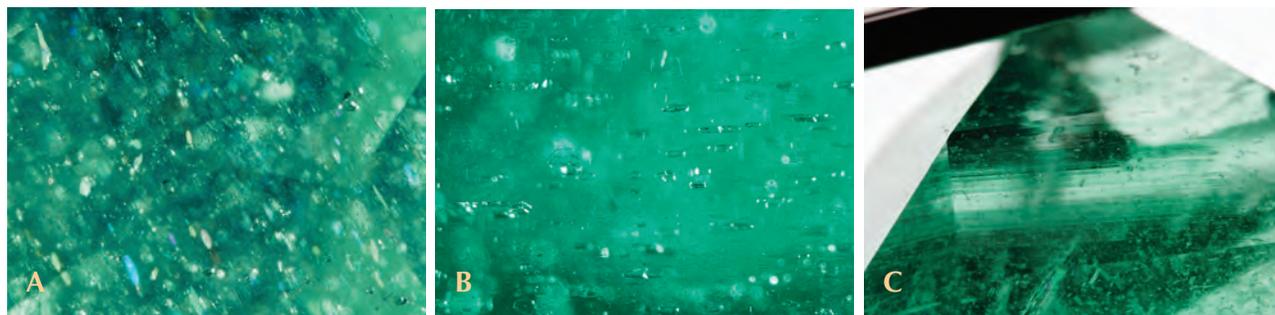
$\text{CO}_2$  in the structural channels) and 2340  $\text{cm}^{-1}$  (figure 15).

The presence in the market of this better-quality Sumbawanga emerald is an encouraging development.

*Pamela Cevallos, William B. (Skip) Simmons, and Alexander U. Falster*

**Gold in trondhemite matrix rock.** Pieces of gold-in-matrix from a variety of sources have been polished for use in jewelry, with the host rock typically consisting of quartz (e.g., Spring 1991 Gem News, pp. 54–55; Spring 2005 Gem News International [GNI], pp. 58–59). At the 2012 Tucson gem shows, this contributor was shown gold in a different type of host rock—trondhemite. This variegated white to dark gray material is a variety of tonalite, an intrusive igneous rock. According to the dealer, Garry Hall of GAPP Marketing Services (previously Gympie Gold Ltd.) in Mt. Lawley, Western Australia, this product was first shown at the 2011 Tucson

Figure 14. With magnification, the Sumbawanga emerald displays iridescent platelets (A, magnified 60×), primary fluid inclusions (B, 80×), and parallel green bands (C, 20×). Photomicrographs by P. Cevallos.



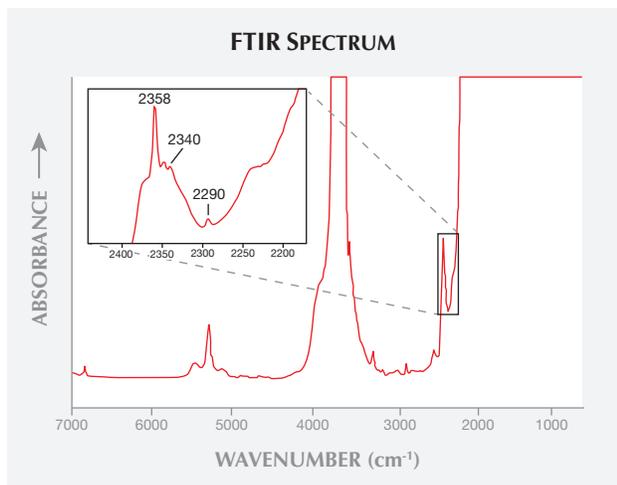


Figure 15. Infrared spectroscopy of the rough Sumbawanga emerald recorded bands at 2358, 2340, and 2290  $\text{cm}^{-1}$ .

shows and comes from the Kalgoorlie region of Western Australia. He had ~1 kg during the 2012 shows, as slabs, cabochons, and finished jewelry (e.g., figure 16), including tie tacks, pendants, and earrings. He had cut approximately 50 cabochons into 20 × 20 mm squares, 20 × 12 mm ovals, and 20 × 15 mm rectangles, all of which were 2.0–3.5 mm thick.

Figure 16. The slab (90 × 41 mm), pendant (24 × 16 mm), and square cabochons (16 × 16 mm each) shown here feature gold in a trondhjemite matrix. Photo by Robert Weldon.



This product provides an attractive variation on the traditional appearance of gold in a white quartz matrix. The overall gray color of the matrix gives a nice contrast to the metallic glow of the gold.

Brendan M. Laurs

**Hemimorphite from China.** At the 2012 Tucson gem shows, Marco Campos-Venuti (Seville, Spain) exhibited some relatively recently produced hemimorphite from China. His selection included about 100 cabochons in oval, cushion, pear, and round shapes, ranging up to 30 × 11 mm. According to Mr. Campos-Venuti, they were polished from ~3 kg of rough material. Most of the hemimorphite formed drusy crusts and had a pale greenish blue color. He obtained just one sample (1+ kg) showing an unusually deep blue color, consisting of a 1-cm-thick vein embedded in a porous limonite-like matrix. When cutting the palen drusy material, he noted that better coloration was usually below the surface, so a fair amount of polishing was required.

The pear-shaped cabochon in figure 17 weighed 6.62 ct and had a vivid blue color. Microscopic examination revealed fractures and a fibrous-banded structure. The back of the cabochon also contained a crystalline matrix, which was unidentifiable by Raman spectroscopy. Spot RI values were 1.61–1.62, and the hydrostatic SG was rather low at 3.13 (apparently due to the presence of the matrix material). The sample was inert to both long- and short-wave UV radiation, and no absorption lines were visible with a desk-model spectroscope. EDXRF spectroscopy showed major amounts of Zn and Si, and traces of Cu and Na. Raman analysis confirmed the identification as hemimorphite. With the exception of the low SG value, the gemological properties are consistent with hemimorphite samples reported in the Fall 2002 issue of *G&G* (see GNI, pp. 263–264, and Lab Notes, p. 254).

Figure 17. This 6.62 ct pear-shaped hemimorphite cabochon is from China's Yunnan Province. Gift of Marco Campos-Venuti, GIA Collection no. 38534; photo by Robert Weldon.



Mr. Campos-Venuti indicated that this Chinese hemimorphite was produced between approximately 2008 and 2011, from the Gejiu tin mine in Yunnan Province. Interestingly, a hemimorphite imitation consisting of partially devitrified glass entered the market during the same time, and was reportedly being sold by Chinese fossil dealers (see Summer 2012 GNI, p. 153).

Jason Darley (*jdarley@gia.edu*)  
GIA, New York

**Update on some Mogok gem mines and markets.** From April 28 to May 2, 2012, this contributor visited active gem mines and markets in the Mogok region of Myanmar with honors students from Taunggyi University.

Near Kyatpyin and Ingaung, both primary and secondary deposits were being mined over a large area. At Ingaung (22°54'10"N, 96°24'11"E), ruby and sapphire were extracted from a secondary deposit in an open pit to a depth of 15 m (figure 18). Excavators and dump trucks were used to remove the gem-bearing soil, which was taken to a nearby washing plant. Another secondary deposit at Shwe Pyi Aye (22°55'22"N, 96°29'25"E) was mined for ruby, sapphire, spinel, black tourmaline, and apatite. Due to a water shortage, a large pile of unwashed earth was being stockpiled. Other sites that we visited included Kyautsaung (a primary ruby deposit; figure 19) and the Kin-Chaung secondary de-

Figure 18. This open pit at Ingaung is a source of ruby and sapphire, which are mined from secondary deposits. Photo by U T. Hlaing.



Figure 19. Potentially ruby-bearing marble is stockpiled for processing near the village of Kyautsaung. Photo by U T. Hlaing.

posit, where gravel pumps and a washing plant are used in search of sapphire.

Near the village of Bawbadan, we visited the Ruby Dragon mine (22°56'03"N, 96°23'12"E), a marble-hosted primary deposit containing assemblages of ruby, spinel, tourmaline, apatite, sphene, and pyrite. The ruby-bearing zone measures 1.5–2.4 m wide and is known to extend more than 180 m deep; it has been worked along nearly 245 m of tunnel. The average grade is 4 grams of ruby per tonne of marble. Ruby was also the main target at another primary mining site near the village of Bawlonggyi (22°54'56"N, 96°23'57"E), where we were shown all the underground workings.

Gem materials were being sold near Mogok's cinema, where we saw glass-filled rough and cut rubies and pink sapphires said to originate from Tanzania (figure 20, left). Also seen in the market were hackmanite bangles (figure 20, right). Overall, business was slow at the city's central gems market.

Local miners can now work small plots in Mogok on an independent basis by applying to the Ministry of Mines. About 500 plots have been approved, with some limited funding available. The use of machinery will not be allowed, as mandated by the government.

U Tin Hlaing  
Dept. of Geology (retired)  
Panglong University, Myanmar

**Rainbow moonstone from Madagascar.** Rainbow moonstone is best known from India (see Summer 1997 Gem News, pp. 144–145), but material from two relatively new localities was sold at the 2012 Tucson gem shows: Zambia



Figure 20. The rubies and sapphires on the left were seen in Mogok, but reportedly consist of glass-filled material from Tanzania; the cabochons weigh 3–10 ct. The hackmanite bangle on the right was offered at the gem market near Mogok's cinema. Photo by U T. Hlaing.

(see Summer 2012 GNI, pp. 146–147) and Madagascar (figure 21). The Madagascar stones were offered by Paul Dragone (Boston Gems, Boston, Massachusetts), who loaned a 4.41 ct sample to GIA for examination. Mr. Dragone first encountered the rough material at the 2011 Tucson gem shows. Initially, from 12 rough pieces weighing about 3 g each, he cut more than a dozen cabochons weighing up to 7.11 ct (18% yield). Later he obtained additional rough material, from which he cut 35 cabochons that averaged approximately 3 ct each.

The gemological properties of the 4.41 ct cushion-shaped double cabochon were: color—near colorless, displaying orange, yellow, green, blue, and violet adularescence; diaphaneity—transparent; spot RI—1.56; hydrostatic SG—2.69; and fluorescence—weak white to long-wave UV radiation, and weak red to short-wave UV. No absorption lines were visible with the desk-model spectroscope. These properties are consistent with those reported for plagioclase (M. O'Donoghue *Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 259–269), and are also similar to the rainbow moonstone (andesine-labradorite) recently reported from Zambia. Microscopic examination revealed polysynthetic twinning, a

typical feature of plagioclase, as well as small “fingerprints” and numerous scattered reflective films. Many of these films were oriented along twinning planes.

EDXRF spectroscopy showed the presence of Al, Si, Ca, and Na (consistent with plagioclase), as well as traces of Fe, Sr, and Ba. Laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) data further placed it approximately halfway between the plagioclase end members albite and anorthite, on the andesine/labradorite border with a compositional range of  $Ab_{48.6-51.7}An_{49.8-46.8}Or_{1.6-1.5}$ .

The rainbow colors were best viewed against the dark background afforded by darkfield illumination (figure 22), but they were also easily seen in transmitted light. In addition, a billowy adularescent effect was produced by a fiber-optic light source positioned over the stone, with orange predominating over other colors, and was best seen when the light was aligned perpendicular to the twin planes. The twin planes, on the other hand, changed from dark to light lines depending on the light orientation. When the stone was viewed down its length—particularly under magnification with the fiber-optic light held close to the surface—it appeared hazy, consistent with the light scattering that accompanies adularescence.

Traditional moonstone (orthoclase) displays a white to blue adularescence thought to be caused by Rayleigh scattering of light from the exsolution of albite within the K-feldspar structure (E. Fritsch and G. R. Rossman, “An update on color in gems, part 3: Colors caused by band gaps and physical phenomena,” Summer 1988 *G&G*, pp. 81–102). Labradorescence is an interference phenomenon that may be exhibited by labradorite due to the diffraction of light from exsolution lamellae of varying Ca content, potentially producing many spectral colors; the relative thicknesses and differing refractive indices of the lamellae determine which colors are visible (Fritsch and Rossman, 1988). The present moonstone (andesine-labradorite) exhibits a rainbow-colored effect that results from a combination of labradorescence and adularescence.

Claire Ito (cito@gia.edu)  
GIA, New York

Figure 21. These rainbow moonstones (1.82–7.62 ct) are from Madagascar. Photo by Robert Weldon.



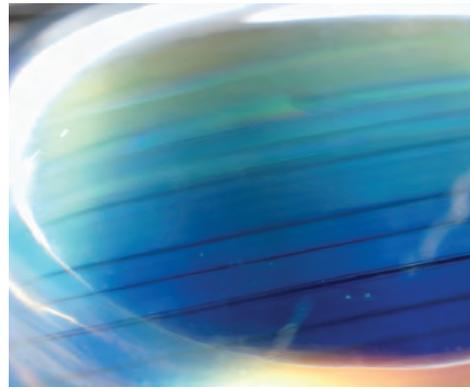
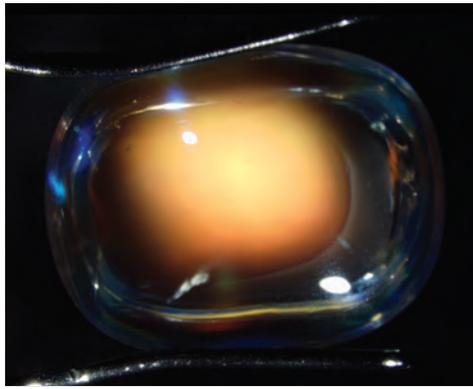


Figure 22. This 4.41 ct rainbow moonstone displays a billowy adularescent effect when the light source is moved over the stone (left, magnified 8×). On the right (11×), in darkfield illumination, various spectral colors are visible as well as polysynthetic twinning. Photomicrographs by Claire Ito.

**Yellow muscovite from Brazil.** Micas are rarely faceted due to their softness (Mohs 2½) and perfect cleavage, but occasionally compact aggregates showing an attractive color are polished into beads, carvings, *objets d'art*, or even faceted stone. At the 2010 Tucson gem shows, a new gem-quality yellow mica debuted from Itinga in the Araçuaí pegmatite district, Minas Gerais, Brazil (e.g., figure 23). It was sold as yellow lepidolite by most dealers or as muscovite (M. Macri, "Lepidolite gialla di qualità gemma," *Rivista Gemmologica Italiana*, Vol. 5, No. 3, 2010, pp. 234–235). A faceted stone and cabochon were donated to the GIA Collection by Mauro Pantò (The Beauty in the Rocks, Laigueglia, Italy). Mr. Pantò has polished approximately 1,000 carats of faceted stones and 2,000 carats of cabochons, ranging from 4 to 12 ct.

The cabochon was chemically analyzed at the University of New Orleans. Electron microprobe data showed that it contained 0.31 wt.% FeO, 0.18 wt.% MnO, and 0.03 wt.% TiO<sub>2</sub>; direct-coupled plasma analysis showed only 0.32 wt.% Li<sub>2</sub>O. The chemical data identified the samples as mus-

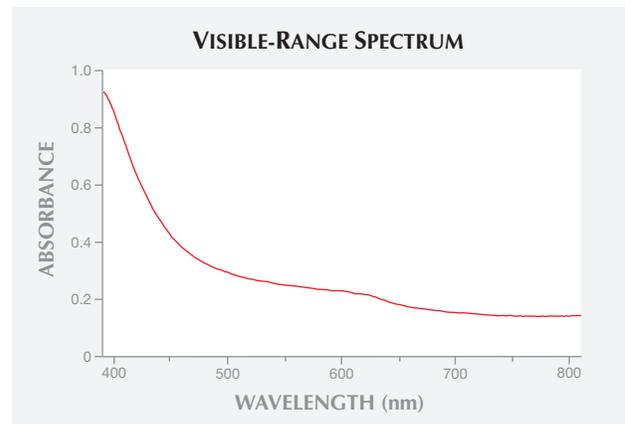
covite. The same piece was also analyzed by both specular reflectance and transmission spectroscopy in the visible range at the California Institute of Technology. Absorption bands from iron and manganese were weak. The yellow color is caused by the rising absorption toward the blue and ultraviolet regions of the spectrum between 400 and 500 nm (figure 24), which shifts the reflected and transmitted light toward a mixture of red through green that the eye interprets as yellow. While the rise in absorption at shorter wavelengths is commonly observed in Fe-rich brown micas, in this yellow muscovite the concentration of iron and other elements is so low that the resulting color is yellow rather than brown.

Facetable micas are rare. Some other examples include pink muscovite from Brazil that is colored by Mn impurities (Spring 2006 GNI, pp. 65–66) and a green muscovite from Tanzania colored by Cr (J. Hyršl, "Emerald green muscovite as a gemstone," *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 59, No. 3/4, 2010, pp. 109–111). Also, at a 2011 gem show in Teófilo Otoni, Brazil,

Figure 23. This unusual faceted yellow mica (3.52 ct) from Itinga, Brazil, was identified as muscovite. Gift of Mauro Pantò, GIA Collection 38533; photo by Robert Weldon.



Figure 24. Visible-range spectroscopy of the yellow muscovite (1 mm sample thickness) shows rising absorption between 400 and 500 nm. This shifts the reflected and transmitted light toward a mixture of red through green that the eye interprets as yellow.



a gem-quality transparent to translucent purple mica (represented as lepidolite) from the Araçuaí pegmatite district was seen by one of the authors (MM). Although this mica was only sold as mineral specimens at the show, it would not be surprising to see it faceted in the future.

*Brendan M. Laurs*

*George R. Rossman  
California Institute of Technology, Pasadena*

*Michele Macrì  
Museo di Mineralogia, Università “La Sapienza”  
Rome, Italy*

*William B. (Skip) Simmons and Alexander U. Falster*

**Blue opal from Arizona showing play-of-color.** At the 2012 Tucson gem shows, a new blue opal debuted from the Southern Skies mine in southern Arizona. The material was offered by Greg Genovese and Vincent Gulino of Southern Skies Opal (Tubac, Arizona), who indicated that the opal has been known for two decades, but significant production only began in 2011. The deposit is located on a remote mountain that is reachable by a four-wheeled all-terrain vehicle, and has been worked with pry bars and other hand tools. The opal is hosted by a hard rhyolite lava flow, and an important mining breakthrough was the use of Dexpan (an expansion agent) to break up opal-bearing boulders without shattering the gem material. Most of the production consists of “picture” material consisting of patterns of blue opal in a mostly brown matrix. About 30% is solid blue opal, ranging from medium light to dark blue, and 10% of the opal shows play-of-color. Thousands of carats have been polished into a variety of shapes.

Three opal samples submitted to GIA for identification illustrate the range of material produced from the deposit (e.g., figure 25). A 16.99 ct freeform cabochon had the following properties: color—mottled light grayish blue; diaphaneity—semitranslucent; spot RI—1.45; hydrostatic SG—2.23; and fluorescence—weak blue to long- and short-wave UV radiation. Microscopic examination showed a milky quality with spotty play-of-color and two iron-stained cracks. A 43.69 ct pear-shaped cabochon was characterized as: color—mottled orangy pink, brown, and blue; diaphaneity—translucent to semitranslucent; spot RI—1.45, 1.47, 1.49, and 1.54 from different areas of the sample; SG—2.44; and fluorescence—inert to UV radiation. A partially polished slab weighing 329.30 g and measuring 109.67 × 89.84 × 28.83 mm showed: color—banded light blue, light brown, and white; diaphaneity—semitranslucent to opaque; and fluorescence—moderate yellow to short-wave UV radiation and moderate blue to long-wave UV radiation. Microscopic examination revealed a banded agate-like structure, and some areas containing rounded colorless grains.

The various RI values recorded from the pear-shaped cabochon suggested the presence of opal and additional sil-



*Figure 25. Blue opal—some showing play-of-color—forms assemblages with other minerals in these pieces from the Southern Skies mine in Arizona. The samples examined for this report include the partially polished slab (top, 109.67 × 89.84 × 28.83 mm), the pear-shaped cabochon (bottom left, 43.69 ct), and the light grayish blue freeform cabochon (bottom, second from the right, 16.99 ct). Photo by Jeff Scovil.*

ica phases, and Raman spectroscopy identified the presence of quartz and cristobalite. There was no opal peak (830  $\text{cm}^{-1}$ ), probably because it was overridden by the cristobalite signal. Raman spectroscopy of the partially polished slab identified chalcedony and opal, as well as inclusions of ludwigite ( $\text{Mg}_2\text{FeBO}_5$ ). Overall, the blue and brown coloration of this material—and the presence of opal, quartz, and cristobalite assemblages—are comparable to samples from Brazil that were documented in the Winter 2007 GNI section (pp. 379–380).

None of the opal samples showed any indications of treatment. The company disclosed that most of the material is untreated, although some has surface fractures that are fitted with Opticon. Additional production of this interesting material is expected as mining proceeds.

*Dino DeGhionno (ddegghionno@gia.edu) and  
Brendan M. Laurs  
GIA, Carlsbad*

**Yellow opal from West Africa.** At the 2012 Tucson gem shows, Mark Kaufman (Kaufman Enterprises, San Diego, California) unveiled a relatively new find of yellow opal. According to his supplier, the opal reportedly came from West Africa, and was initially thought to be prehnite. Mr. Kaufman first encountered this opal in April 2011, as a rough parcel weighing ~500 grams. In November 2011 he saw more rough material, consisting of 5 kg that showed

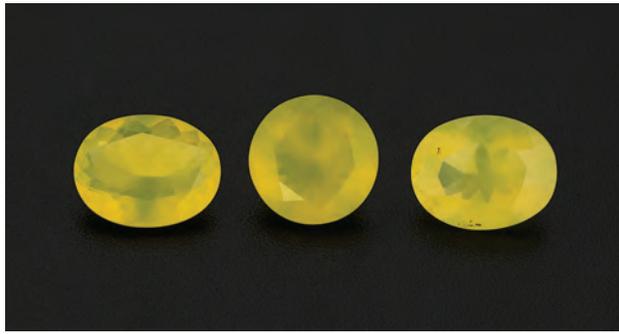


Figure 26. These opals, which weigh up to 1.40 ct, are reportedly from West Africa. Gift of Mark Kaufman, GIA Collection no. 38538–38542; photo by Robert Weldon.

good transparency. He was also shown some later production, but it was milky and of low quality.

Mr. Kaufman donated five of the opals to GIA (0.59–1.40 ct; e.g., figure 26), and the following properties were obtained: color—slightly greenish yellow, diaphaneity—transparent to translucent, RI—1.44–1.48, hydrostatic SG—2.14, and all stones were inert to both long- and short-wave UV radiation. These properties are consistent with opal (see, e.g., M. O’Donoghue, Ed., *Gems*, 6th ed., Butterworth-Heinemann, Oxford, UK, 2006, pp. 314–322). The stones were placed in water for 30 minutes to check for hydrophane character, but there was no improvement in their transparency. Microscopic observation revealed a transparent flow structure with an oily appearance in every sample (e.g., figure 27, left). In addition, two specimens contained whitish flow structures (figure 27, right). Yellowish brown stains were seen along fractures between these whitish structures (figure 28, left). The brown color was darker near the surface, especially in one sample. Small dark inclusions and whitish globules were observed in one stone (figure 28, right), and partially healed fractures were seen in some samples.

While the sharpness of the peaks in the opals’ Raman spectra suggested opal-CT (crystalline opal), the whitish flow structures showed broader Raman bands, indicating poorly crystalline opal-CT (see the *G&G* Data Depository at [gia.edu/gandg](http://gia.edu/gandg)). The whitish globular inclusions were de-

termined to be anatase, but the dark minerals could not be identified.

Opal gradually transforms from opal-A (amorphous opal) to opal-CT to a quartz polymorph—that is, from amorphous to crystalline—through a diagenetic process determined by temperature, time, porosity, and depth. Normally, only one polymorph occurs at a given time. If the diagenetic process is slow enough, however, different polymorphs can coexist. Interestingly, a coexisting variation within a single opal polymorph—both poorly and highly crystalline opal-CT—was observed in two samples.

Several minor and trace elements were detected by LA-ICP-MS: Na, Al, Ca, Fe, Mg, K, Sc, Ni, Zn, Ba, and La were in the 10–10,000 ppmw range. Trace elements with concentrations less than 10 ppmw included Ti, V, Mn, Co, Cu, Ga, Rb, Sr, Zr, Sn, Te, Hf, Hg, Tl, Pb, U, and several rare-earth elements.

Future production of this attractive opal is uncertain. Mr. Kaufman expects to cut 2,000 carats in calibrated sizes up 10 × 8 mm. Although larger pieces are possible to cut, they have diminished transparency.

Kyaw Soe Moe ([kmoe@gia.edu](mailto:kmoe@gia.edu))  
GIA, New York

**Quartz with green rutile inclusions.** As far as “inclusion stones” are concerned, rutilated quartz is one of the most sought after. These inclusions are generally recognized by the golden metallic color they impart to their quartz host. Sometimes, however, other colors are seen, such as red and brown (Summer 2001 GNI, p. 146). One quartz specimen recently examined by this contributor (figure 29) was host to a trellis-like network of unusual green rutile inclusions (identification confirmed by Raman analysis). This 11.31 ct pear-shaped tablet was also host to several fluid inclusions and some small rhombohedral carbonate crystals.

The stone was obtained from Leonardo Silva Souto (Cosmos Gems, Teófilo Otoni, Brazil), who indicated that this material comes from the Brazilian state of Espírito Santo. He purchased approximately 100 kg of the rutile-included quartz from a mineral collection of the late João das

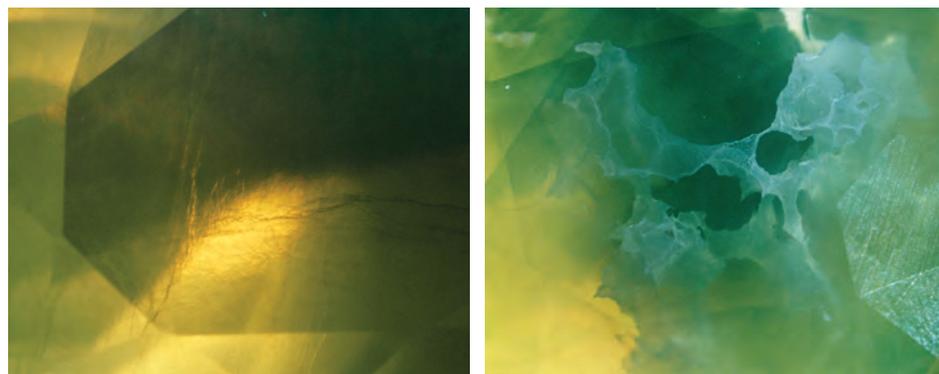


Figure 27. Transparent flow structures with an oily appearance are visible in the opals (left, magnified 30×). Less common are whitish flow structures (right, 35×). Photomicrographs by K. S. Moe.

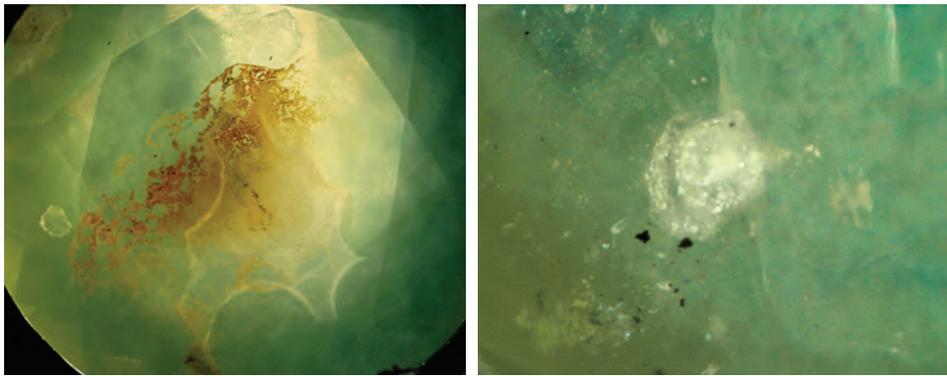


Figure 28. Yellowish brown stains are seen near the whitish flow structures in the opal on the left (magnified 25×). Another sample displays whitish globular inclusions of anatase along with dark unidentified inclusions (right, 60×). Photomicrographs by K. S. Moe.

Moças. Mr. Silva Souto added that the inclusions were only present in the tips of the quartz crystals, and that one side of the crystals contained the more typical “golden” rutile, while the other side showed the green rutile. From the quartz lot, ~5,000 carats of included stones were cut, of which ~3,000 carats contained the green rutile. Most of the stones were cut as beveled tablets in pear, oval, and freeform shapes up to 57 × 32 mm.

The uncommon green color displayed by these rutile inclusions and the limited production make it an appealing collector’s stone for those who enjoy unusual inclusions.

Nathan Renfro (nrenfro@gia.edu)  
GIA, Carlsbad

**Quartz from Tanzania with red epidote-piedmontite inclusions.** At the 2012 Tucson gem shows, Werner Radl (Mawingu Gems, Liesenfeld, Germany) had rough and polished samples of quartz containing bright red inclusions

Figure 29. The green inclusions in this 11.31 ct quartz tablet were confirmed to be rutile by Raman analysis. Photo by Robison McMurtry.



from the Dodoma area of central Tanzania. He obtained the rough material in early 2011, and indicated that large quantities were available in pieces weighing up to 1 kg. He polished several spheres measuring up to 6 cm in diameter, as well as a few cabochons (e.g., figure 30).

Prior to the Tucson show, Mr. Radl had one sample analyzed by X-ray diffraction, which showed the inclusions consisted of epidote. He loaned and donated several rough and polished samples to GIA for examination, and they were analyzed by EDXRF and Raman spectroscopy. The chemical composition and Raman spectra were consistent with a mineral in the epidote-piemontite series containing some manganese and strontium.

Reddish quartz-rich metamorphic rocks containing piemontite have been known from central Tanzania for decades (see, e.g., K. D. Meinhold and T. Frisch, “Manganese-silicate-bearing metamorphic rocks from central Tanzania,” *Schweizerische Mineralogische und Petrographische Mitteilungen*, Vol. 50, No. 3, 1970, pp. 493–507). In particular, piemontite-quartz schists occur in the Iringa area (Mwhana Hills), where the piemontite is thought to

Figure 30. These quartz cabochons (18.57–61.06 ct) from central Tanzania contain bright red inclusions of a mineral in the epidote-piemontite series. Photo by Robert Weldon.



have formed during primary amphibolite-facies metamorphism (Meinhold and Frish, 1970).

Similar red inclusions—probably Mn-rich epidote—were also recently documented in scapolite from Peru (Spring 2012 GNI, pp. 57–58).

Brendan M. Laurs and David Nelson  
GIA, Carlsbad

**Unusual trapiche sapphire.** The word *trapiche*, Spanish for “mill,” refers to the wheel that was once used to crush sugar cane. The same term is used for gems that show a characteristic six-rayed star-shaped growth zoning in cross section. This peculiar appearance, long thought to occur only in emerald, is due to bands of inclusions that radiate from the center of the crystal—the optic axis—toward the prism faces. Only in the past 20 years have other gems been discovered with a distinct trapiche structure, namely ruby and sapphire (K. Schmetzer et al., “Trapiche rubies,” Winter 1996 *G&G*, pp. 242–250) and tourmaline (T. Hain-schwang et al., “Trapiche tourmaline from Zambia,” Spring 2007 *G&G*, pp. 36–46). Generally, the trapiche effect in these stones (as in emerald) is caused by dark inclusions. In some blue sapphires, however, it is due to strong color banding parallel to the hexagonal growth zoning. Such trapiche sapphires are known only from the Mogok region of Myanmar (K. Schmetzer, pers. comm., 2012).

Recently, the Gübelin Gem Lab examined such a sapphire, a 36.16 ct cabochon measuring 22.91 × 16.93 × 6.69 mm (figure 31). The stone showed a very pronounced blue zoning along the corners of the hexagonal growth structure, while zones corresponding to the prism faces were white. In addition, many of the boundaries between the blue and the white areas displayed elongated white patches perpendicular to the growth direction of the prism faces (figure 32).

Semiquantitative chemical analysis using EDXRF spectroscopy identified both areas as corundum, with similar chemical compositions. Yet the Ti and Fe values (which cause the blue color in sapphire) as well as the Cr content were higher in the blue areas. Comparing the chemical composition of the blue portions with average concentrations of these elements in Burmese blue sapphires also indicated Myanmar as a likely origin.

Lore Kiefert (l.kiefert@gubelingemlab.ch)  
Gübelin Gem Lab, Switzerland

**Stichtite-dominated intergrowths with serpentinite from Tasmania.** Colorful opaque cabochons of purple stichtite ( $\text{Mg}_6\text{Cr}_2\text{CO}_3[\text{OH}]_{16}\cdot 4\text{H}_2\text{O}$ ) and green serpentinite have been seen in the gem trade for years from Dundas, Tasmania, Australia (e.g., L. D. Ashwal and B. Cairncross, “Mineralogy and origin of stichtite in chromite-bearing serpentinites,” *Contributions to Mineralogy and Petrology*, Vol. 127, No. 1–2, 1997, pp. 75–86, <http://dx.doi.org/10.1007/s004100050266>).



Figure 31. This 36.16 ct trapiche sapphire shows distinct blue and white color zoning. Courtesy of Mayer & Watt (Maysville, Kentucky); photo by Alessandra Spingardi.

Most of these cabochons are dominated by serpentinite and contain subordinate stichtite, although rarely cabochons of pure stichtite have been encountered (e.g., Fall 2003 Lab Notes, p. 221).

At the 2012 Tucson gem shows, Robert Sielecki (Crystal Universe, Melbourne, Australia) had dozens of cabochons that were cut specifically to showcase the purple stichtite. According to Mr. Sielecki, the rough was mined from Tasmania in August–September 2010. He polished ~10 kg of material into ~2 kg of oval cabochons ranging

Figure 32. With magnification, the transition between some of the blue and white areas in the trapiche sapphire showed unusual oval white patches aligned perpendicular to the prism faces. Photomicrograph by L. Kiefert; magnified 10×.

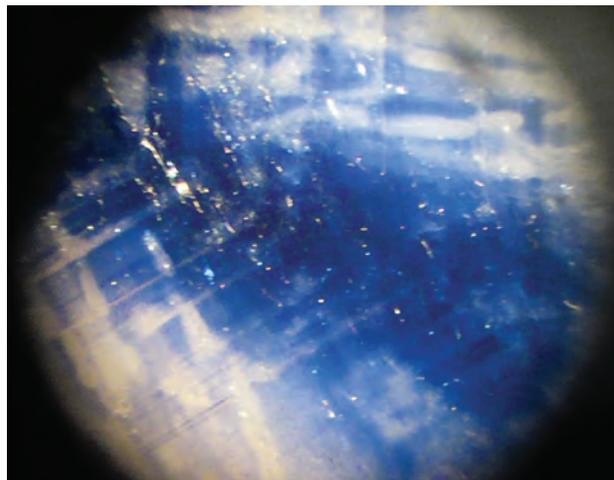




Figure 33. The cabochon on the lower left (3.42 ct), consisting mainly of purple stichtite with subordinate green serpentinite, is representative of the newer Tasmanian material being cut. The other cabochons (5.63 and 9.24 ct) show the range of proportions of stichtite and serpentinite more typically seen in this colorful material. Gift of Crystal Universe, GIA Collection nos. 38535–38537; photo by Kevin Schumacher.

from 14 × 10 mm to 40 × 30 mm, which he marketed as Atlantisite (figure 33). The mainly purple cabochons provide an interesting option for designers who wish to incorporate this unusually vibrant color into jewelry.

Brendan M. Laurs

**Zoisite from Pakistan.** Fine specimens of light brown clinozoisite are well known from northern Pakistan (J. S. White, "Clinozoisite and epidote from Pakistan," *Rocks and Minerals*, Vol. 76, No. 5, 2001, p. 351), and excellent crystals of green zoisite have also been reported from this area (Winter 1992 GNI, pp. 275–276). Both of these Pakistani minerals typically contain only small transparent areas, so gems faceted from them are rare. In late 2011, gem and mineral dealer Dudley Blauwet reported an increase in the production of pale-colored zoisite/clinozoisite from Alchuri in Pakistan's Shigar Valley. He estimated that at least 50 kg of mixed-quality material was produced, and in the Peshawar gem market he saw one parcel weighing ~100 grams that was very clean, with some pieces exceeding 5 g. He reported that the color shifted from greenish gray in daylight to grayish tan in incandescent light.

Zoisite and clinozoisite are both species of the epidote group, which share the same chemical formula  $[\text{Ca}_2\text{Al}_3\text{Si}_3\text{O}_{12}(\text{OH})]$  but may contain differences in minor or trace-element content. Since zoisite (orthorhombic) is a dimorph of clinozoisite (monoclinic), investigating the crystal structure by X-ray diffraction analysis and Raman spectroscopy is more reliable for separating them than comparing their standard gemological properties or

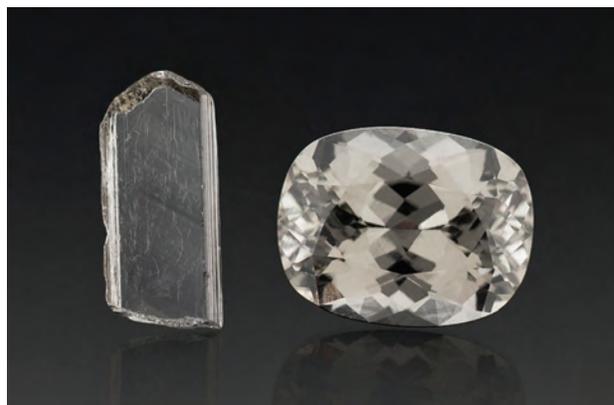


Figure 34. These zoisites, consisting of a 0.6 g crystal and a 3.14 ct cushion cut, are from Alchuri, Pakistan. Photo by Kevin Schumacher.

chemical composition.

Mr. Blauwet donated to GIA several crystals and a 3.14 ct desaturated brownish yellow-green modified cushion cut from the 2011 production (e.g., figure 34). Standard gemological testing of the faceted stone gave the following properties: RI—1.701–1.707; hydrostatic SG—3.38; fluorescence—inert to both long- and short-wave UV radiation; and absorption features at 430 and 450 nm seen with the desk-model spectroscope. These properties are consistent with both zoisite and clinozoisite. The absorptions at 430 and 450 nm, which are probably due to iron, gave the stone its brownish yellow-green color. Microscopic examination revealed strong, straight growth structures throughout the stone and a long tubule-like needle.

Qualitative chemical analysis using EDXRF spectroscopy indicated major Ca and Si; moderate Fe, Al, and Sr; and trace amounts of Ti, V, Mn, and Ga. The Fe content was more consistent with clinozoisite than zoisite, since the latter mineral typically contains much less iron. However, Raman spectroscopy (figure 35) and X-ray diffraction (XRD) analysis both identified the sample as zoisite.

In June 2012, Mr. Blauwet informed us that additional "zoisite" had recently been recovered from another site called Skinsar, which is located above Alchuri at an elevation exceeding 4,000 m. The deposit was being worked by drilling and blasting, in a tunnel extending ~15 m into the hillside. In the Alchuri area he saw several parcels of this new production, totaling ~10 kg, with about 5–10% gem quality consisting of many clean pieces weighing 1–3 g and partially transparent fragments of 10+ g. He reported that the material showed more color variation than the samples shown in figure 34, ranging from an attractive "minty" green to yellow and pale brownish lavender.

HyeJin Jang-Green ([hjanggre@gia.edu](mailto:hjanggre@gia.edu))  
GIA, New York

Brendan M. Laurs and Andy H. Shen  
GIA, Carlsbad

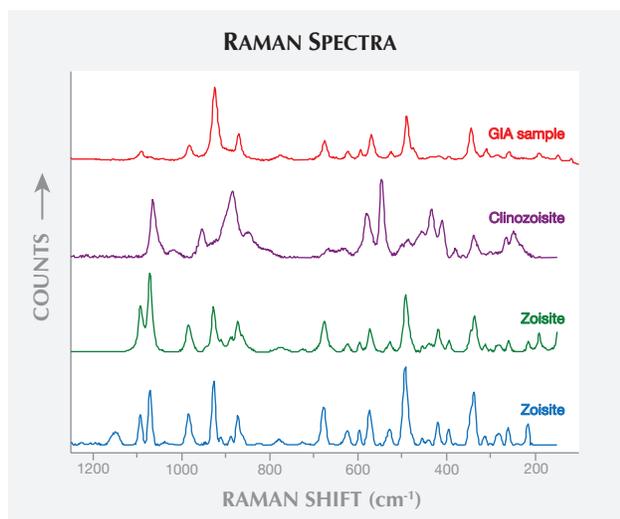


Figure 35. The Raman spectrum of the 3.14 ct sample from Pakistan show the best match to the reference spectra for zoisite rather than clinozoisite.

**Pink to purple zoisite from Merelani, Tanzania.** A Summer 2012 GNI entry (p. 153) recently documented some of the wide variety of zoisite colors that are produced from the tanzanite mines at Merelani, Tanzania. As if on cue, a new find at Merelani has produced significant amounts of unusual pink to purple zoisite (e.g., figure 36). According to Steve Ulatowski (New Era Gems, Grass Valley, California), the material was recovered over an approximately three-week period, from late June to mid-July 2012. He was told that it came from the Junga mine in Block D, from a depth of ~800–900 m. The colors ranged from pink to purplish red to purple, and associated minerals included bright green tremolite and some green diopside.

Mr. Ulatowski indicated that most of this zoisite is color banded, so cutting attractively colored gems is quite difficult. Faceted stones weighing more than 1 ct are rare, and from an estimated ~1 kg of cuttable rough that was produced, he predicted that about 80% will yield gems ranging from 0.1 to 0.5 ct. Nevertheless, a few much bigger stones have been cut, including a 20.38 ct heart-shaped gem that shows intense pink and purplish red hues and is the largest known to Mr. Ulatowski from this find. He also reported seeing some attractive crystal specimens, including one that weighed 38 g.

The zoisite from this find is being sold without any heat treatment, since heating washes out the purple color.

*Brendan M. Laurs*

## SYNTHETICS AND SIMULANTS

**Artistic cutting of Russian synthetic moissanite.** Technological improvements in the growth of synthetic moissanite have resulted in larger and higher-quality rough material for gem cutters. One Russian faceter, Victor Tu-

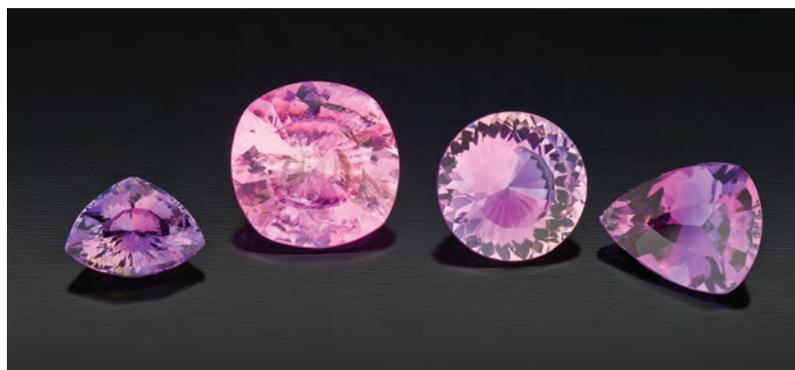


Figure 36. Some unusual pink to purple zoisite was found in mid-2012 at Merelani, Tanzania. The stones shown here weigh 1.78–5.12 ct and were faceted by Meg Berry (Mega Gem, Fallbrook, California). Photo by Robert Weldon.

zlukov (Russian Faceters Guild, Moscow), showed this author two impressive pieces of Russian synthetic moissanite at the 2012 Tucson gem shows.

The first piece consisted of a unique faceted ring cut from green synthetic moissanite (figure 37). The rough material was originally grown in 2010 for lapidary use. Mr. Tuzlukov used a core drill to obtain the blank for the ring, and then polished facets on the outside surface using a BATT lap and 100,000 grit (0.25  $\mu\text{m}$ ) diamond spray. The other piece was a 9.3 ct near-colorless synthetic moissanite that was notable for its size and cutting perfection (figure 38). He completed the gem in November 2011 using his own faceting design that incorporates the concept of the “golden ratio” in art and architecture. Viewed face-up, the pattern created by the faceting design was both attractive and perfectly symmetrical. This gem won the Most Beautiful Stone award in a competition organized by the U.S. Faceters Guild in February 2012.

Figure 37. This ring (19 mm in diameter) was cut from a single piece of synthetic moissanite. Photo by Robert Weldon.





Figure 38. This large (9.3 ct) synthetic moissanite displays attractive symmetry. Photo by Robert Weldon.

Mr. Tuzlukov indicated that the largest synthetic moissanite he has cut weighed 27 ct and was greenish blue. Such material has strong blue and greenish yellow dichroism, and it is important to orient the optic axis perpendicular to the table for best color appearance. He noted that cylinders of synthetic moissanite measuring up to  $1 \times 4$  in. ( $2.5 \times 10.2$  cm) have been grown in Russia, giving faceters ample material to work with.

Brendan M. Laurs

**“True” red synthetic spinel grown by a “pulled” technique in Russia.** While red spinel is one of the most sought-after gems, the synthetic version is actually quite rare. Flame-fusion synthetic spinel is more often light pink than red, and its chemical composition is different from the nominal spinel formula. One red variety, Russian flux-grown synthetic spinel, has been on the market for years (S. Muhlmeister et al., “Flux-grown synthetic red and blue spinels from Russia,” Summer 1993 *G&G*, pp. 81–98). This is a “true” synthetic, with a chemical composition and atomic structure identical to that of natural spinel.

At the 2011 Tucson gem and mineral shows, one of us (EF) purchased a 9.27 g piece of transparent red synthetic spinel (figure 39). The piece was sold by Morion Co. (based in Brighton, Massachusetts, in partnership with Russian crystal growers), and was represented as “true” synthetic spinel. It resembled a sawn cross-section of a bottle and had one polished face. The shape was suggestive of a “pulled” synthetic rod, such as those produced by the Czochralski method.

The gemological properties were typical for spinel, with an RI of 1.720 and a hydrostatic SG of 3.59. This is close to the theoretical SG calculation for pure spinel of 3.58, based on atomic composition. A typical red spinel spectrum due to  $\text{Cr}^{3+}$  was visible with the handheld spectroscope. Viewed with the polariscope, it showed a singly refractive reaction (extinction). The material fluoresced strong red to long-wave UV radiation and moderate red to short-wave UV. With magnification, the piece showed small round and elongated bubbles in the outer rim (figure 40), the signature of pulled synthetic material. The interior appeared to be free of inclusions, and no color zoning was observed.

Quantitative chemical analysis was performed on a JEOL 5800LV scanning electron microscope (SEM) equipped with a Princeton Gamma Tech energy-dispersive IMIX-PTS detector. This revealed only Mg and Al as major components, with a minor amount of chromium (slightly less than 0.5 wt.%  $\text{Cr}_2\text{O}_3$ ), the coloring agent. Compared to a reference spectrum for red Burmese spinel obtained in identical conditions, this new synthetic showed slightly more Cr, and an absence of Fe, V, and Zn.

Raman analysis produced a spectrum that was similar to that of the Russian flux-grown synthetic spinel mentioned above. Its Raman bands were located at about the same positions as for natural spinel (three main bands at 765, 667, and  $405 \text{ cm}^{-1}$ ) but were three times as broad. This large bandwidth is attributed to cation disordering: Part of the Al substitutes into the tetrahedral site occupied by Mg, instead of going into its normal octahedral site (H. Cynn et al., “High-temperature Raman investigation of order-dis-

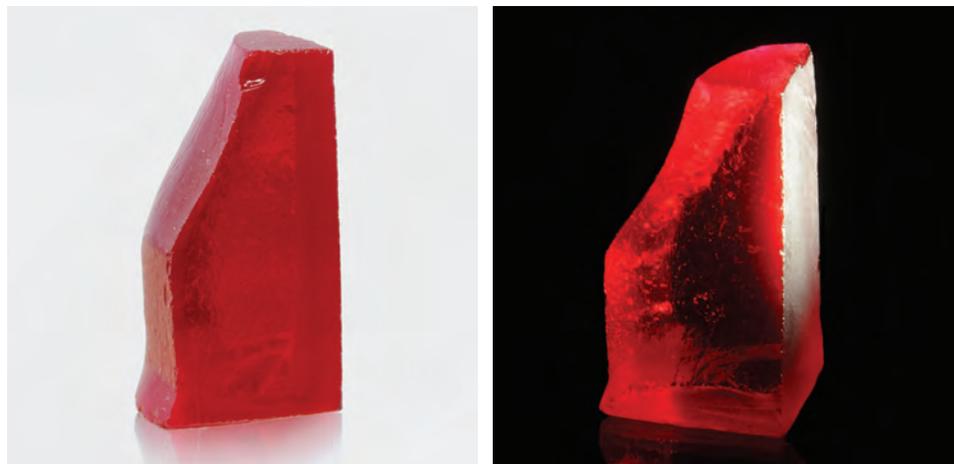


Figure 39. The 9.27 g pulled synthetic spinel is a “true” synthetic, with the bulk chemical composition and atomic structure of nominal spinel. The specimen is shown in D65 daylight-equivalent light (left) and in incandescent light, which accentuates its red color (right). Photos by O. Segura.

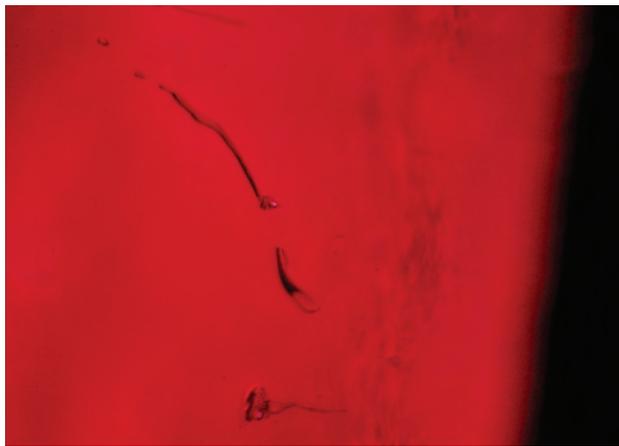


Figure 40. A few elongated bubbles are visible in the outer part of the red synthetic spinel. Photomicrograph by O. Segura; magnified 50 $\times$ .

order behavior in the MgAl<sub>2</sub>O<sub>4</sub> spinel," *Physical Review B*, Vol. 45, No. 1, 1992, pp. 500–502). Therefore, like the flux-grown red synthetic spinel, Raman spectroscopy showed that this pulled material is structurally disordered. Since there was no significant shift in the position of the Raman bands compared to natural spinel, this pulled synthetic has the same atomic structure as its natural counterpart.

This pulled synthetic is indeed a "true" red synthetic spinel. It is easily separated from natural material, even in the absence of inclusions, on the basis of its trace-element composition (Zn and Ga below the detection limit of EDXRF). Because of this pulled material's similarity to flux-grown Russian synthetic spinel, and its virtual absence of inclusions, it may be difficult to separate these two synthetics.

Olivier Segura ([o.segura@bjop.fr](mailto:o.segura@bjop.fr))

Laboratoire Français de Gemmologie, Paris

Yves Lulzac

Centre de Recherches Gemmologiques, Nantes, France

Emmanuel Fritsch

## MISCELLANEOUS

**Automated colored stone cutting.** While robotic diamond cutting has been widespread for more than a decade, automated colored stone cutting equipment and software are just becoming readily available. At the 2012 Tucson gem shows, one manufacturer's booth was drawing a great deal of attention.

KLM Technology (New Brunswick, New Jersey) demonstrated its smallest automated cutting machine, the Jang 801 (figure 41). The system is designed to cut stones from 2 to 25 mm with an accuracy of 0.05 mm. The exact size, shape, proportions, and facet arrangement are determined by Windows-based software that is compatible with most GemCad designs. Kiwon Jang of KLM noted that the machine can cut up to 100 stones per day in 2–3 mm sizes,

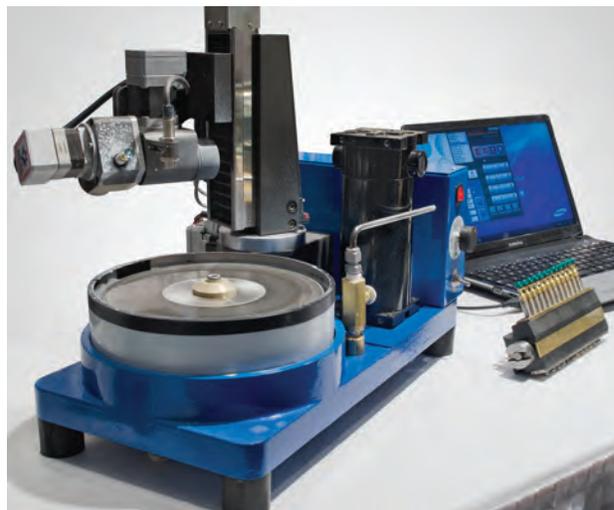


Figure 41. Automated colored stone cutting is now being done with compact machines such as the Jang 801. Photo by Eric Welch.

and up to 50 stones in 3.5–10 mm sizes. The production rate depends on the size of the stones, the time required for processing each stone, and whether separate machines are dedicated to cutting and polishing. A 1 ct stone takes about one hour from start to finish on a single machine. With two machines, the system can reportedly cut 50 stones per day in 6.5–10 mm sizes.

Mr. Jang also presented a video of KLM's larger models, which can cut up to 90 stones at a time. The Jang 1440 is designed to facet 12,000 stones per day in 2–3 mm sizes and up to 2,400 stones in 3.5–10 mm sizes. For peak production, he suggested that factories use one apparatus for preforming, one for cutting, and two for polishing. He said that this four-machine system can produce 1,000 stones per day at 6.5–10 mm.

Cassettes holding multiple stones can transfer dopping from crown to pavilion while keeping the stones centered. After the cutter orients the stone and dops it with a centering jig, the Jang machines can automatically do the preforming, cutting, and polishing.

Mr. Jang added that he can train technicians to operate these systems in two days.

Andy Lucas ([alucas@gia.edu](mailto:alucas@gia.edu))

GIA, Carlsbad

## ERRATUM

Figure 10 of the Summer 2012 Micronesian cultured pearl article by L. Cartier et al. (pp. 108–122) should have stated "An oyster that yielded a first-generation cultured pearl was *re-beaded* to produce four cultured blister pearls." The word *re-grafted* implied the insertion of mantle tissue, whereas cultured blister pearls are produced using bead nuclei without inserting any mantle tissue.