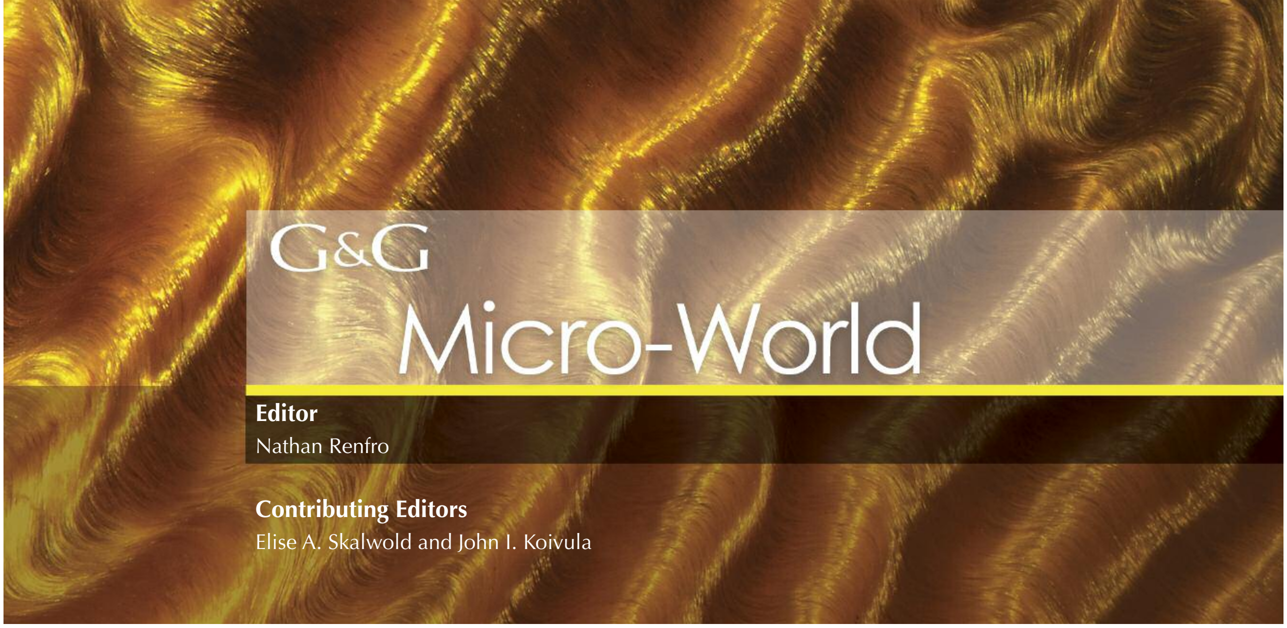


Intergrown Emerald Specimen from Chivor

Colombia's Chivor emerald mines are located in the eastern zone of the Eastern Cordillera range of the Andes Mountains. *Chivor* translates to "green and rich land" in Chibcha, the language of the indigenous people who were already mining emerald more than 500 years ago, before the arrival of the Spanish conquistadors (D. Fortaleché et al., "The Colombian emerald industry: Winds of change," Fall 2017 *G&G*, pp. 332–358). Chivor emeralds exhibit a bright green color with a tint of blue; they have relatively high clarity and fewer inclusions than emeralds found in Colombia's western belt.

The authors recently examined a rough emerald crystal specimen (figure 1), measuring 18.35 × 10.69 × 9.79 mm, reportedly from Chivor. This crystal weighed 3.22 g (16.10 ct) and had a prismatic hexagonal crystal shape. Standard gemological examination confirmed the gemstone to be emerald, and ultraviolet/visible/near-infrared (UV-Vis-NIR) spectroscopy showed a classic Colombian emerald absorption spectrum. The crystal's color was typical of Chivor emeralds, a medium dark green showing a blue tint. The emerald, which hosted jagged three-phase inclusions that are typically observed in Colombian material, showed no signs of clarity enhancement.

The emerald specimen hosted a large, unique inclusion of emerald almost perpendicular to the c-axis, measuring approximately 2.67 × 2.71 × 5.43 mm. The inclusion's identity was confirmed by Raman spectroscopy. The inclusion exhibited a well-formed hexagonal prismatic shape with pyramid-like termination (figure 2). Although intergrowth emerald crystals have been described and documented in the literature several times (G. Grundmann and G. Giuliani, "Emeralds of the world," in G. Giuliani et al., Eds., *Emeralds of the World*, extraLapis English, No. 2, 2002, pp.

About the banner: A unique wavy structure is preserved in this tiger's eye from South Africa. Photomicrograph by Nathan Renfro; field of view 8.72 mm. Specimen courtesy of the John Koivula Inclusion Collection.

Editors' note: Interested contributors should contact Nathan Renfro at nrenfro@gia.edu for submission information.

Gems & Gemology, Vol. 55, No. 2, pp. 260–269.

Figure 1. An emerald crystal inclusion measuring ~2.67 × 2.71 × 5.43 mm is found inside this large emerald specimen (18.35 × 10.69 × 9.79 mm) from Colombia's Chivor mine. Photo by John Jairo Zamora.

Figure 2. Left: A well-formed emerald inclusion, showing a hexagonal prismatic shape with pyramidal termination. Right: The view from below shows a perfect hexagonal crystal outline. Photomicrographs by John Jairo Zamora; field of view 12 mm.

24–35; I. Sunagawa, *Crystals: Growth, Morphology and Perfection*, Cambridge University Press, 2005, pp. 127–149), it is always a spectacular feature to observe, making this emerald rough crystal from Chivor with an emerald crystal inclusion a unique collector's specimen.

Luis Gabriel Angarita and John Jairo Zamora
CDTEC, Bogotá

Jonathan Muyal
GIA, Carlsbad

Purple Fluorite Inclusion in Emerald from Russia

Fluorite inclusions in emeralds from various localities have been reported extensively in the literature. They have been described as "whitish-colorless, octahedral-cube and/or corroded rounded shapes" (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Publishers, Basel, Switzerland, 2008). However, purple fluorite in an emerald host is rare.

Author CM previously documented a purple banded fluorite inclusion in an emerald submitted to GIA for identification (Fall 2016 Lab Notes, pp. 302–303). This was noted as "an interesting and unexpected addition to an otherwise typical (emerald) inclusion scene." Surprisingly, the current authors recently found another purple fluorite inclusion in an emerald (figure 3) from GIA's research reference collection. Purchased from Alexey Burlakov (Tsarina Jewels, JTC, Bangkok), it was reportedly from the Maly-

Figure 3. A Russian emerald hosts a crystal inclusion—identified by laser Raman microspectrometry analysis as fluorite—that exhibits a distinct purple color. Photomicrograph by Jonathan Muyal; field of view 1.44 mm.

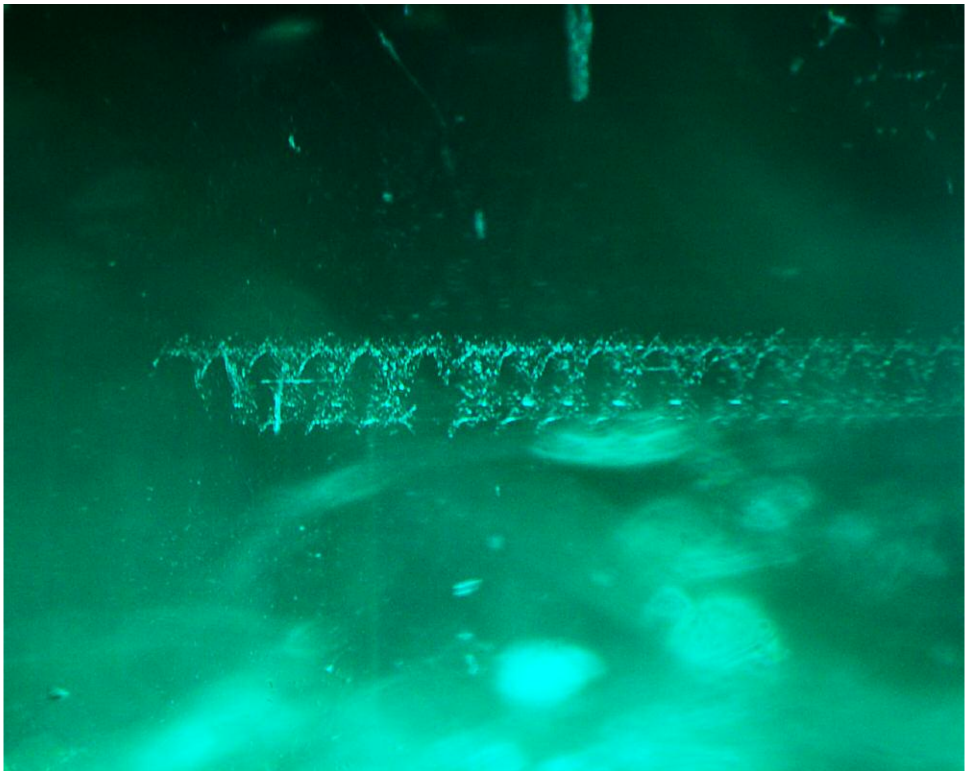


Figure 4. A three-dimensional helical inclusion in emerald. Photomicrograph by Taku Okada; field of view 2.93 mm.

sheva mine, located a few kilometers northeast of Yekaterinburg, Russia.

Closer examination of the inclusion revealed a large, distinct purple zone, as well as a purple band and a subhedral crystal form. The inclusion proved to be singly refractive when viewed between crossed polarizers. Laser Raman microspectrometry confirmed that the inclusion was fluorite. Trace-element chemistry of the host emerald collected via laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) matched well with GIA's Russian emerald chemistry reference data.

Raman analysis and microscopic observation conclusively identified the inclusion as fluorite. This strongly suggests that the unusual purple inclusion observed by author CM in 2016 was indeed fluorite; in that case, the inclusion was too deep in the stone to analyze with Raman. It is possible that purple fluorite is an unusual internal feature found only in Russian emerald, since that is the only known source from which we have observed this inclusion.

Jonathan Muyal and Claire Malaquias
GIA, Carlsbad

Helical Inclusion in Colombian Emerald

GIA's Tokyo laboratory recently examined a 7.54 ct natural emerald containing a 3D helical inclusion (figure 4) resembling a DNA double helix or fish bone. This helix, consisting of whitish grains, reached the emerald's surface. The other associated inclusions were jagged three-phase fingerprints, growth tubes, and the *gota de aceite* optical effect (R. Ringsrud, "*Gota de aceite*: Nomenclature for the finest Colombian emeralds," Fall 2008 *G&G*, pp. 242–245). All these features supported a Colombian origin. To date, three emeralds examined in GIA's Tokyo laboratory that were reportedly Colombian have exhibited similar inclusions. This helical inclusion may therefore be a characteristic of Colombian emeralds. Such a discovery within a stone is always pleasing.

Taku Okada
GIA, Tokyo

Piradee Siritheerakul
GIA, Bangkok

Mexican Opal with Large Fluid Inclusion

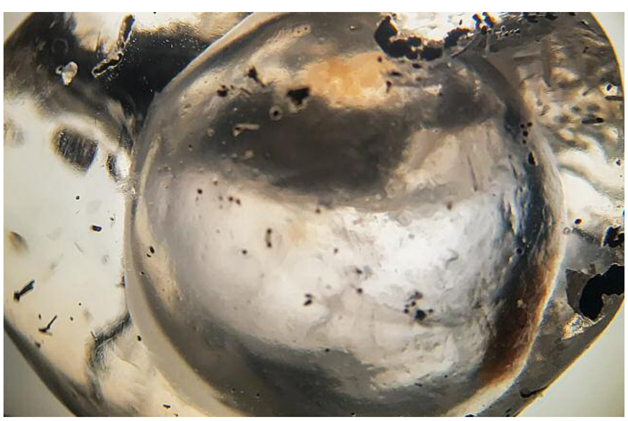
Although opals generally contain water in their structure, fluid inclusions large enough to be resolved with the microscope are rare; those that can be seen with the unaided eye are exceedingly rare. While at the JCK Show in Las Vegas, the author examined a most unusual common opal with a very large eye-visible fluid inclusion (figure 5). The fluid cavity was approximately 14 mm in diameter, and most of the space inside was occupied by a large gas bubble. An aqueous liquid could clearly be observed wetting the walls of the cavity, along with some unknown solid particles (figure 6). Since this fluid inclusion contained solid, liquid, and gaseous phases, it is appropriately described as a three-phase inclusion. According to

Figure 5. This 19.94 ct polished freeform opal contained a large, eye-visible three-phase fluid inclusion. Photo by Jian Xin (Jae) Liao; courtesy of Javier Lopez Ávila.

Javier Lopez Ávila, the stone's owner, this rare opal specimen was mined from the San Simon mine in Jalisco, Mexico, by Opalos de México. It is the first opal with a large fluid inclusion that he has observed from this deposit. This rare inclusion in Mexican opal is an interesting gemological oddity that any collector can appreciate.

Nathan Renfro
GIA, Carlsbad

Figure 6. This eye-visible three-phase fluid inclusion in a Mexican opal was just over 14 mm in diameter and contained solid, liquid, and gaseous phases. Photomicrograph by Nathan Renfro.



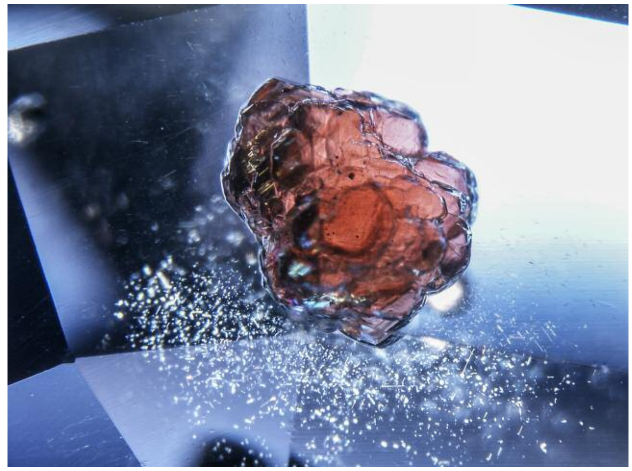


Figure 7. A protogenetic crystal of pyrope-almandine garnet with reflective needles in a greenish blue sapphire. Photomicrograph by Nattida Ng-Pooresatien; field of view 2.70 mm.

Pyrope-Almandine Garnet in Sapphire Host

In gemology, garnet occurs in a wide variety of colors, including red, orange, yellow, and green. Garnet is also found as inclusions in diamond, quartz, topaz, aquamarine, and zircon (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 1, ABC Edition, Zurich, 1986, pp. 158–160).

GIA's Bangkok laboratory recently received a 3.97 ct transparent greenish blue sapphire for a colored stone identification report. Standard gemological testing and advanced analysis revealed properties consistent with natural sapphire. Interestingly, microscopic examination with a combination of darkfield and oblique fiber-optic illumination revealed a well-formed brownish orange crystal cluster with reflective needles (figure 7). The crystal was singly refractive, and Raman spectrometry matched it with pyrope-almandine garnet. Sapphires with garnet inclusions are rarely seen in laboratory examination, although they are occasionally found in samples from Tanzania and the state of Montana (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Publishers, Basel, Switzerland, 2008, pp. 228–242).

Nattida Ng-Pooresatien
GIA, Bangkok

Euhedral Phantom Sapphire in Sapphire

A phantom sapphire crystal within a host sapphire crystal was recently examined at GIA's Carlsbad laboratory. The inclusion showed euhedral morphology as one half of a partially tapered bipyramid. The visible boundaries of the included crystal were composed of unaltered fingerprints with geometric patterns and fine linear rows. The crystal's

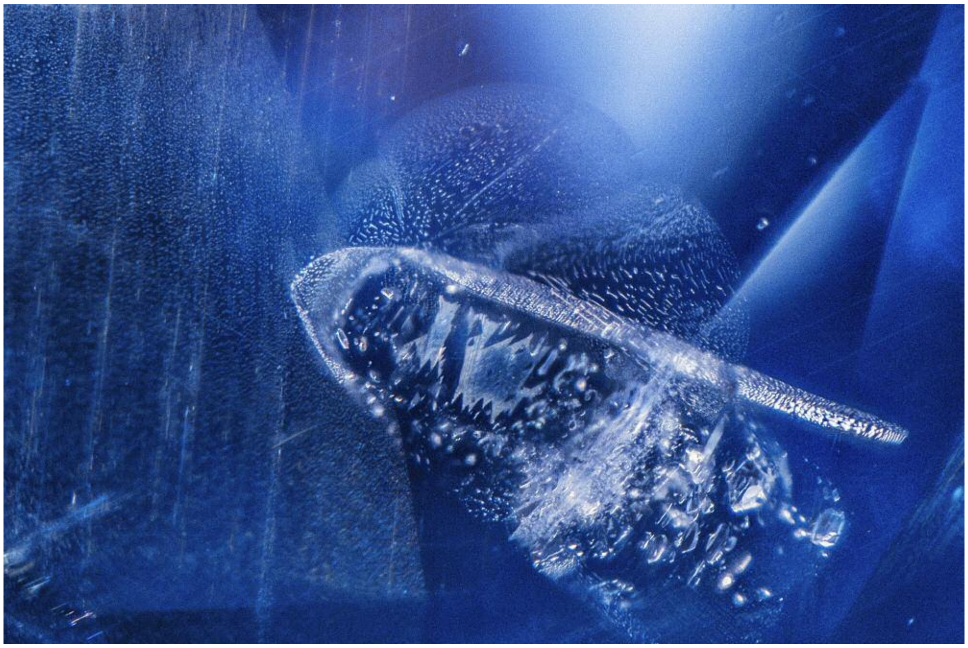


Figure 8. A partially tapered bipyramid sapphire inclusion within a sapphire. Photomicrograph by Britni LeCroy; field of view 2.90 mm.

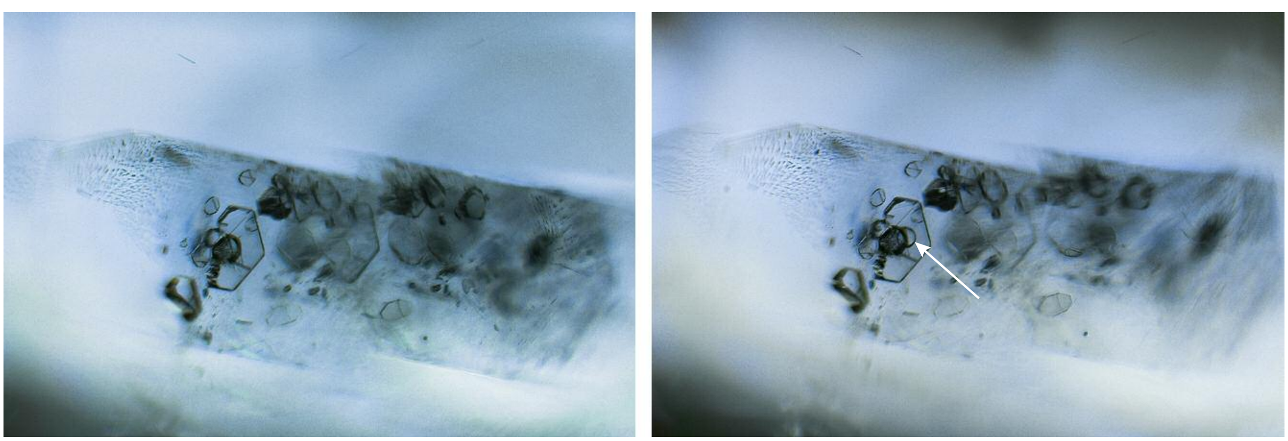
surface also showed moderate-order birefringence colors; these represented the shared interface between the host's crystal lattice and the inclusion's crystal lattice (figure 8). External local fingerprints also terminated around the crystal's end point. Negative crystals within the inclusion showed tabular hexagonal habit (figure 9, left). When the host sapphire was exposed to temperatures below the freezing point of water, a CO_2 bubble was seen within the largest negative crystal (figure 9, right). A sapphire with this inclusion combination is rarely seen.

Britni LeCroy
GIA, Carlsbad

Curved Banding in Flame-Fusion Synthetic Sapphires

Most synthetic ruby and sapphire on the market is grown by Verneuil flame fusion. It can usually be separated from natural corundum by its distinctive curved banding, in contrast to the angular zoning seen in natural stones. Gemologists may see these features in the microscope when using darkfield or brightfield illumination. This zoning can also be seen with use of a short-wave fluorescent light, as noted in *Ruby & Sapphire: A Gemologist's Guide* (R.W. Hughes et al., Lotus Publishing, Bangkok, 2017).

Figure 9. Left: Negative crystals with tabular hexagonal habit within a euhedral sapphire inclusion. Right: A CO_2 bubble appears within the largest negative crystal (see arrow) after the stone was exposed to temperatures below the freezing point of water. Photomicrographs by Britni LeCroy; field of view 1.76 mm.



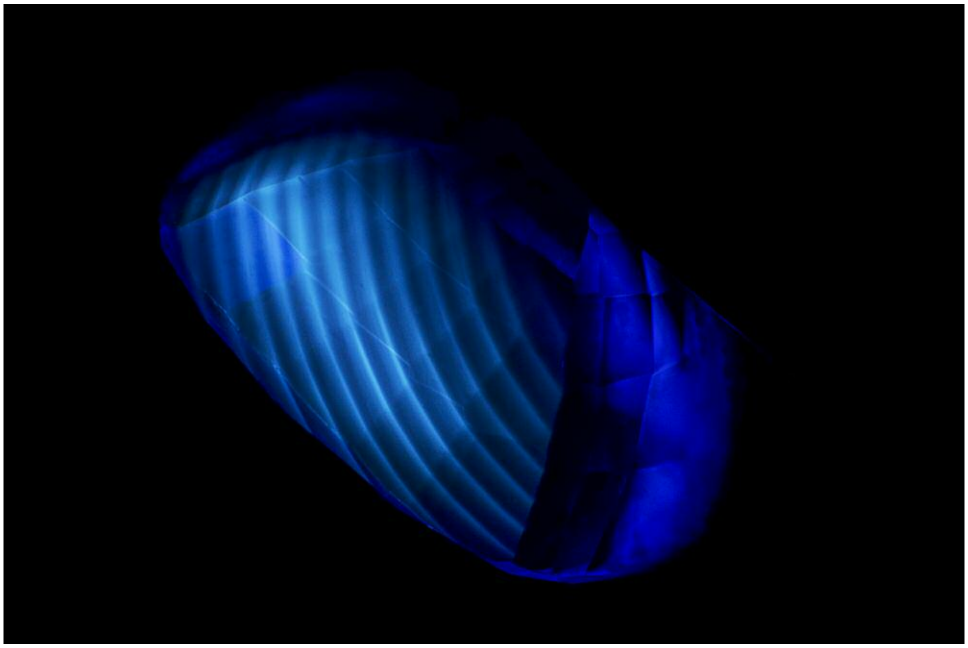


Figure 10. Curved banding is easily spotted in this flame-fusion blue synthetic sapphire when illuminated with the Magilabs deep-UV fluorescence system, a short-wave UV source. Photomicrograph by E. Billie Hughes; field of view ~13 mm.

Recently the author noticed two excellent examples. When viewed with the Magilabs deep-UV fluorescence system (a proprietary short-wave UV source), the curved banding in the synthetics was clear (figures 10 and 11), allowing them to be easily separated from natural corundum. Gemologists using a DiamondView may see the same reaction.

E. Billie Hughes
Lotus Gemology, Bangkok

Iridescent Tabasco Geode

Tabasco geodes are a small geode variety named for the area where they are mined in the Mexican state of Zacatecas, near the city of Tabasco. Typically, these geodes are lined with water-clear drusy quartz, but the author recently examined one that was filled with greenish blue botryoidal chalcedony that also showed iridescent colors (figure 12). The cause of the colors was not immediately

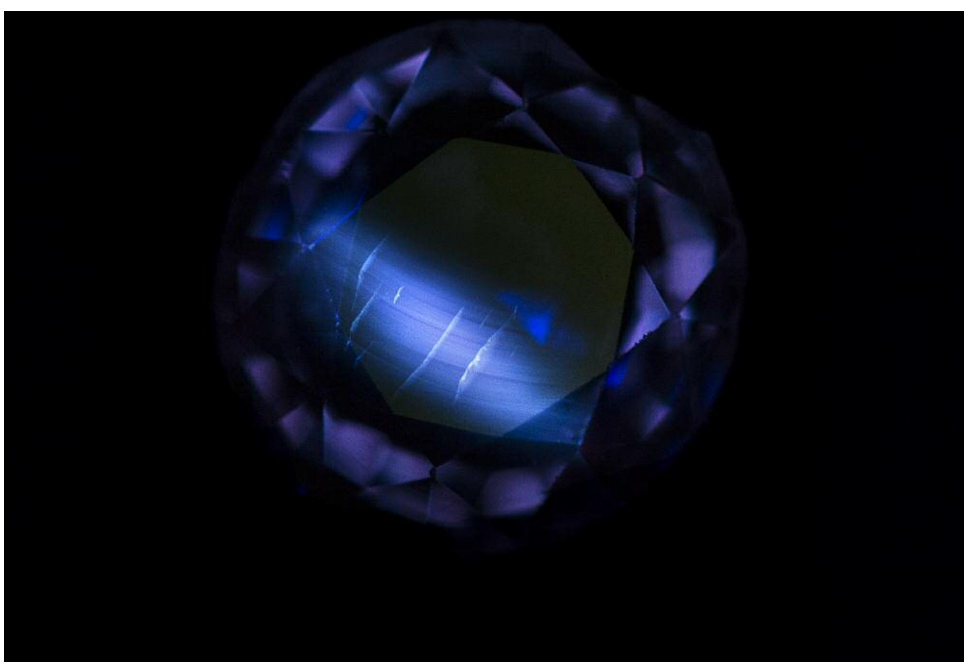


Figure 11. Observed with a short-wave UV light source, the sample displays curved banding, a telltale sign of a flame-fusion synthetic sapphire. Photomicrograph by E. Billie Hughes; field of view ~24.5 mm.

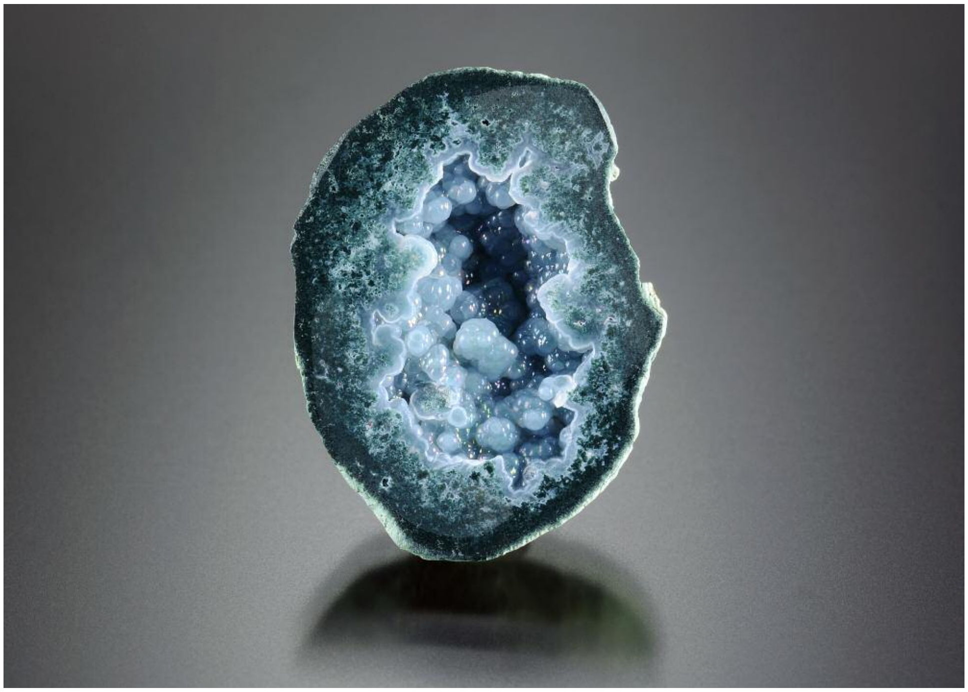


Figure 12. This unique Tabasco geode from Mexico's Zacatecas State, containing greenish blue botryoidal chalcedony, measures 24 mm in the longest dimension. Photo by Diego Sanchez; courtesy of Marquez Mining.

apparent, but microscopic examination revealed clues. The outermost layer of chalcedony had not firmly adhered to the underlying botryoidal mass. This delamination allowed an air gap along the interface of the thin outermost layer of chalcedony and the botryoidal mass of greenish blue chalcedony underneath. This air gap, in addition to the transparent nature of the very thin chalcedony shell, created thin-film interference colors along the interface of the chalcedony shell and substrate (figure 13). This explanation was supported by the observation that where areas of the delicate shell were damaged, the iridescence was not present. This Tabasco geode is one of the most visually interesting geodes examined by the author.

Nathan Renfro

Inclusion-Rich Black Topaz from the Thomas Mountains, Utah

Topaz is an important gemstone that occurs in various colors. The authors had the opportunity to examine some unusual black topaz crystals and crystal fragments whose

Figure 13. The Tabasco geode hosts greenish blue chalcedony, with a thin chalcedony shell that was responsible for the iridescent thin-film interference colors. Photomicrograph by Nathan Renfro; field of view 1.83 mm.

Figure 14. The black appearance of a topaz was due to these small dark mineral inclusions. Photomicrograph by Jonathan Muyal; field of view 1.44 mm.

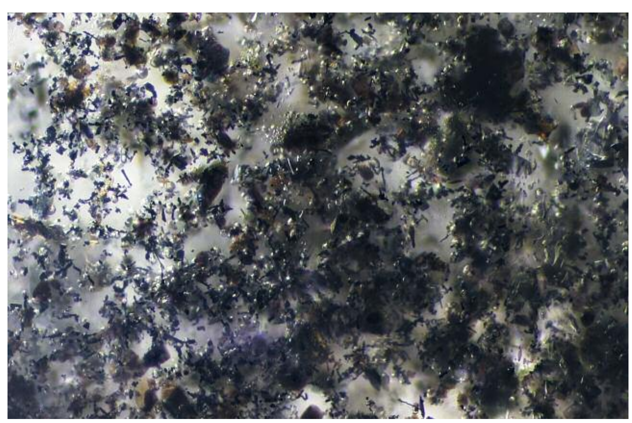


Figure 15. A black topaz crystal specimen from the Thomas Mountains in Utah (24.8 × 17.92 × 12.29 mm). Photo by Kevin Schumacher.

appearance was the result of numerous small dark mineral inclusions (figures 14 and 15). The topaz originated from an undisclosed locality in the Thomas Mountains in Juab County, Utah. They were provided by Shaun Rasmussen and Krisann Morrill (SK Star Claims, Provo, Utah), who discovered the occurrence. Careful microscopic examina-

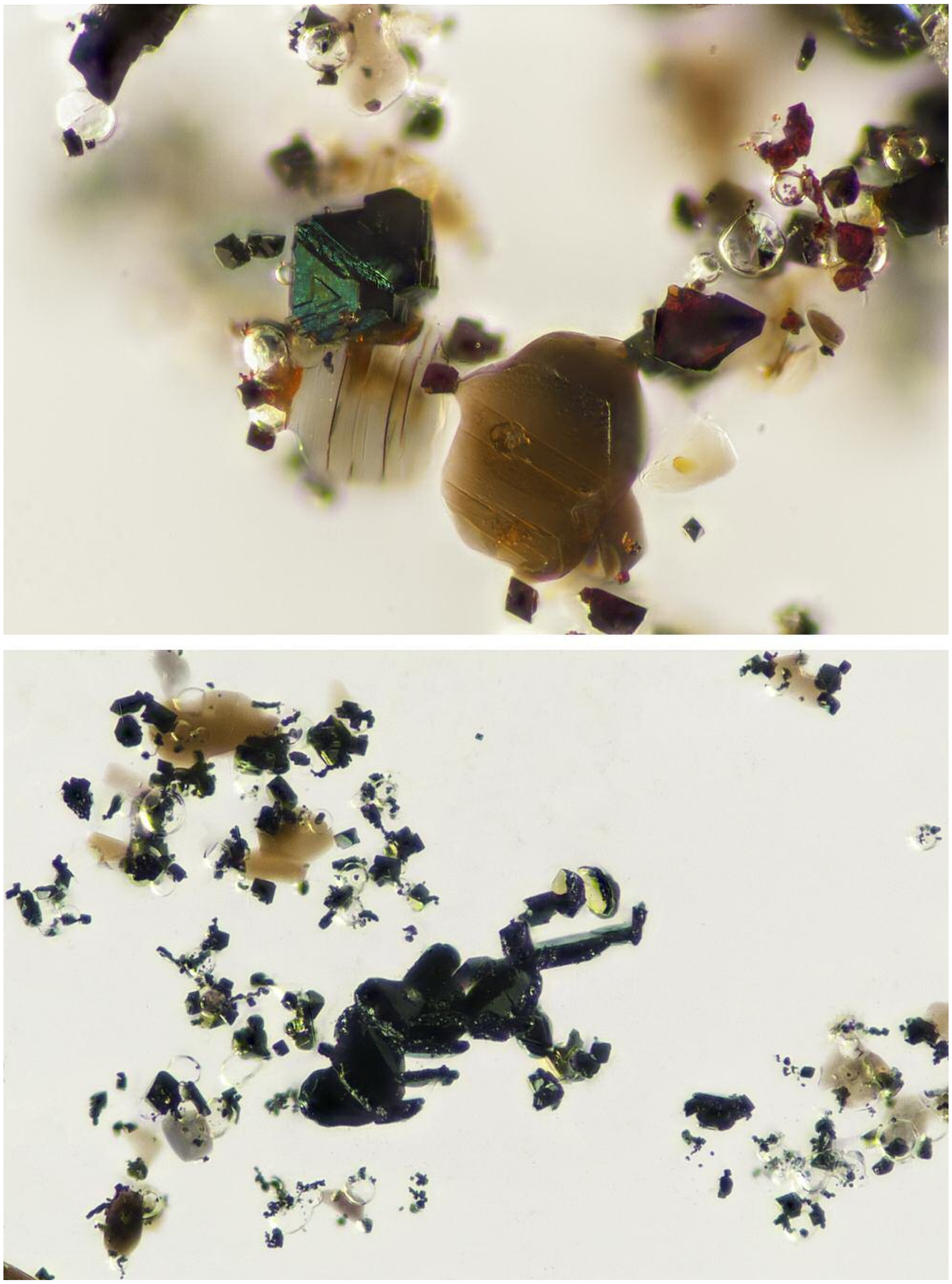


Figure 16. Top: Inclusions seen in this photomicrograph include black magnetite, colorless fluorite, and brown annite/phlogopite. Bottom: Clusters of tabular wolframoixiolite crystals along with fluorite and mica inclusions. Photomicrographs by Jonathan Muyal; fields of view 0.288 mm (top) and 0.36 mm (bottom).

tion revealed the presence of several inclusion minerals (figure 16, top). Among these were thin, translucent brownish plates of annite/phlogopite mica; transparent colorless, spherical crystals of fluorite; and opaque black octahedral crystals of magnetite. These minerals, which are well-known inclusions in topaz, were confirmed by Raman microspectrometry.

The most abundant inclusions—and apparently the principal cause of the black appearance—were numerous opaque flattened or stubby crystals of wolframoixiolite (figure 16, bottom), a rare complex oxide mineral with the ideal formula $(Nb,W,Ta,Fe,Mn,Nb)_2O_4$ (N. Ray, "Mineralogy and geochemistry of unusual localized W-Nb included black topaz from the Thomas Mountain Range, UT," unpublished and undated manuscript, provided by SK Star Claims to the authors). Quantitative chemical analysis by LA-ICP-MS revealed a composition of 1.66 wt.% CaO, 2.28 wt.% TiO_2, 5.52 wt.% MnO, 19.93 wt.% Fe_2O_3, 1.94 wt.% ZrO_2, 24.66 wt.% Nb_2O_5, 1.17 wt.% MoO_3, 1.17 wt.% Ta_2O_5, 40.15 wt.% WO_3, and 1.53 wt.% other elements. This gave a calculated chemical formula of $(Ca_{0.074}, Ti_{0.071}, Mn_{0.193}, Fe^{3+}_{0.620}, Zr_{0.039}, Nb_{0.461}, Mo_{0.020}, Ta_{0.013}, W_{0.430}, others_{0.026})_{1.948}O_4$,

Figure 17. Measuring 25.28 × 17.51 × 7.67 mm and weighing 15.65 ct, this colorless quartz crystal from Namibia hosts numerous transparent blue-green inclusions of dioptase. Photo by Diego Sanchez.

which is consistent with the chemistry of this uncommon mineral.

The presence of both magnetite and wolframoixiolite inclusions in the topaz resulted in a slight magnetic behavior. The corroded and sometimes altered appearance of both dark inclusion phases suggests that they represent protogenetic inclusions that formed during an earlier stage of mineral crystallization in the growth environment and were subsequently incorporated within the topaz. In spite of their abundance, these different inclusion minerals did not create any optical phenomena.

We thank those who provided these samples, which represent the first black-appearing topaz we have examined.

Jonathan Muyal, Ziyin Sun, and James Shigley
GIA, Carlsbad

Figure 18. Trigonal blue-green crystals in and on the surface of this colorless quartz were identified by Raman analysis as dioptase. Photomicrograph by Nathan Renfro; field of view 11.75 mm.

Quarterly Crystal: Dioptase in and on Quartz

Crystals of transparent colorless rock crystal quartz play host to a wide variety of mineral inclusions, some of which are highly attractive. Due to its transparency and bright blue-green color, one of the most visually striking inclusions occasionally found in quartz is dioptase. Occurring in the oxidized zones of some copper deposits, dioptase gets its vibrant color from copper, the chemical formula of dioptase being $Cu_6Si_6O_{18}\cdot 6H_2O$.

Recently we had the opportunity to examine an unusual arrowhead-shaped, fully terminated colorless quartz crystal that was decorated on one side with a crust of numerous trigonal transparent dioptase crystals that were both in and on their host. The geographic source for the crystal shown in figure 17 is Kaokoveld, Namibia. Weighing 15.65 ct and measuring 25.28 × 17.51 × 7.67 mm, this unusual example of rock crystal plays host to numerous near-surface trigonal crystals (figure 18) up to 3.0 mm in length.

The visual characteristics of the features—the trigonal micromorphology, degree of transparency, and color of the numerous inclusions—suggested dioptase; this was confirmed using laser Raman microspectrometry. The euhedral dioptase inclusions were situated on only one side of the quartz, which illustrates that they developed through directional deposition late in the quartz growth cycle.

John I. Koivula and Nathan Renfro
GIA, Carlsbad