Breyite Inclusion in Diamond

Sublithospheric or "superdeep" diamonds are rare, estimated to make up only 1–3% of mined diamonds globally. They are recognized on the basis of their mineral inclusions. Breyite ($CaSiO_3$) is one of the minerals sometimes encountered in this curious geological family of diamonds. Diamonds containing breyite are often interpreted to come from depths greater than 360 km, where the breyite would have initially had a high-pressure perovskite-type crystal structure. The perovskite-structured $CaSiO_3$ would have changed to the breyite crystal structure in response to the drastic decrease in pressure during the diamond's journey to the surface. Alternatively, it is theoretically possible that breyite could be trapped directly in a diamond at much shallower depths, say within 150–200 km, although such an occurrence within a known lithospheric diamond has yet to be encountered.

The breyite inclusion in figure 1 was recently observed in a 1.00 ct D-color type IIa diamond submitted to GIA's New York laboratory. Raman spectroscopy was used to identify it as breyite. This large inclusion, 450 μm in its longest dimension, is colorless and transparent. A conspicuous healed fracture surrounds it, containing graphite (black) and smaller "sub-inclusions" of breyite that appear to emanate from the main inclusion. Based on this breyite inclusion, the diamond is suspected to be sublithospheric in origin.

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About the banner: This topaz from Madagascar contains a negative crystal etch tube, highlighted in blue using Rheinberg illumination. Photomicrograph by Nathan Renfro; field of view 2.21 mm. Stone courtesy of the John Koivula Inclusion Collection.

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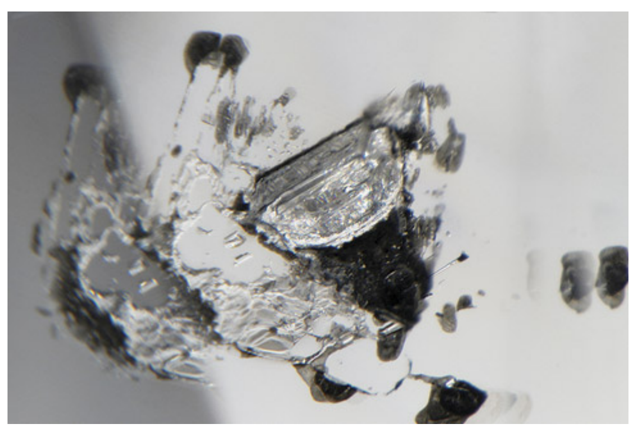
Small "Surprise" in Elbaite Tourmaline

Recently, a 0.86 ct orange-yellow elbaite tourmaline cabochon was submitted to Taiwan Union Lab of Gem Research (TULAB) for identification service. The stone contained many prismatic and round xenocrysts. Among these inclusions was a prismatic crystal associated with a

Figure 1. A breyite inclusion in diffuse illumination. Doubling of some features to the right and left of the inclusion is an artifact of viewing through multiple pavilion facets. Photomicrograph by Evan M. Smith; field of view 1.58 mm.



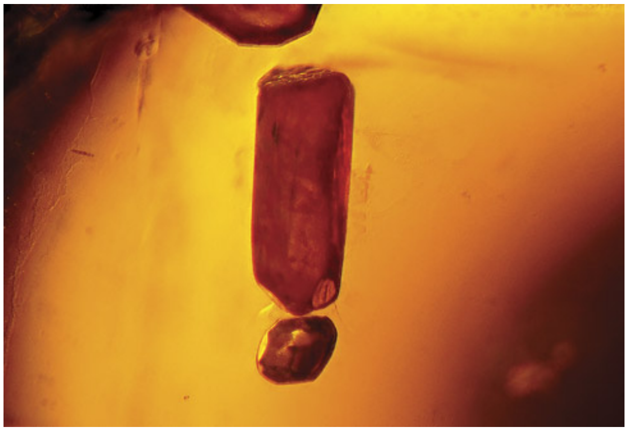


Figure 2. The "exclamation point" inclusions were identified as diopside crystals using Raman spectroscopy. Photomicrograph by Shu-Hong Lin; field of view 4.11 mm.

round crystal, a composition resembling an exclamation point (figure 2). The crystals were later confirmed to be diopside using Raman spectroscopy. Darkfield illumination, plane polarized light, and extended depth of field were adopted to obtain a clear microscopic image of this little "surprise" inside the gemstone.

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Figure 3. This 27.76 ct pear-shaped double cabochon contained several fluid inclusions with a vibrant purple component. Photo by Annie Haynes; courtesy of Mike Bowers.

Unusual Purple Fluid in Quartz

Recently the authors examined a 28.93 mm long, 27.76 ct transparent pear-shaped double cabochon rock crystal quartz that contained numerous fluid-filled negative crystals (figure 3). Oddly, some of the negative crystals also hosted a brightly colored purple liquid in addition to what appeared to be a colorless liquid, the two liquid phases being immiscible (figure 4).

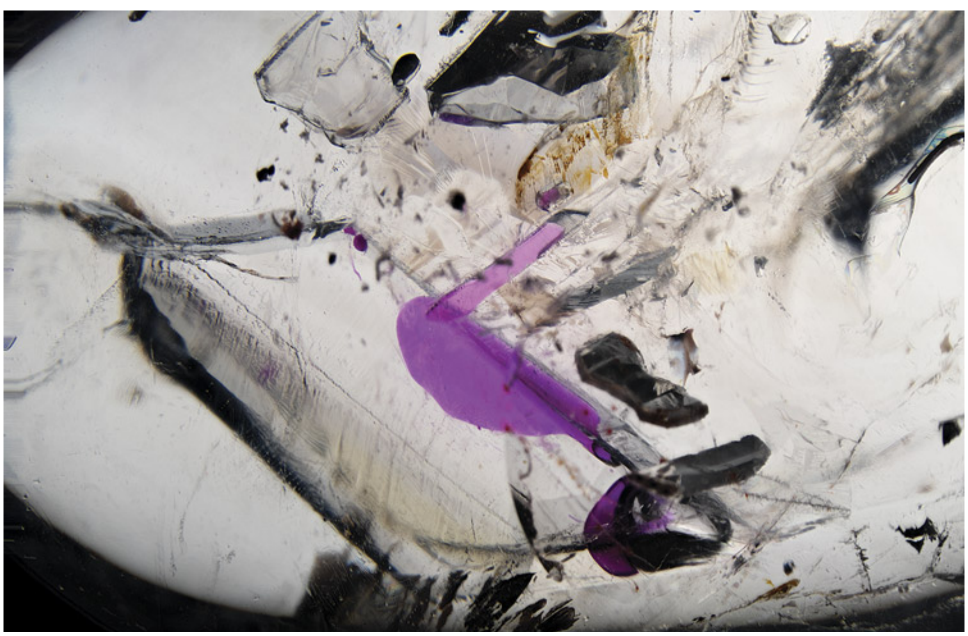

Figure 4. Several fluid-filled negative crystals were present in this rock crystal quartz cabochon, a few of which contained a highly unusual brightly colored purple liquid. Photomicrograph by Nathan Renfro; field of view 14.50 mm. Courtesy of Mike Bowers.

Not all of the fluid inclusions within this quartz contained the purple component. However, all of the purple liquid–hosting negative crystals did contain partially healed, limonite-stained fractures intersecting them. This suggests that the purple fluid may have entered the negative crystal cavities through a post-growth or secondary process rather than homogeneous entrapment during growth.

While colored fluid inclusions have been previously reported in quartz—colors that include blue, yellow, and orange (see e.g., Spring 2004 Gem News International, pp. 79–81; Spring 2006 Gem News International, p. 71)—this is the authors' first observation of a purple fluid trapped within quartz. Unfortunately, Raman spectroscopy to identify the fluid was unsuccessful, as the fluid was too deep in the crystal. While the composition of the fluid is unknown, as well as the conditions under which the fluid entered the quartz, there is no obvious indication that it resulted from an artificial process. However, the possibility of such artificial tampering cannot be ruled out entirely. This fascinating purple fluid inclusion is one of the strangest and most interesting the authors have examined.

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Large Orange Rutile Inclusion in a "Chameleon" Diamond

The author recently received for analysis a 1.51 ct round brilliant diamond with very light green color and SI_2 clarity. The diamond exhibited "chameleon" properties, showing a clear color change from green to yellow upon heating with an alcohol lamp. An ~0.2 mm orange inclusion was clearly visible on the crown (figure 5). The crystal was partially enclosed, confirming it was an actual inclusion rather than a crystal adhered to the diamond surface. It was also partially exposed, enabling simple Raman spectroscopy for identification without the spectra showing any contribution from the diamond itself. The crystal was determined to be rutile (TiO_2), suggesting an eclogitic origin.

Rutile inclusions in diamond are themselves relatively uncommon, and we rarely see such a large, eye-catching crystal. Rutile inclusions can also provide useful clues about a diamond's age. Geochemists can determine the age of rutile crystals by measuring the concentration of isotopes of various elements that are present at parts-per-million concentrations, allowing for constraints on the age of the diamond itself (see A.K. Schmitt et al., "U-Pb ages of rare rutile inclusions in diamond indicate entrapment synchronous with kimberlite formation," *Lithos*, Vol. 350-351, 2019, article no. 105251). It will be interesting to see what scientific information this rare inclusion in diamond may reveal.

Mike Jollands
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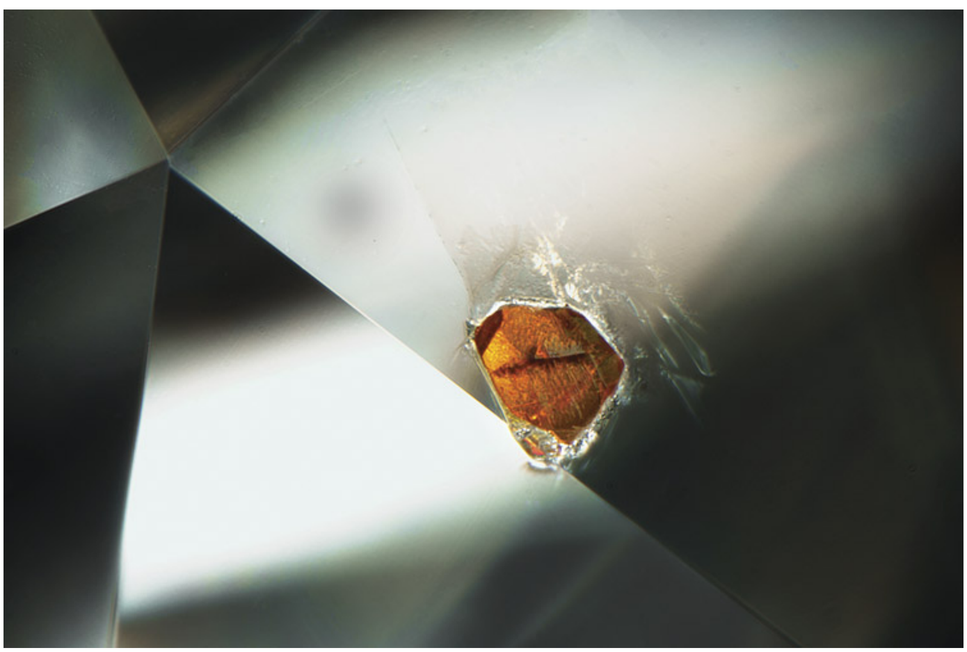

Figure 5. An orange rutile crystal partially enclosed on the crown of a faceted diamond (the sharp line from top left to bottom right is the facet junction). Photomicrograph by Tyler Smith; field of view 0.8 mm.

"Smoke Rings" in a Non-Beryllium-Diffused Sapphire

When analyzing corundum for evidence of heat treatment, one of the most useful and standard methods for gemologists is microscopic examination (N.D. Renfro et al., "Inclusions in natural, synthetic, and treated sapphire," Summer 2017 *G&G*, pp. 213–214). Inclusion suites can

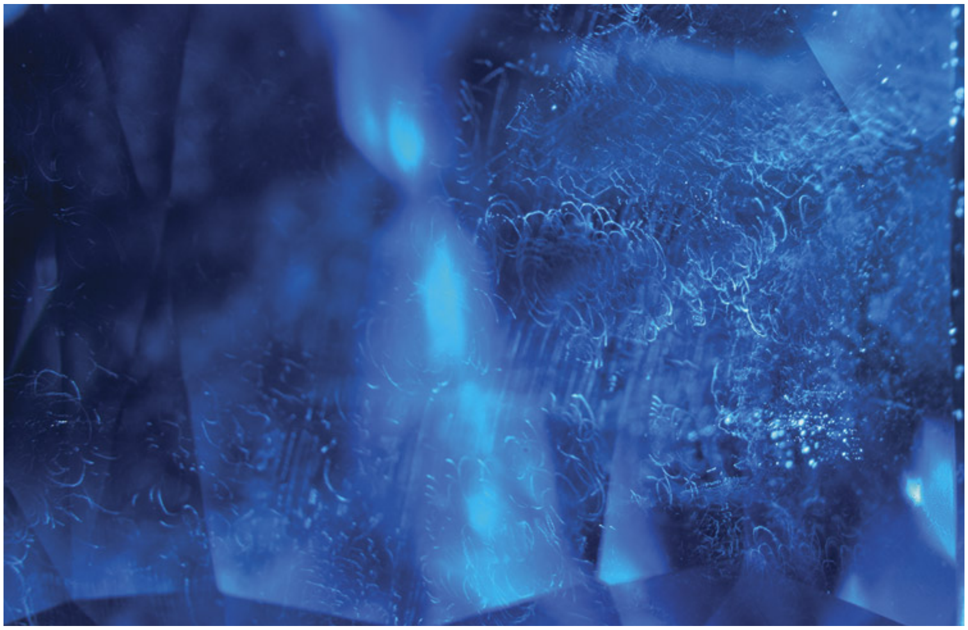

Figure 6. This "smoke ring" pattern was observed in a heat-treated blue sapphire. While this pattern is commonly associated with beryllium-diffused blue sapphires, no beryllium was detected in this stone. Photomicrograph by Nicole Ahline; field of view 7.39 mm.

start to alter at temperatures as low as 200°C. As the temperature rises, many inclusions start to show clear evidence of heat treatment, such as the internal diffusion of titanium, resulting in a spotty blue color, and discoid tension cracks with healed fringes around crystals. Standard temperature heat treatment for corundum happens between 500° and 1700°C, whereas high-temperature heat treatment, such as beryllium diffusion, occurs at temperatures above 1750°C. These high temperatures can modify inclusions in a way that renders them unidentifiable, suggesting that a stone may have undergone beryllium diffusion.

While examining a heated blue sapphire recently, the author observed "smoke ring" inclusions throughout it (figure 6) using fiber-optic illumination. Trace element chemistry analysis of the blue sapphire via laser ablation–inductively coupled plasma–mass spectrometry revealed no signs of beryllium. This came as a surprise, as this dislocation pattern is associated with beryllium-diffused corundum. These "smoke ring" dislocations are consistent with sapphires that have been heated at high temperatures, but chemistry ruled out beryllium diffusion treatment. This sapphire offers a striking example of why continuous documentation of inclusions, in both treated and untreated gemstones, is an important tool in gemstone analysis.

Nicole Ahline
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Stellate Zircon in a Paraíba Tourmaline

While examining a 1.17 ct blue-green Paraíba tourmaline with a fiber-optic light, the author observed a remarkable set of stellate inclusions (figure 7). The striking suite consisted of one larger cluster with scattered smaller needles trailing behind it. Reflective lighting revealed needles breaking the surface with a different luster from the host tourmaline. Raman spectroscopy identified the needles as zircon.

Tourmalines form in a pegmatite environment and contain inclusions that reflect this type of growth, most notably fluid inclusions, transparent crystals, and tubular inclusions. Zircon has been observed in tourmaline as prismatic or rounded crystals. The zircons in this 1.17 ct Paraíba tourmaline were atypical as they were needles and in a stellate formation. This type of zircon morphology has been previously documented in morganite (Winter 2013 Lab Notes, pp. 253–254), but stellate inclusions, specifically those composed of zircon, are a rather unique find. The stellates in this Paraíba tourmaline make the gemstone quite unusual.

Nicole Ahline

Figure 7. Zircon needles in a stellate formation observed in a 1.17 ct blue-green Paraíba tourmaline. Photomicrograph by Nicole Ahline; field of view 2.18 mm.

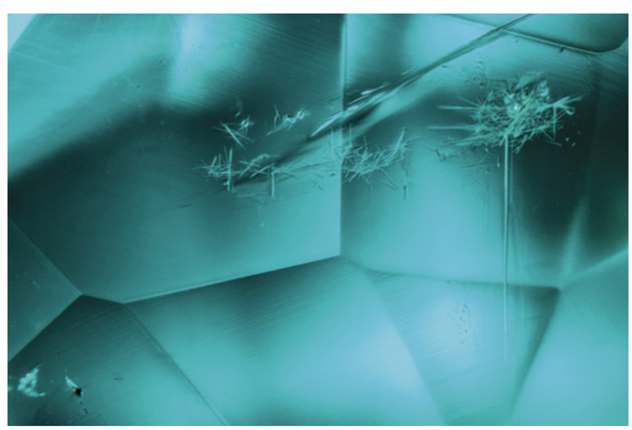

Figure 8. Weighing 751.95 ct, this parallel cluster of two quartz crystals contains a directional phantom plane composed of numerous green to near-colorless hexagonal inclusions. Photo by Adriana Gudino.

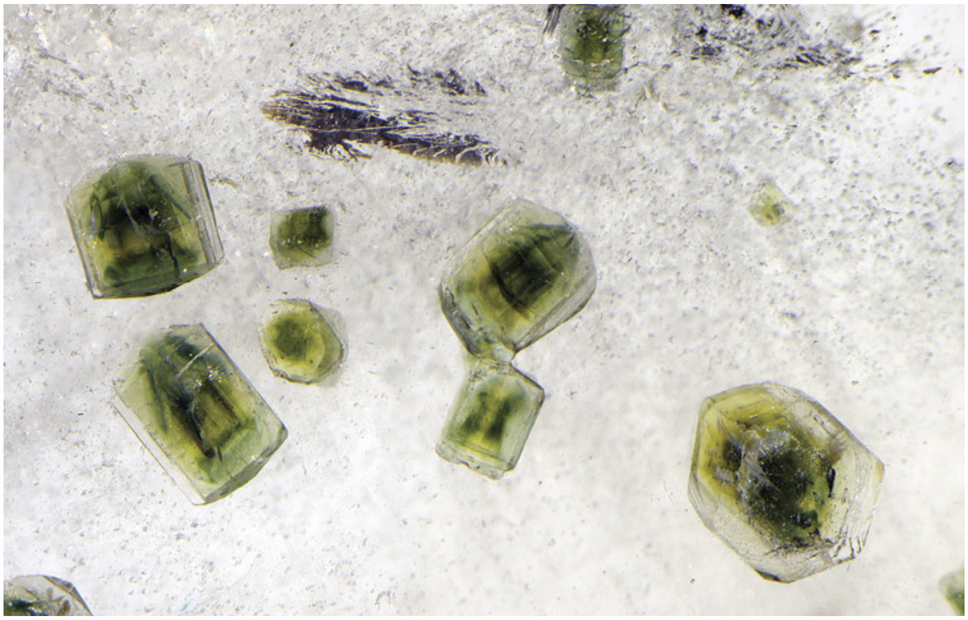

Figure 9. The translucent green-colored crystals along the phantom plane in the Portuguese quartz were identified as fluorapatite by Raman analysis. Photomicrograph by Nathan Renfro; field of view 12.47 mm.

Quarterly Crystal: Panasqueira Quartz

With its relatively high hardness and high degree of transparency, colorless rock crystal quartz is the perfect host for an abundance of fluid and mineral inclusions. As a common crustal mineral, it sometimes forms as solid single crystals and crystal clusters.

This issue's Quarterly Crystal, a 751.95 ct double crystal measuring 110.54 × 50.30 × 24.82 mm from Minas da Panasqueira in Portugal (figure 8), comes from the personal collection of Jordi Fabre of Fabre Minerals in Barcelona. Examination of the two parallel quartz crystals revealed numerous colorless to green, transparent to translucent euhedral inclusions, identified by Raman analysis as fluorapatite (figure 9). Some of these fluorapatite inclusions surrounded a much larger dark brownish orange protruding crystal confirmed as cassiterite (figure 10).

The colorless to green fluorapatite crystals show directional deposition and are along a phantom plane, situated only on one side of the quartz specimen. This suggests that they are syngenetic with the quartz host.

Quartz is relatively common at the Panasqueira mine. This "floater" quartz crystal group, which is recrystallized at its base, is an excellent host for the numerous inclusions of fluorapatite and the solitary cassiterite crystal.

John I. Koivula and Nathan Renfro

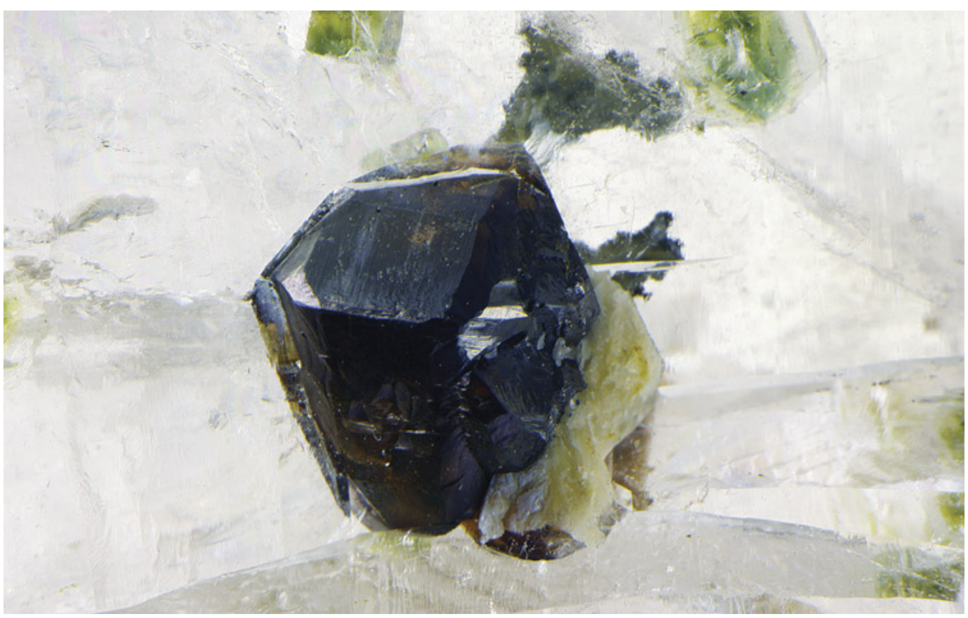

Figure 10. Using Raman microspectrometry, this single protruding dark brownish orange crystal was identified as cassiterite. Photomicrograph by Nathan Renfro; field of view 13.64 mm.