G&G Micro-World

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Actinolite in Spinel

Lotus Gemology received a vivid cobalt blue spinel from Vietnam for laboratory testing. Despite its small size of well under a carat, its stunning color stood out immediately. The stone proved to be exceptionally clean. Most cobalt spinels we test contain fissures, small crystals, or other inclusions. After careful examination, we found just one tiny inclusion, a transparent teardrop-shaped crystal (figure 1).

Raman microscopy revealed the crystal to be actinolite, a mineral in the amphibole group. As far as we are aware, this is the first reported inclusion of actinolite in spinel.

E. Billie Hughes
Lotus Gemology, Bangkok

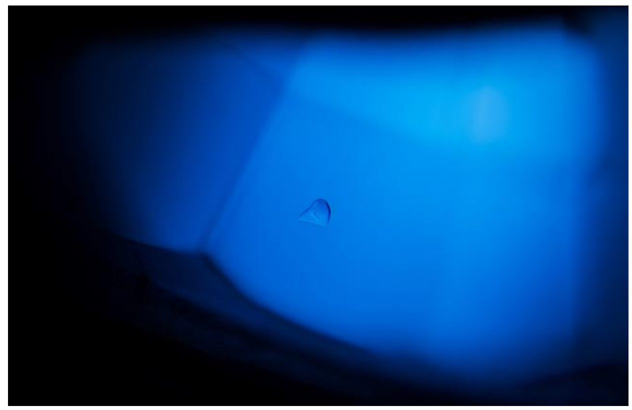

Figure 1. This small transparent colorless crystal in spinel was identified by Raman analysis as actinolite. Photomicrograph by E. Billie Hughes; field of view 1.7 mm.

Bavenite in Quartz

The author recently had the opportunity to examine a 233.60 ct faceted quartz containing numerous white radial inclusions, courtesy of Mike Bowers (figure 2). The unusual inclusions were identified as the mineral bavenite by Raman and laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) analysis.

South America claims a long history of gemstone production and arguably produces some of the finest gem specimens in the world. Of the South American gem-producing areas, Brazil is by far the most prolific source of important gemstones. Due to the array of different geologic environments, a number of uncommon minerals can be found. The mineral bavenite, $Ca_4Be_2Al_2Si_9O_{26}(OH)_2$, is an uncommon orthorhombic mineral that occurs as drusy in

Figure 2. Clusters of white radial needles of the mineral bavenite were seen in this 233.60 ct quartz. Photomicrograph by Nathan Renfro; field of view 13.43 mm. Courtesy of Mike Bowers.

About the banner: Green crystals of tangeite are perched on bright blue needles of papagoite in this quartz from the Messina mine in Transvaal, South Africa. Photomicrograph by Nathan Renfro; field of view 3.35 mm.

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

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miarolitic cavities in granite and associated pegmatite, formed by a low-temperature alteration of beryl and other beryllium-bearing minerals, and also in hydrothermal veins and skarns. It generally forms in more alkali environments and is often associated with bertrandite, titanite, danalite, and zeolites (J.W. Anthony et al., Eds., *Handbook of Mineralogy*, Mineralogical Society of America, http://www.handbookofmineralogy.org). This is believed to the first time GIA has encountered bavenite inclusions in quartz.

Maxwell Hain
GIA, Carlsbad

Figure 3. This negative crystal in a diamond is colored green by radiation staining and contains a loose green diamond crystal. Photomicrograph by Nathan Renfro; field of view 4.23 mm.

Diamond with Mobile Green Diamond Inclusion

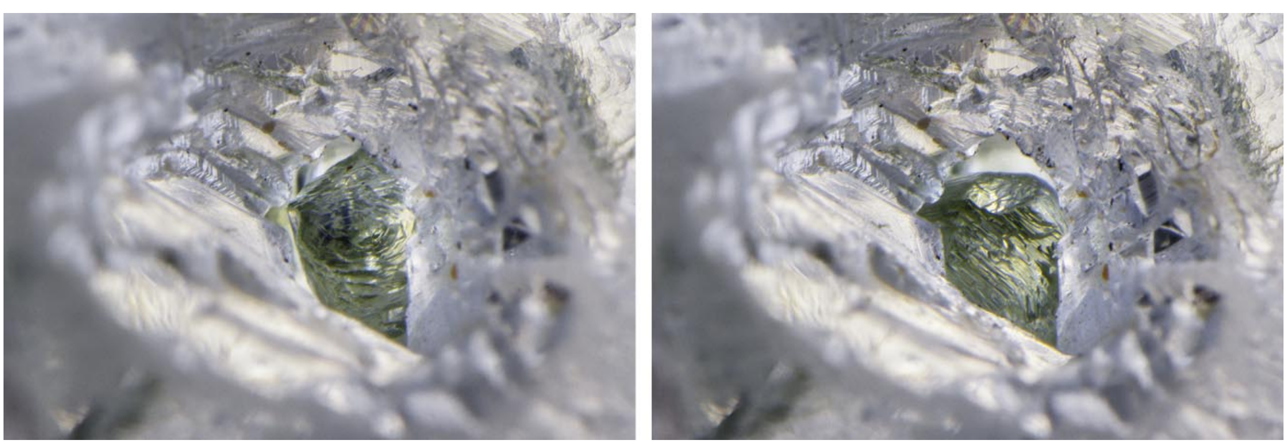
Diamond inclusions are relatively common guests in diamond crystals. They generally go unnoticed as the refractive index of the host and guest are the same. So it is often the case that the only visual clues to such an inclusion lie in the interface between the host and guest, where the slight mismatch traps fluids from the growth environment and leaves a delicate optical irregularity with the appearance of a ghost-like framework of diamond. Inclusions like this can be further explored by examining stones in polarized light, which often reveals significant strain around the guest diamond.

One of the most interesting examples of a diamond inclusion in diamond the authors have encountered is a 0.87 ct sawn crystal section containing a negative crystal cavity (figure 3) that is open at the surface. Inside is a tiny green octahedral diamond crystal that is free to rattle around but too large to exit through the opening at the surface (figure 4). For a video of the green diamond inclusion moving inside the negative crystal contained in the host diamond, go to https://www.gia.edu/gems-gemology/spring-2020-microworld-diamond-mobile-diamond-inclusion.

Presumably this diamond inclusion was completely encased in its diamond host, but dissolution occurred as the host made its way to the earth's surface, causing the interface between the two crystals to widen until the small entrapped crystal was liberated enough to become mobile (J.I. Koivula, *The MicroWorld of Diamonds*, Gemworld International, Northbrook, Illinois, 2000, 157 pp.). Subsequently, the diamond must have been exposed to fluids carrying radioactive materials that entered through the small opening, causing green radiation staining of the negative crystal and guest diamond inclusion. While mobile diamond inclusions in diamond are always remarkable (see Lab Notes, pp. 127–129 of this issue), this example is the only one the authors have observed of a mobile green diamond inclusion trapped in a colorless diamond.

Nathan Renfro and John I. Koivula
GIA, Carlsbad

Figure 4. This registered pair of images shows how the green diamond contained inside the negative crystal can change position inside the host diamond and how the green diamond is too large to fit through the opening to the surface. Photomicrographs by Nathan Renfro; field of view 3.20 mm.



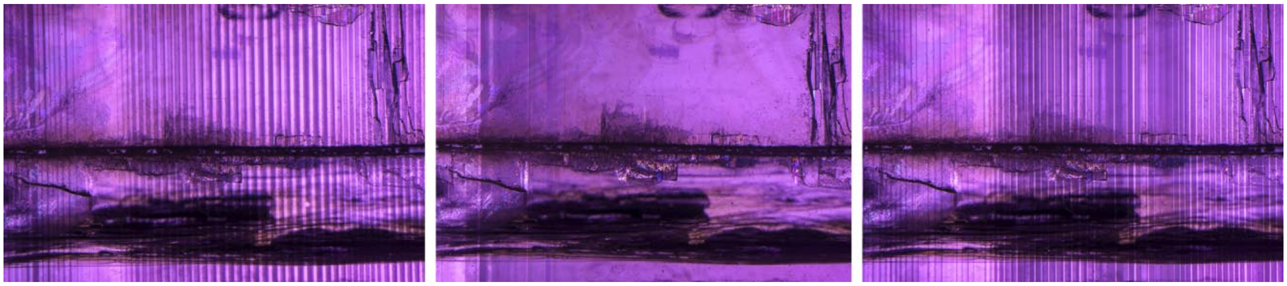


Figure 5. Neodymium pentaphosphate is a rare experimental synthetic material that shows reversible lamellar twinning under polarized light when gentle pressure is applied perpendicular to the twinning planes. This series of images shows vertical striations that have changed with slight pressure. Photomicrographs by Nathan Renfro; field of view 14.10 mm.

Reversible Twinning in Neodymium Pentaphosphate

Unusual synthetic gem materials are often the result of experimental crystal growth for industrial applications, including use in the laser industry. One such experimental synthetic that was produced in a very limited quantity is neodymium pentaphosphate, with the chemical formula of NdP_5O_{14} (Winter 1997 Gem News, pp. 307–308). Examined using polarized light, it displays very prominent lamellar twinning. Lamellar twinning is a regular parallel repeated reversal in growth that causes the twinning planes to appear as alternating dark and light bands when observed in polarized light (figure 5). The material's most unusual property is that when slight pressure is applied perpendicular to the twinning planes, the twinning reverses so that the dark areas can become light, and the light areas become dark. See video of this at https://www.gia.edu/gems-gemology/spring-2020-microworld-reversible-twinning-ndp. Interestingly, the reversal is also accompanied by a weak clicking sound. The unusual elastic twinning of this material makes it exceedingly difficult to cut into a gem, though a 5.33 ct stone was faceted by Art Grant of Coast-to-Coast Rare Gems in the 1990s. To the authors' knowledge, no other material displays this interesting property.

Nathan Renfro and John I. Koivula

Pallasitic Peridot with Iridescent Needle-Like Inclusions

Pallasite is a rare type of stony iron meteorite that contains crystalline olivine. The author recently had the opportunity to examine a suite of pallasitic peridot that were reported to have originated from the Jepara meteorite found on the Indonesian island of Java in 2008 (figure 6). The stones were selected by Bradley Payne for the abundance of needle-like inclusions that showed vibrant interference colors. To observe the inclusions, oblique fiber-optic illumination was used to explore the gems until the light re-

Figure 6. This suite of pallasitic peridot (0.17–1.40 ct) from the Jepara meteorite contains colorful needle-like inclusions. Photo by Robison McMurtry; courtesy of Bradley Payne.

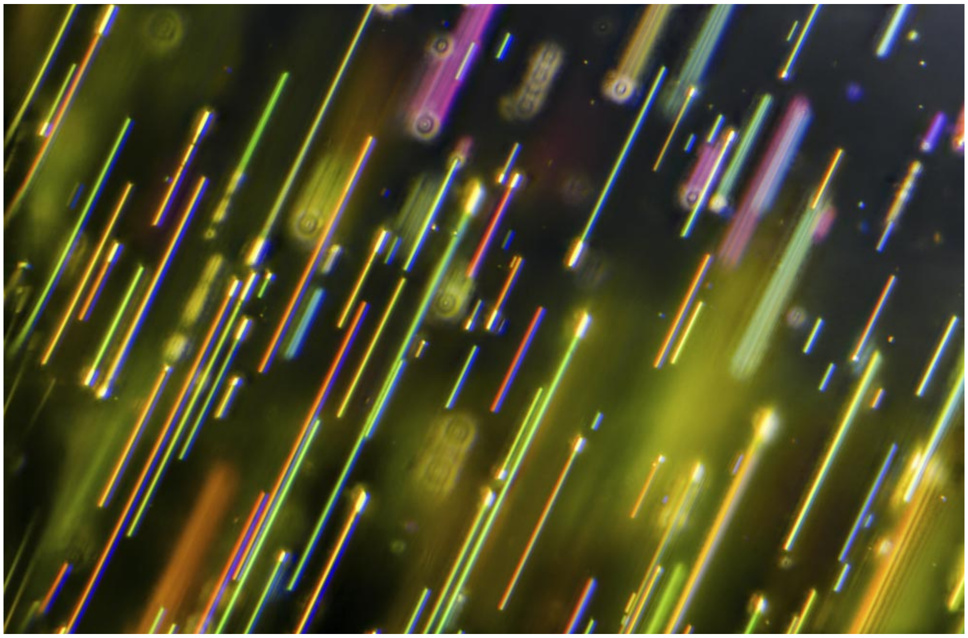


Figure 7. Oblique fiber-optic illumination revealed colorful iridescent needle-like inclusions in the pallasitic peridot from Java. Photomicrograph by Nathan Renfro; field of view 1.83 mm.

flected off the inclusions at the same time, revealing their hidden colorful beauty (figure 7) and confirming the crystallographic alignment of the inclusions. According to Payne, less than 5% of the gems from the Jepara meteorite show these types of inclusions. These are the most beautiful inclusions the author has examined in a suite of pallasitic peridot from the Jepara meteorite.

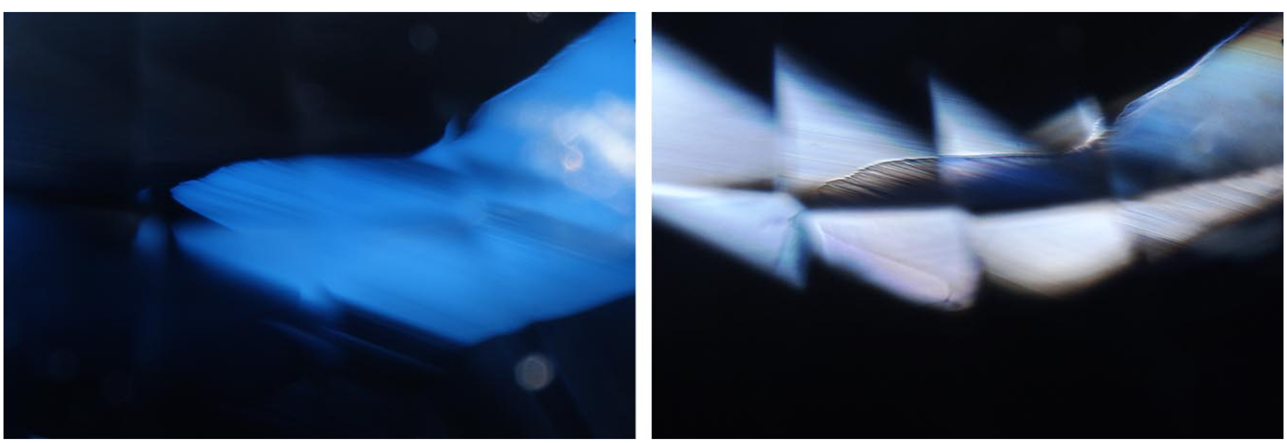
Nathan Renfro

Phenomenon Resembling Play-of-Color in Sapphire

A phenomenon resembling play-of-color was seen in a 4.13 ct unheated sapphire recently examined by the author. When tilted in darkfield lighting (watch the video at https://www.gia.edu/gems-gemology/spring-2020-microworld-play-of-color-sapphire), the sapphire displayed this noteworthy effect, which is most commonly seen in precious opal. It occurred within a small section of a single fine, milky cloud with an unusual shape (figure 8, left). The cloud also possessed extensive transparent graining confined within its borders, best seen in brightfield illumination (figure 8, right).

Some regions of the cloud displayed an appearance of rainbow graining with spectral colors confined to the linear grain lines and looked one-dimensional. Other regions, however, expressed a soft billowy broad flash of altering colors with diffuse edges resembling play-of-color and did not follow linear grain lines (figure 9). Play-of-color in opal is defined

Figure 8. Left: A fine, angular milky cloud as seen in darkfield illumination. Right: Brightfield illumination of the same cloud reveals fine transparent graining causing diffraction of light into spectral colors. Photomicrographs by Britni LeCroy; field of view 3.57 mm.



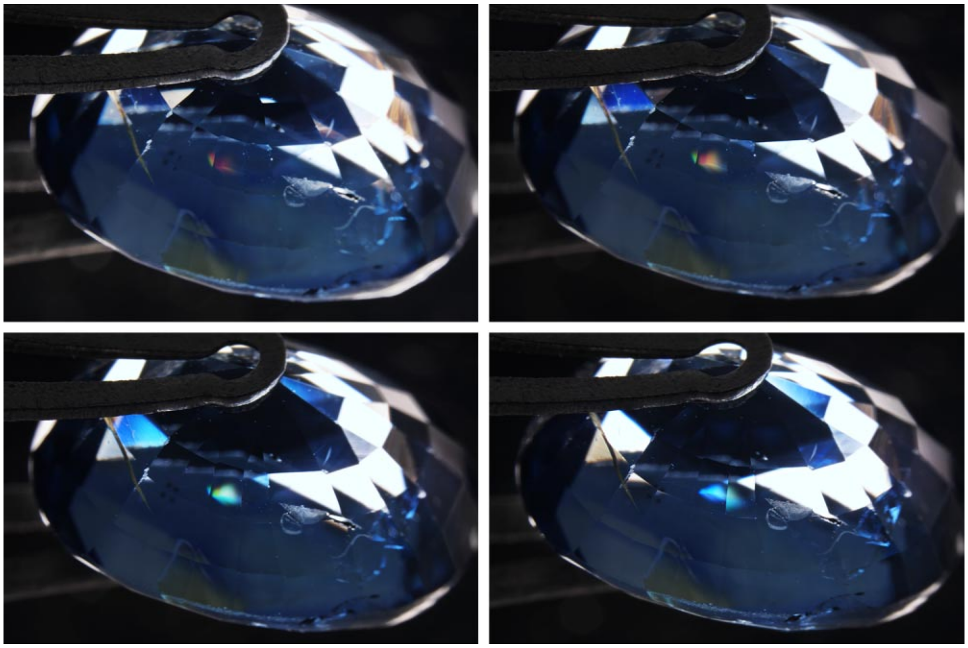


Figure 9. Subtle tilting of the sapphire, as shown in this image sequence viewed with darkfield illumination, revealed a play-of-color phenomenon within the milky cloud. Photomicrographs by Britni LeCroy; field of view 14.52 mm.

as a display of spectral colors due to the diffraction of light as it passes through organized, submicroscopic spherical particles. It is possible that the combination of fine milky particles and abundant transparent graining within the cloud were able to diffract light in a way that resembles play-of-color.

Britni LeCroy
GIA, Carlsbad

Staurolite in Ruby

We have examined thousands of rubies in Lotus Gemology's laboratory, yet the hours spent peering into the microscope are never mundane because each stone captures its own piece of history through its inclusions. Recently a client submitted one such gem for testing, a 3.04 ct specimen measuring 11.98 × 7.13 × 4.21 mm that was identified as an untreated ruby from Madagascar based on inclusions.

In the microscope, a few bright brownish red crystal inclusions immediately stood out. They were transparent, with a saturated red hue that, in darkfield illumination, was conspicuous even against their ruby-red background (figure 10). Some were also cut through on the surface, allowing us to view them with reflected light. Observation of the surface showed that the crystals had a luster just

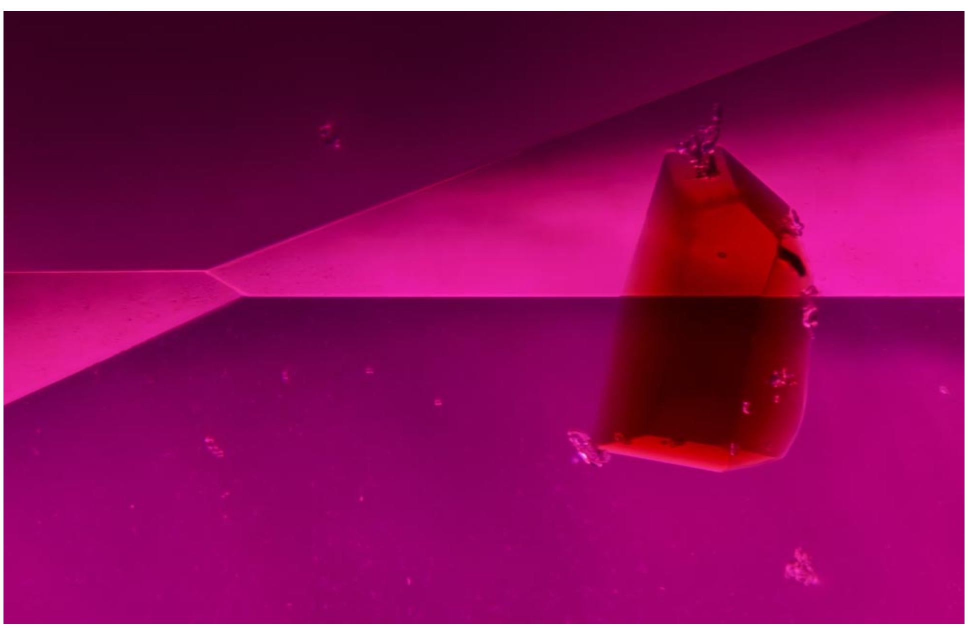


Figure 10. Viewed with darkfield illumination, a transparent brownish red crystal inclusion clearly stands out, even in a ruby matrix. This is believed to be the first staurolite inclusion found in corundum. Photomicrograph by E. Billie Hughes; field of view 2 mm.

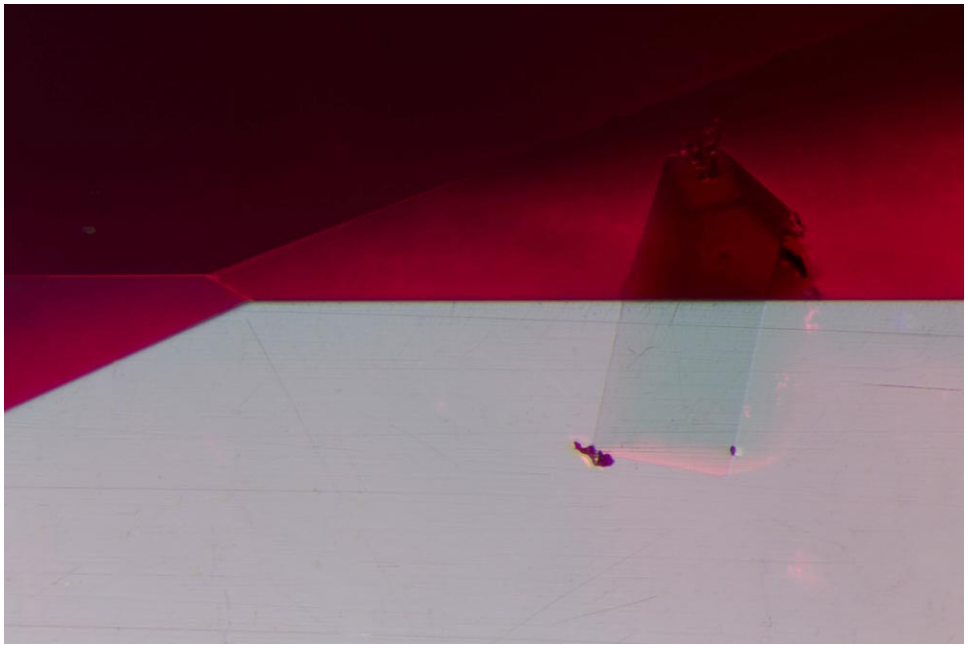


Figure 11. When viewed in reflected light, the staurolite inclusion, which is cut through on the surface, displays a slightly lower luster than its corundum host. This suggests that the inclusion has an RI slightly below that of corundum. Darkfield and diffuse fiber-optic illumination. Photomicrograph by E. Billie Hughes; field of view 2 mm.

slightly lower than that of the surrounding corundum, suggesting a slightly lower RI (figure 11).

To get a better idea of the crystals' identity, we examined them using micro-Raman spectroscopy with a WITec Alpha 300R Raman imaging system with a 532 nm laser, which identified them as staurolite. Staurolite, $Fe_2Al_9Si_4O_{22}(OH)_2$, is a red to brown mineral known to occur in Madagascar. Its RI values are n_α = 1.736–1.747, n_β= 1.740–1.754, and n_γ = 1.745–1.762. Corundum has a slightly higher RI range, with n_ω = 1.767–1.722 and n_ε = 1.759–1.763. The combination of microscopic observation and Raman spectroscopy gave us confidence that these were indeed staurolite crystals.

It is no wonder these crystals initially stood out. To the best of our knowledge, this is the first recorded observation of staurolite as an inclusion in corundum. This Madagascar ruby has encapsulated a fascinating kernel of history within its depths.

E. Billie Hughes

Triplite in Beryl

Among our Lotus Gemology lab clients and the gem trade as a whole, inclusions have often been seen as negative features. However, people are starting to become more interested in inclusions and see them as unique characteristics rather than mere imperfections.

One such client brought us a colorless beryl with a large brownish orange crystal near the culet (figure 12), hoping to learn the inclusion's identity. Raman microscopy revealed it to be triplite. Triplite, $(Mn,Fe)_2PO_4(F,OH)$, is a mineral named for the Greek *triplos*, or triple, which refers to its three directions of cleavage. While some triplites have been faceted, they are quite rare both as a mineral and as a gem material. The specimen's owner stated that the beryl came from Pakistan. As triplite is known to be found in Pakistan, this is certainly a possibility. The owner was happy to learn that his gem contained a relatively rare mineral.

We are excited to see these examples of inclusions being viewed as points of interest within a gem.

E. Billie Hughes

Quarterly Crystal: Unknown Inclusion in Triphane Spodumene

When exploring in the micro-world, we occasionally run into problems we cannot solve and inclusions that cannot

Figure 12. A dark orange triplite inclusion stands out against its colorless beryl host. Photomicrograph by E. Billie Hughes; field of view 8 mm. Courtesy of Ayub Muhammad.

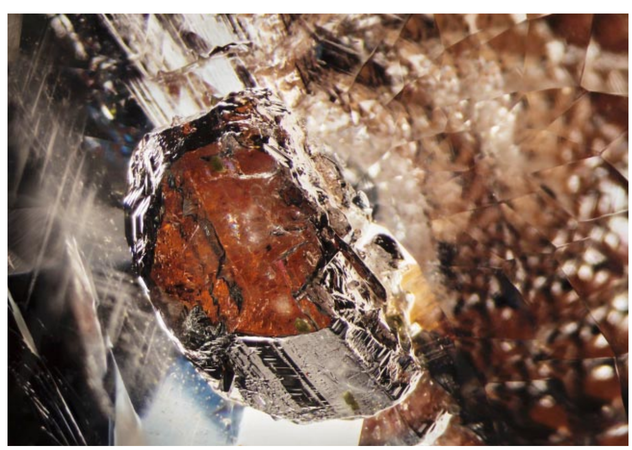


Figure 13. The interior of this 91.02 ct Afghani spodumene plays host to a 4 mm translucent orange crystal. Photo by Diego Sanchez.

be identified. Such was the case with the dominant orange inclusion in this 91.02 ct, 39.29 × 19.34 × 12.93 mm, terminated light yellow triphane spodumene crystal. This spodumene crystal clearly hosts a prominent 4 mm translucent orange crystal surrounded by a stress-related iridescent cleavage halo (figure 13). The spodumene crystal, from Dara-

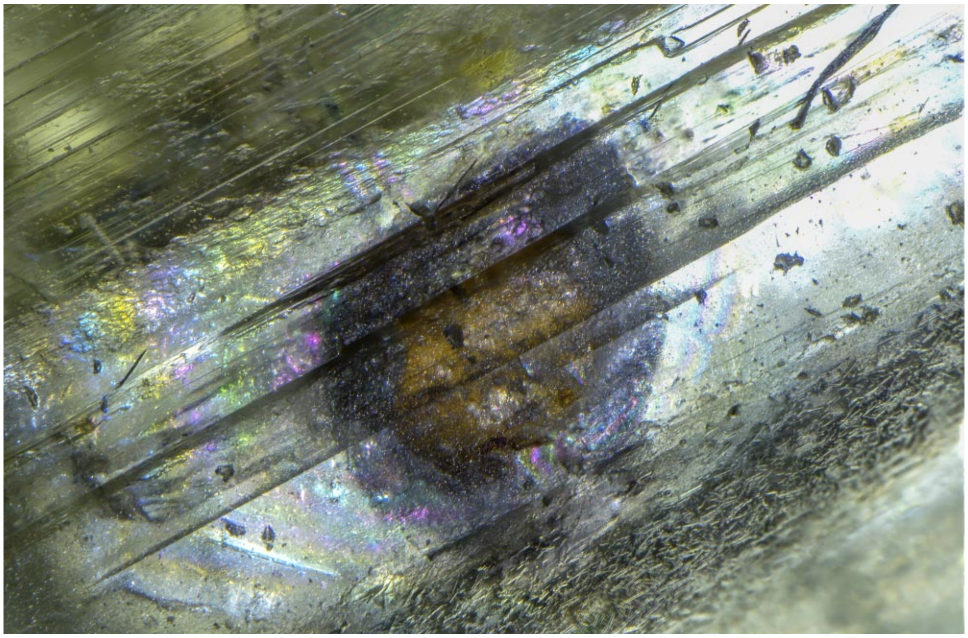


Figure 14. None of the analytical techniques at our disposal were able to conclusively pin down the identity of the orange inclusion. Photomicrograph by Nathan Renfro; field of view 9.31 mm.

i-Pech pegmatite field, Chapa Dara District, Konar Province, Afghanistan, was acquired from gem and mineral dealer Russell E. Behnke of Meriden, Connecticut. The bodycolor and rounded habit of the orange inclusion (figure 14), together with its origin in spodumene from a pegmatite field, suggested that it might be spessartine. However, laser Raman microspectrometry was not able to pin down the identification of that inclusion. This was because the crystal faces of the spodumene were etched, which interfered with the passage of the laser in the hosting spodumene. As a next step, energy-dispersive X-ray fluorescence (EDXRF) was tried to see if we could pick up any hints of the chemistry in the inclusion. In particular, we were looking for manganese which did show up in the EDXRF scan. Through the microscope, in polarized light, no pleochroism was detected in the inclusion which pointed to the inclusion being isometric. This was as far as we could take the analysis. In order to determine for certain what the unknown inclusion was we realized that destructive analysis would be needed to get a clear identification of the orange inclusion. Since this inclusion specimen was relatively valuable we decided that destructive analysis would not be used, and we would keep the spodumene crystal as it is for future exploration.

John I. Koivula and Nathan Renfro