Beryl Crystal in Fluorite

Recently, the authors examined a purple fluorite specimen that contained an elongate hexagonal rod-shaped crystal (figure 1). The crystal host had been collected by Chris Lehmann (Lehmann Minerals, Benton, California) in the Birch Creek area of the White Mountains in Inyo County, California. This area was host to volcanic activity that resulted in granitic dikes cutting across dolomite and other sedimentary rock types. The most abundant minerals found in the area are quartz, calcic oligoclase, microcline, biotite, and muscovite. Smaller amounts of apatite, zircon, tourmaline, magnetite, epidote, purple fluorite, and beryl have also been reported (C.A. Nelson and A.G. Sylvester, "Wall rock decarbonation and forcible emplacement of Birch Creek Pluton, southern White Mountains, California," *Geological Society of America Bulletin*, Vol. 82, No. 10, 1971, pp. 2891–2904). While the morphology of the prismatic inclusion hinted at its identity, the hexagonal crystal was conclusively identified as beryl by laser Raman spectrometry. Also present in the fluorite were numerous veils of fluid inclusions and prominent color zoning (again, see figure 1). This exciting discovery was the authors' first encounter with beryl as an inclusion in fluorite.

Figure 1. A colorless prismatic beryl crystal within a fluorite specimen from the White Mountains in Inyo County, California. Photomicrograph by Nathan Renfro; field of view 8.60 mm.

Ian Nicastro
San Diego, California

Nathan Renfro
GIA, Carlsbad

About the banner: This thin wafer of agatized fossil dinosaur bone from Utah was photographed using diffuse reflected light and transmitted light in conjunction with a blue filter for contrast. Photomicrograph by Nathan Renfro; field of view 9.6 mm.

Editors' note: Interested contributors should contact Nathan Renfro at nrenfro@gia.edu and Jennifer-Lynn Archuleta at jennifer.archuleta@gia.edu for submission information.

Gems & Gemology, Vol. 54, No. 1 pp. 66–73.

Type IIa Diamond with Extraordinary Etch Channels

Etch channels are rare inclusions in natural diamonds, both type I and type II (see T. Lu et al., "Observation of etch channels in several natural diamonds," *Diamond and Related Materials*, Vol. 10, No. 1, 2001, pp. 68–75). Recently, the Laboratoire Français de Gemmologie received a 1.77 ct round brilliant-cut diamond containing numerous large etch channels, a feature appreciated by inclusion collectors. The gem had K color and I_1 clarity due to the etch channels and their reflectors (figure 2). Infrared absorption spectroscopy revealed a type IIa diamond.

Dissolution etch channels in diamond are rare but can have various forms (M. Philippe and E. Fritsch, "Dissolved dislocation: Inclusions not always easy to identify, part I," *Revue de Gemmologie*, Vol. 200, 2017, pp. 11–22, in French). They are due to the dissolution of dislocations in-

Figure 2. A rare 1.77 ct type IIa diamond with significant etch channels caused by dissolution along dislocations. Photo by Aurélien Delaunay.

side the crystal. These dislocations might be growth dislocations or caused by later deformation. One type of etch channel in diamond consists of regular and parallel lines related to diamond's crystallographic structure. The other type, the kind exhibited in this diamond, is a worm-like ribbon due to crystallographic defects. All of the dissolution etch channels have rhombic openings at the surface of the diamond (figure 3); a few have a pyramidal termination and restart in another direction (figure 4). This is a rare occurrence and confirms that dissolution can be stopped—or slowed—by defects in the crystal structure. In addition, the dissolution can start in an easier direction, such as a dislocation.

Etch channels are rarely observed in cut gem diamonds. But when gemologists observe a specimen like this one, it is always a pleasure for the eyes and a curiosity of nature.

Aurélien Delaunay
Laboratoire Français de Gemmologie, Paris

Emmanuel Fritsch
University of Nantes, France

Omphacite and Chromite: A "Bimineralic Inclusion" in Diamond

The micro-world of diamonds is fascinating not only to gemologists interested in inclusions but also to mineral physicists who study the deep earth, arguably one of the last frontiers and one not yet accessible to us. Diamond inclusions offer a window into that world and help us piece together its nature to unravel the mysteries of the earth's very formation (J.I. Koivula and E.A. Skalwold, "The microworld of diamonds: Images from the earth's mantle," *Rocks & Minerals*, Vol. 89, No. 1, 2014, pp. 46–51). Sometimes even relatively common inclusions in diamond present an uncommon sight.

In this case, two minerals identified by Raman microspectroscopy, omphacite and chromite, are in such close association that they appear joined (figure 5). Such a "bimineralic inclusion" poses the question of how they might have ended up that way: Was it just fate or attrac-

Figure 3. Etch channels with rhombic openings at the surface of the diamond. Photomicrograph by Aurélien Delaunay; field of view 2.22 mm.

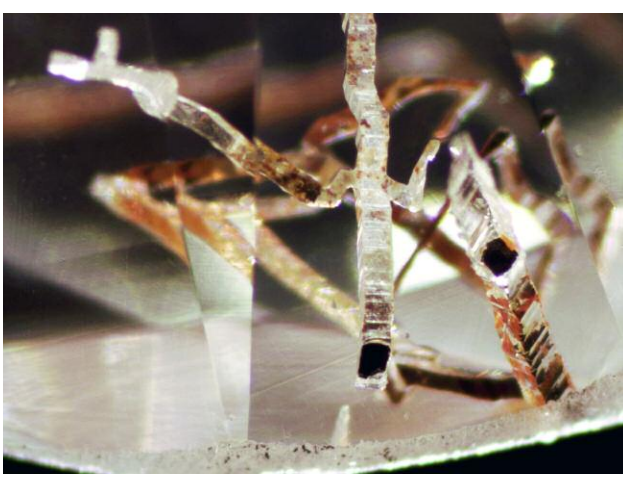


Figure 4. Rare etch channel with a pyramidal termination in a 1.77 ct type IIa diamond. Note the lateral continuation of the dissolution. Photomicrograph by Aurélien Delaunay; field of view 1.39 mm.

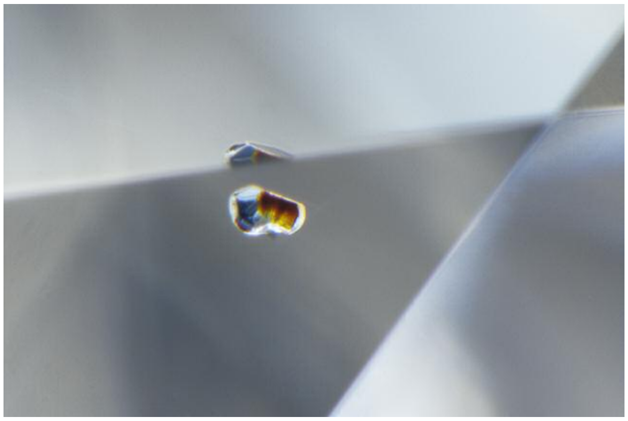


Figure 5. Sometimes a clue to the identity of an inclusion is its color. Diffuse transmitted lighting reveals the colors of the omphacite (left) and chromite (right) crystals composing a "bimineralic inclusion" in a 90-point diamond. Photomicrograph by Nathan Renfro; field of view 0.95 mm.

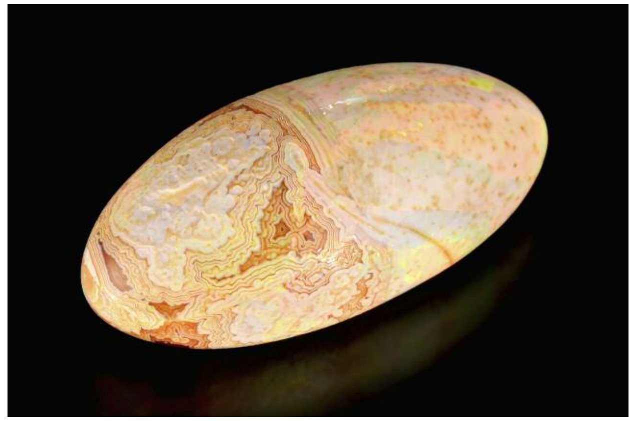


Figure 6. This opal from the Shewa region of Ethiopia, weighing just over 10 ct, shows areas of agate-like banding. Photo by Diego Sanchez and Robison McMurtry.

tion? There is even the possibility that they were a single mineral at the time of inclusion into the diamond but separated when pressure and temperature dropped as the diamond found its way to the earth's surface. Future detailed chemical analysis of this pair may yield valuable information about the earth's interior, including the compositions, pressures, and temperatures of the host rocks in which the diamonds formed.

Many gemologists are familiar with so-called carbon spots in diamonds. Often these are actually chromite crystals—not carbon at all, but rather a chromium-rich iron oxide mineral of the spinel group. If thin enough, these may appear dark red-brown to yellowish brown in transmitted light, as seen in this specimen. Chromite is classified in both the peridotitic and eclogitic inclusion suites found in diamonds. By contrast, the omphacite crystal next to it is a monoclinic pyroxene mineral (clinopyroxene) that is typically pale to dark grayish green or grayish blue in transmitted light and considered a member of the eclogitic suite of inclusions found in diamonds. This inclusion specimen is not only worthy of the photomicrographer's artistry but also a very valuable portion of the earth's interior puzzle, which is slowly being put together one piece at a time.

Elise A. Skalwold and William A. Bassett
Ithaca, New York

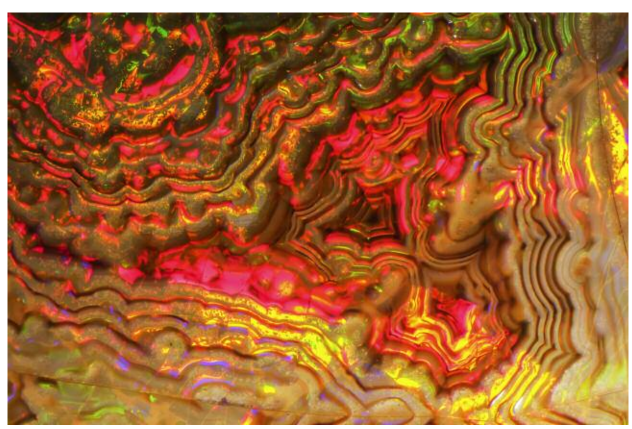
Nathan Renfro

Opal with Agate-Like Banding

Recently, author SC purchased an interesting Ethiopian opal (figure 6) that displayed a most unusual growth structure. A portion of the orangy brown opal displayed a small patch of wavy "varve" banding much like one would expect to see in an agate (figure 7). The banded area was composed of layers of translucent dark brown material alternating with lighter opaque material. It was also evident that the dark layers were much harder than the lighter layers, which had significant undercutting on the polished surface. These lighter areas also showed play-of-color, which made it obvious that they were precious opal layers. The dark areas did not show play-of–color, leaving it unknown if they were also opal or perhaps chalcedony, consistent with their banded pattern. It was also interesting to note that the lighter areas readily absorbed water and became transparent, an indication of hydrophane opal.

To test the composition of the various layers, we polished a flat surface on the back of the stone in order to accu-

Figure 7. Prominent agate-like banding was seen in the opal. Photomicrograph by Nathan Renfro; field of view 8.22 mm.



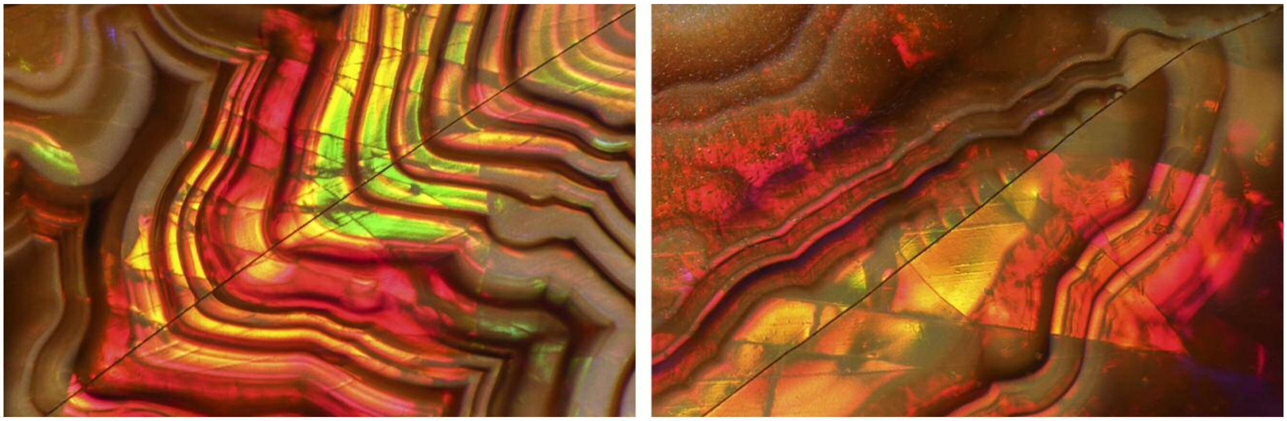


Figure 8. Left: A crack running diagonally across the banding exhibits an offset shifting indicative of a strike-slip type of "microfault." Right: A second area in this stone also shows "micro-faulting" with movement along the banding and no movement across the photonic crystal, indicating that opalization of the chalcedony was a secondary process. Photomicrographs by Diego Sanchez and Robison McMurtry; fields of view 2.50 mm (left) and 2.62 mm (right).

rately measure the refractive index (RI). Two measurements were resolvable with the refractometer, at 1.43 and 1.47. Further testing revealed an extremely low specific gravity measurement of 1.42 (compared to a typical SG of about 2.00 for opal), implying that the hydrophane areas were very porous. Further testing by Raman spectrometry was unable to detect the presence of quartz in either the light or dark brown bands, a finding consistent with the RI measurements.

Careful microscopic observation yielded some interesting conclusions. A few small healed cracks in this stone were naturally repaired with opal infilling. Some of these cracks showed a lateral offset as they cut across the banding (figure 8, left). We also observed that the fractures that showed an offset in the banding showed no offset in the "photonic crystal" (B. Rondeau et al., "On the origin of digit patterns in gem opal," Fall 2013 *G&G*, pp. 138–146), or in the single play-of-color patches (figure 8, right). These observations are important in revealing the order of events that took place to produce such a specimen. First, the deposition of chalcedony had to occur in order to produce the crenulated (wavy) banded pattern. Second, stress cracks were introduced into the agate and then laterally shifted, creating several "micro-faults." These micro-faults were subsequently "healed" with a secondary deposit of opal. This secondary opal deposition also replaced the chalcedony while preserving the original agate-like banding, which was apparent since there was no offset along the micro-faults in the patches of play-of-color.

This is one of the most unusual opals the authors have encountered to date. The microscopic observations tell an interesting story about the formation of a unique gem.

Nathan Renfro
Stephen Challener
Raleigh, North Carolina

Dendritic Inclusions in Cambodian Sapphire

A 0.66 ct piece of blue sapphire rough from the Bo Tang Su mining area of Cambodia's Pailin region displayed dendritic inclusions, commonly found in quartz and chalcedony but rarely seen in corundum.

These epigenetic inclusions occur as a dendritic pattern trapped along surface-reaching fractures and show higher luster than the host under reflected light. Viewed in fiber-optic light, they appear black along the fracture and the trapped unknown fluid phases (figure 9). Raman spectroscopy identified the inclusions as a compound of manganese oxide-hydroxides. The presence of these dendritic

Figure 9. Fiber-optic illumination reveals dendritic inclusions of a manganese oxide-hydroxide compound trapped within a fracture. Photomicrograph by Charuwan Khowpong; field of view 1.05 mm.

Figure 10. The dendritic inclusions were trapped in a triangular fracture. Photomicrograph by Charuwan Khowpong; field of view 1.75 mm.

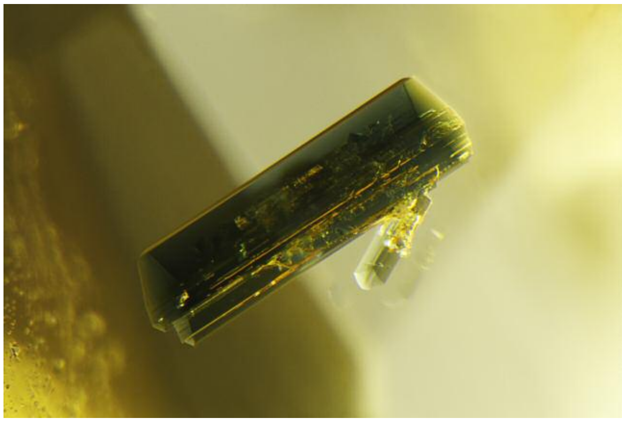


Figure 12. A beautiful euhedral pargasite crystal displaying its monoclinic nature in yellow sapphire. Photomicrograph by Nathan Renfro; field of view 1.43 mm.

inclusions, seen trapped in a triangular fracture in figure 10, is quite unusual in sapphire from Cambodia.

Charuwan Khowpong
GIA, Bangkok

Green Crystals in Yellow Sapphires

Two yellow sapphires recently examined by the authors each contained a green crystal inclusion. Upon analysis, however, the two inclusions turned out to be very different minerals.

A yellow sapphire of Sri Lankan origin hosted a saturated bluish green crystal inclusion. Optically it was singly refractive, and Raman spectroscopy proved it to be a spinel crystal (figure 11). Spinel inclusions of this color have been documented in yellow sapphires before (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 1, ABC Edition, Zurich, 1986, pp. 353–354), but this crystal was remarkably large and completely enclosed in the stone.

The second yellow sapphire contained a green semi-transparent crystal that, unlike the previous inclusion, was doubly refractive and more rectangular in shape (figure 12),

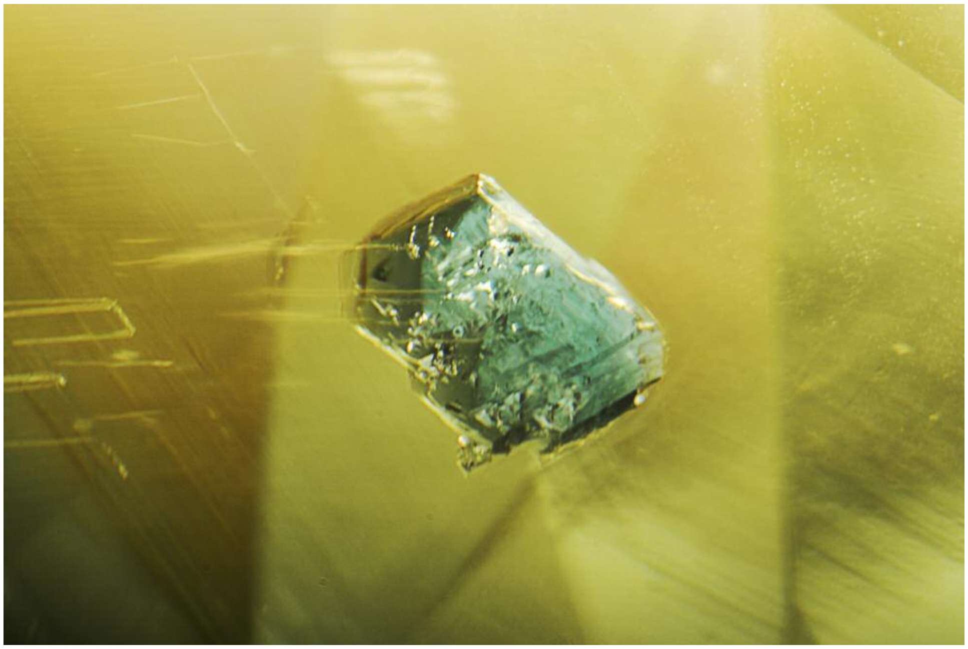


Figure 11. A bluish green spinel crystal found in a Sri Lankan yellow sapphire. Photomicrograph by Tyler Smith; field of view 1.76 mm.

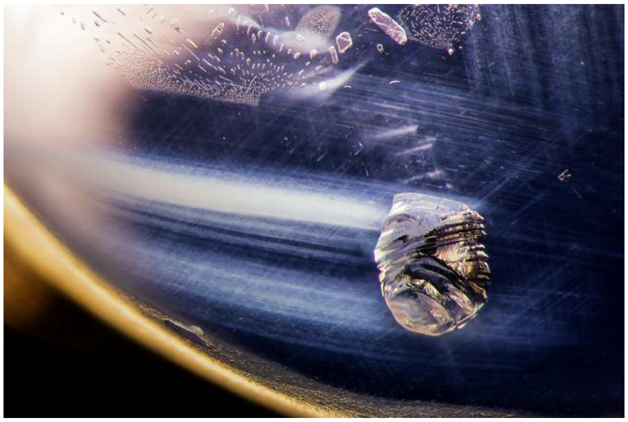


Figure 13. This inclusion scene features an apparent iron sulfide crystal against a midnight blue backdrop. It is reminiscent of the night sky, echoing the surface appearance of the star sapphire host. Photomicrograph by E. Billie Hughes; field of view 2.15 mm.

with sublinear striations and a smaller secondary crystal on the opposite side. With the aid of Raman spectroscopy, the brownish green crystal was identified as pargasite, a metamorphic calcium-dominated amphibole mineral associated with spinel and corundum deposits (J.W. Anthony et al., *Handbook of Mineralogy*, Vol. 2, Mineral Data Publishing, Tucson, Arizona, 1995). As an inclusion, pargasite has been previously documented in corundum—more frequently in rubies from Myanmar, Pakistan, and Tanzania, and in blue sapphires from Kashmir (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Verlag, Basel, Switzerland, 2008). The fact that the host sapphire was yellow makes this inclusion a fascinating discovery for the authors.

Nicole Ahline
GIA, Carlsbad

Tyler Smith
GIA, New York

Six-Rayed Star in Sapphire from Myanmar

Gems are renowned for their outward beauty, but their internal world can be just as striking. Lotus Gemology recently came across a Burmese sapphire, cut as a cabochon and measuring 8.92 × 7.10 × 4.75 mm, that displayed a six-rayed star. Once we examined it under the microscope, we were surprised to find that this celestial theme carried through to the inclusion scene inside (figure 13).

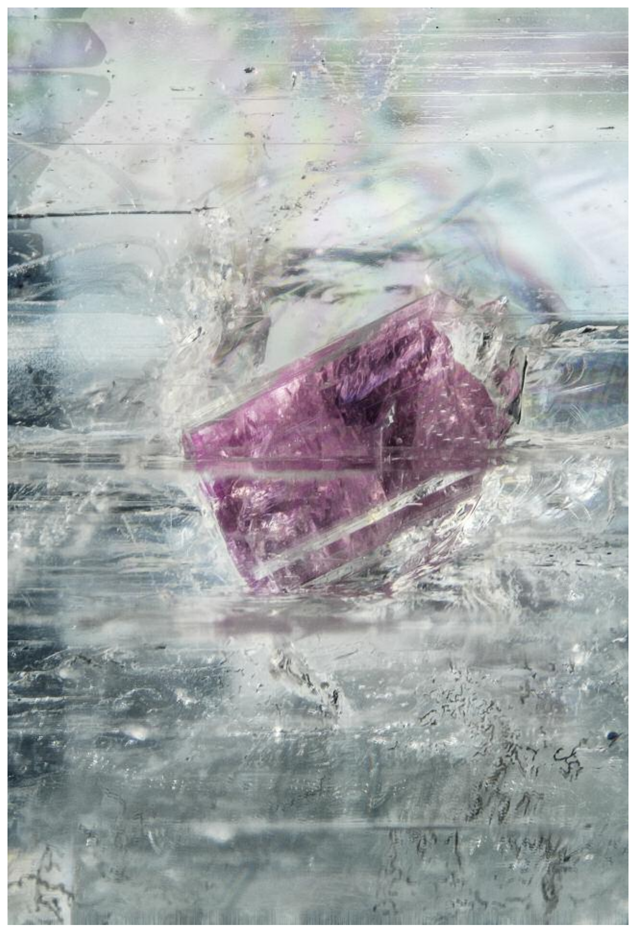
The long, undissolved rutile silk needles that form the six-rayed star are evident in angular zones. We could also see other inclusions typical of unheated sapphire, such as the tiny negative crystals forming a "fingerprint" at the top of the image. What was most interesting about this piece was the large, irregularly shaped crystal with a metallic appearance hovering close to the surface of the cabochon dome, which we believe is an iron sulfide crystal based on its appearance. This highly reflective crystal seems to float across a midnight blue backdrop, reminiscent of an asteroid floating in space and making for a fitting inclusion in a star sapphire.

E. Billie Hughes
Lotus Gemology, Bangkok

Pink Tourmaline in Spodumene

The pegmatitic mineral spodumene commonly exhibits fluid inclusions as well as muscovite-mica, feldspar, and clay mineral inclusions (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 1, ABC Edition, Zurich, 1986). A colorless 7.85 ct emerald-cut spodumene, purportedly from Afghanistan, was of particular interest for the eye-visible pink tourmaline crystal inclusion (figure 14) under

Figure 14. Appearing as if suspended in water, a pink tourmaline inclusion in spodumene is illuminated by diffuse and fiber-optic illumination. Photomicrograph by Jonathan Muyal; field of view 7.19 mm.



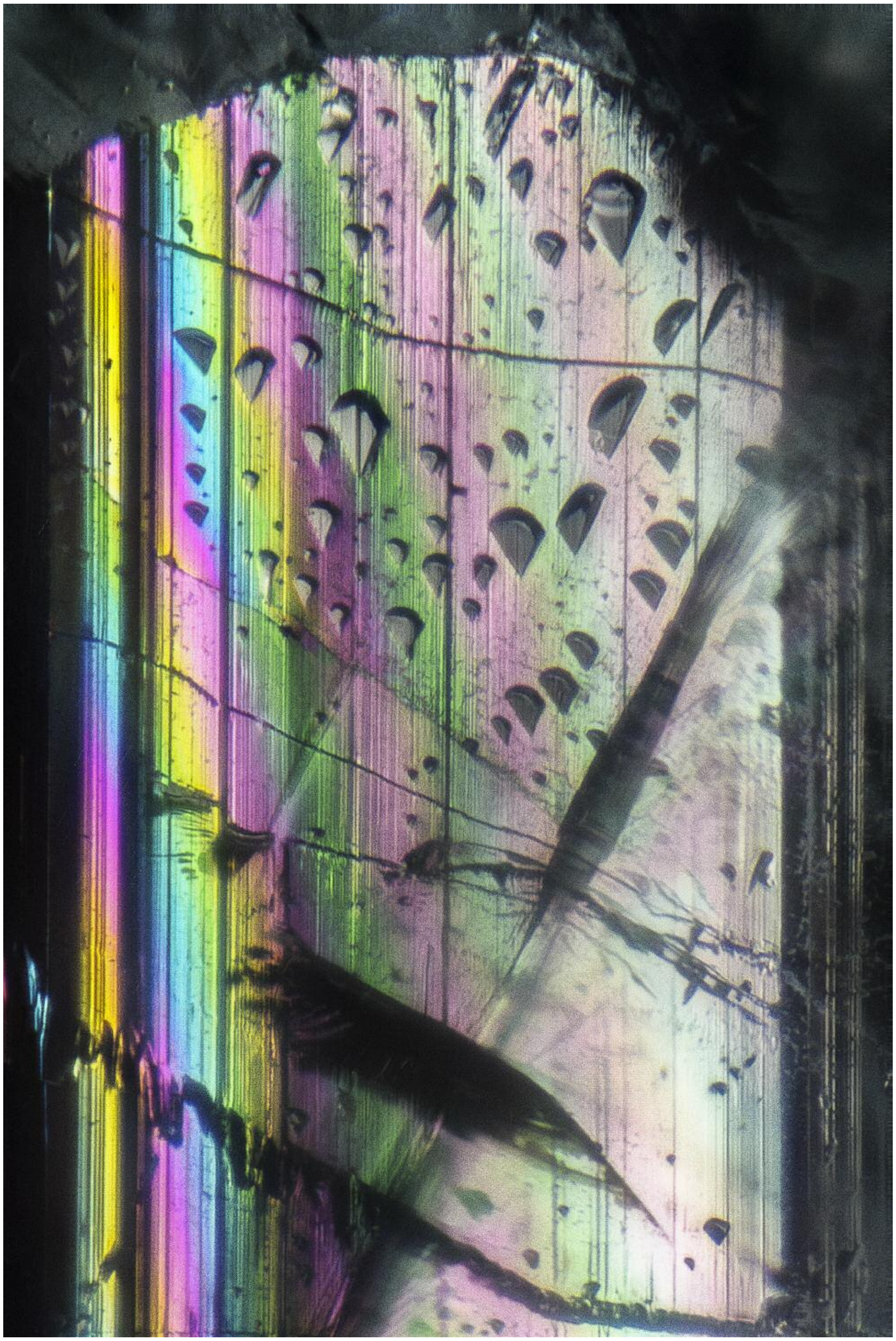


Figure 15. Diffuse and fiber-optic illumination reveal the fine striations common to tourmaline along the length and the shallow triangular etch markings typical of spodumene along the interface, as well as vivid iridescent colors. Photomicrograph by Jonathan Muyal; field of view 1.26 mm.

the table facet. The mineral inclusion's identity was confirmed by Raman microspectrometry analysis.

Although green tourmaline inclusions in spodumene have been documented (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Publishers, Basel, Switzerland, 2008, p. 642), very few references are found in the literature, and pink tourmaline in spodumene remains a rare occurrence. The transparent inclusion showed a well-formed trigonal prismatic crystal habit with fine vertical striations along its length (parallel to the c-axis). It exhibited a hemimorphic nature, with a flat termination on one end and a low pyramidal termination on the other.

Figure 16. Measuring 7.59 mm in largest dimension and weighing 1.84 ct, this partially etched diamond octahedron contains a bright green inclusion of chromium diopside. Photo by Robison McMurtry.

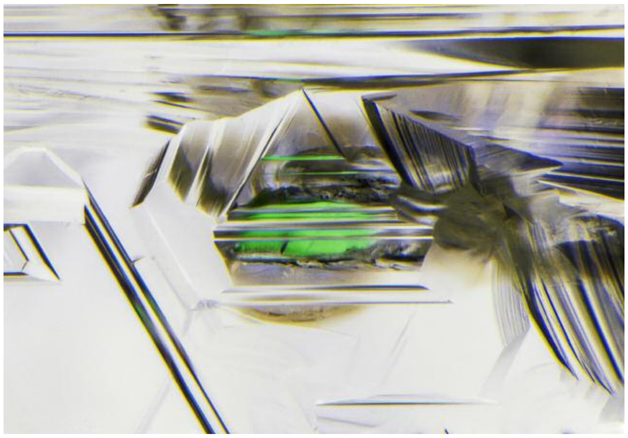


Figure 17. Rich green transparent crystals of chromium diopside are very uncommon inclusions in diamond. The example shown here has a typical rounded, etched habit. Photomicrograph by Nathan Renfro; field of view 1.80 mm.

Abundant uneven wavy fractures, more or less perpendicular to the c-axis, were also visible within the crystal.

Of interest were some triangular etch marks common to spodumene. Although at first they appeared to be on the inclusion's surface, they were actually on the spodumene interface. Additionally, the interface space exhibited vibrant iridescent colors when illuminated with oblique fiber-optic illumination (figure 15). This special guest inclusion thus gives the impression of having been "dressed and embellished" by its host spodumene and is displayed in its best attire.

Such a large tourmaline inclusion specimen in spodumene also provides valuable mineralogical information for the gemologist. The syngenetic inclusion and the host reflect their common pegmatitic geological genesis. The lithium-bearing granitic pegmatitic occurrence of spodumene strongly suggests that the inclusion is a lithia tourmaline variety, with lithium and aluminum substituting for iron and magnesium.

While spodumene is not known and prized for its inclusions, the beautifully highlighted pink tourmaline inclusion makes this gem a rare collector specimen.

Jonathan Muyal
GIA, Carlsbad

Quarterly Crystal: Cr-Diopside in Diamond

Brightly colored mineral inclusions in diamonds are rare. Some examples of these rarities are dark blue kyanite, yellowish orange almandine-pyrope, and deep purplish red pyrope garnet. This year's first Quarterly Crystal offering expands on this bright inclusion theme with a transparent colorless partially etched octahedron from the Kimberley mine in South Africa. Shown in figure 16, the diamond measures 7.59 × 6.59 × 4.79 mm and weighs 1.84 ct.

Situated along the edge of one of the octahedral planes, the diamond crystal plays host to a bright green transparent elongated mineral inclusion. Laser Raman microspectrometry was used to identify this included crystal as diopside, and the bright green color results from a trace amount of chromium.

As a diamond inclusion, chromium diopside is a medium to deep green transparent mineral with a vitreous luster. As shown in figure 17, it typically forms as rounded protogenetic mineral grains. Geologically, the presence of a Cr-diopside inclusion in a diamond is an indicator that the host diamond formed in a rock type known as peridotite.

John I. Koivula
GIA, Carlsbad