



G&G

Micro-World

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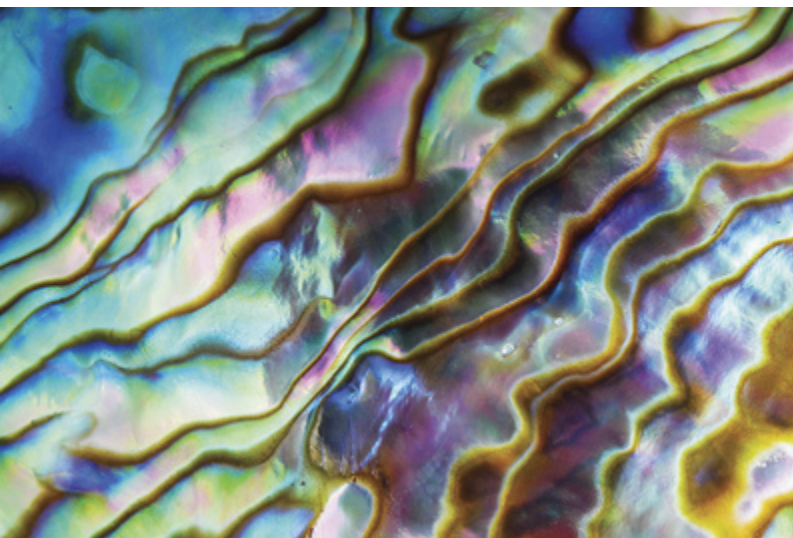
Iridescent Abalone Shell

The glowing rainbow-colored image resembling a topographic map in figure 1 was captured over the polished surface of an abalone shell. Abalone is a common marine gastropod (univalve mollusk) belonging to the family Haliotidae and the genus *Haliotis*. Abalone mollusks are distributed along coastal waters worldwide and associated with rocky habitats. They are well known as nutrition-rich seafood, and their ear-shaped shells are also popular in jewelry owing to their uniquely vibrant iridescent nacre known as mother-of-pearl.

Figure 1. The surface of this colorfully iridescent abalone shell resembles a topographic map. Photomicrograph by Michaela Stephan; field of view 23.14 mm.

Iridescence is an optical phenomenon frequently observed in gem materials, as well as in nacreous shells and pearls. *Orient* is the specific term for the iridescent effects attributed to interference and diffraction of light in the multilayered aragonite platelet structure. Shells and pearls produced by the *Haliotis* species generate the highest degree of iridescence, with a full range of distinct rainbow colors. These colors are caused by the fine grating structure created by the thin and closely packed nacre layers, similar to that of a diffraction grating (T.L. Tan et al., "Iridescent colours of the abalone shell (*Haliotis glabra*)," *Journal of Gemmology*, Vol. 29, No. 7/8, 2005, pp. 395–399). This extraordinary property lends a charming appearance to shell, pearl, and assembled cultured blister "pearls" (mabe) produced by abalone mollusks and makes them widely popular in the gem and jewelry industry.

Artitaya Homkrajae and Michaela Stephan
GIA, Carlsbad



Colorful Inclusions in Diamond

Inclusions can be found in a variety of different gemstones; they create a window that allows the viewer to picture a stone's formation history. Diamond possesses the ideal characteristics for preserving these features. Chemically inert and durable, it is the perfect host for inclusions.

About the banner: This topaz crystal from Minas Gerais, Brazil, shows interesting circular etch patterns on a prism face, while subsurface fractures display vivid interference colors. This image was taken using episcopic differential interference contrast microscopy. Photomicrograph by Nathan Renfro; field of view 1.44 mm.

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Figure 2. The 2.56 ct diamond oval (left) contains green crystals of diopside and enstatite, while the 1.48 ct round brilliant (right) contains a purplish pink pyrope garnet. Photos by Towfiq Ahmed.

In general, inclusions in gem diamonds are considered undesirable. While extremely common in a number of forms, they almost always lower the clarity grade of a diamond to varying degrees depending on their type, size, quantity, and location. This happens because they are “imperfections” within the crystal that can ultimately affect the way light interacts with the stone, detracting from the overall brilliance of a properly faceted gem. In some cases, however, inclusions can make a diamond uniquely special.

Recently the New York lab examined two gem-quality diamonds (figure 2) possessing vivid green and purplish pink inclusions. With Raman spectroscopy, the green inclusions were identified as enstatite and diopside while the purplish pink inclusion was identified as pyrope garnet (figure 3). Both are common in ultramafic rocks, typically from a peridotite host. Chromium, an element character-

istic of the earth’s very deep rocks, is the chromophore responsible for both the green and the pink within these different minerals. The different lattice environments within these minerals results in distinct octahedral Cr-O bond lengths, and therefore they differ in light absorption and color produced. The vivid green color and shape of the diopside and enstatite are similar to those of the inclusions captured in *The Microworld of Diamonds: A Visual Reference Guide*, by John I. Koivula (Gemworld International, Northbrook, Illinois, 2000). As these diamonds formed, they enveloped the inclusions.

It is rare to see such high-quality diamonds with these types of inclusions. These timeless diamonds possess valuable relics of Earth’s beginnings, making their clarity features noteworthy.

*Stephanie Persaud, Anthony Galati, and Paul Johnson
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Figure 3. Microscopic observation revealed a green chromium-colored diopside in the 2.56 ct diamond (left) and a purplish pink pyrope garnet inclusion in the 1.48 ct diamond (right). Photomicrographs by Stephanie Persaud; field of view 1.00 mm (left) and 2.50 mm (right).

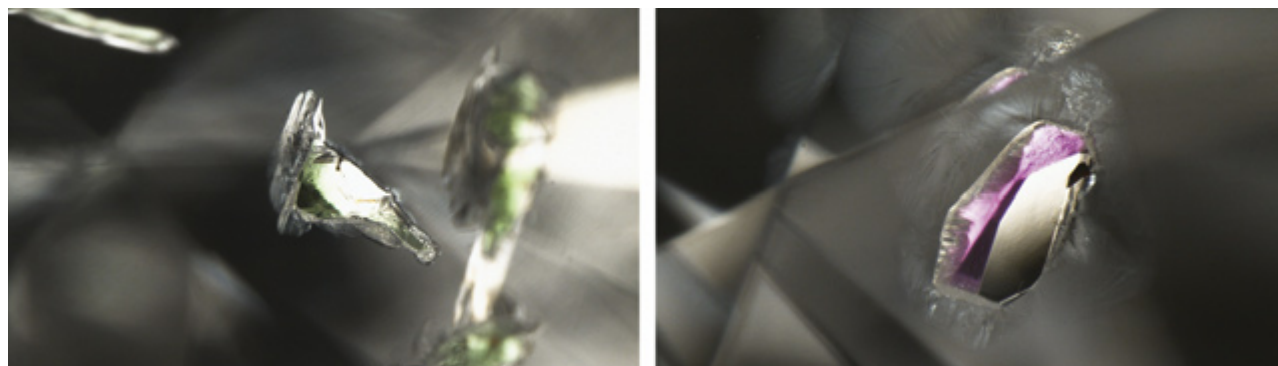




Figure 4. This sapphire contains a beautiful garnet inclusion and a trail of dust-like rutile particles. Photomicrograph by Michaela Stephan; field of view 4.79 mm.

Garnet in Sapphire

The author recently examined a 3.26 ct sapphire that changed from green-blue in fluorescent light to reddish purple in incandescent light. The color-change sapphire contained a large eye-visible crystal inclusion (figure 4). Microscopic examination of the singly refractive inclusion revealed garnet's characteristic dodecahedral crystal shape with rounded edges.

Of all the possible inclusions contained within sapphire, garnet is a rare and beautiful occurrence. When garnet crystal inclusions do occur, they often indicate an origin of Tanzania or the U.S. state of Montana (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio-Verlag Publishers, Basel, Switzerland, 2008, pp. 228–242). In this sapphire, a large vibrant orange garnet is followed by a trail of dust-like rutile particles, much like an asteroid streaking across the night sky.

Michaela Stephan

Neptunite Inclusion in Benitoite

The authors recently examined a round, slightly zoned blue and near-colorless faceted benitoite that contained an interesting inclusion. Microscopic observation revealed a well-formed euhedral semitransparent reddish brown crystal surrounded by fine short needles and fluid fingerprints (figure 5). Because of the color and structure of the inclusion, both neptunite and joaquinite were considered as the possible identity. In benitoite, these minerals are often found in association and may have a similar color to the inclusion observed in this particular example. One method of separating neptunite from joaquinite is pleochroism. A yellow-orange, orange, and deep red pleochroism is consistent with neptunite, while light yellow

and colorless pleochroism is consistent with joaquinite (webmineral.com). This inclusion showed a reddish orange to red pleochroism that was more consistent with neptunite. Raman analysis confirmed the host crystal was benitoite and the orangy red inclusion was neptunite, which has been previously documented (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 1, 5th ed., 2008, Opinio-Verlag Publishers, Basel, Switzerland, p. 416).

Benitoite is a barium titanium silicate ($\text{BaTiSi}_3\text{O}_9$). This rare gem is found primarily in San Benito County, California, though it also occurs in other locations worldwide. Neptunite's chemical formula is $\text{KNa}_2\text{Li}(\text{Fe}^{2+}, \text{Mn})_2\text{Ti}_2\text{Si}_8\text{O}_{24}$, and it also occurs in San Benito County. Neptunite is found in association with other minerals in New Mexico, Greenland, and Canada, to name just a few (W.L. Roberts et al., *Encyclopedia of Minerals*, 2nd ed., 1990, Van Nostrand Reinhold, New York, pp. 603–604). The gem-quality benitoite material comes from the Benitoite Gem mine and the Junnila Claim (B. Laurs et al., "Benitoite from the New Idria District, San Benito County, California," Fall 1997 *G&G*, pp. 166–187). This faceted benitoite contains one of the best examples of neptunite in benitoite seen by the authors.

Amy Cooper and Nathan Renfro
GIA, Carlsbad

Xenomorphic Olivine Inclusion in Diamond

The author recently examined a faceted diamond that contained an oddly shaped near-colorless crystal with a low-relief tension crack surrounding it. The inclusion was identified by Raman spectroscopy as olivine, a rather common inclusion in diamond. The remarkable thing about this particular example was its shape, which consisted of three spokes intersecting at approximately

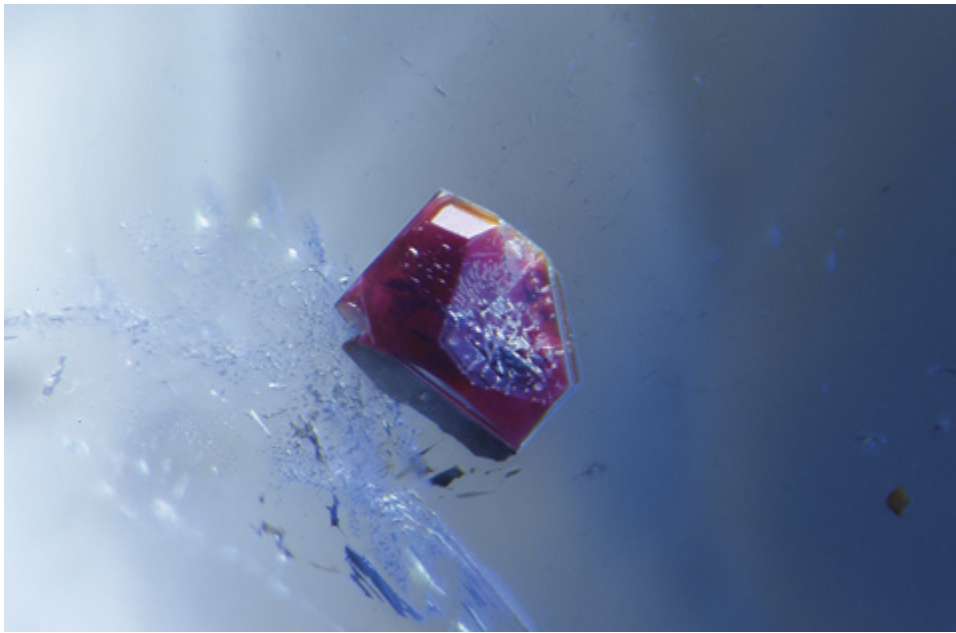


Figure 5. This faceted benitoite contains a small reddish brown inclusion of neptunite that was identified by Raman spectroscopy. Photomicrograph by Nathan Renfro; field of view 1.20 mm. Courtesy of Michael Jakubowski.

120° (figure 6). This is not the shape one would typically associate with the orthorhombic mineral olivine, but there is an explanation for the unusual morphology of this inclusion.

As diamonds form at extreme temperature and pressure conditions, they can impose their morphology on syngenetic minerals that become included in them. When a guest mineral adopts the host diamond's morphology, this is known as *xenomorphism*. The triangular morphology seen here suggests that the olivine inclusion is oriented parallel to an octahedral crystal face of the host

diamond crystal. This is one of the most unusually shaped inclusions observed in diamond examined by the author.

Nathan Renfro

Bent Rutile in Rock Crystal Quartz

The authors recently examined a polished quartz disk with an unusual rutile (TiO₂) inclusion (figure 7). Although rutile in quartz is reasonably common and has been well documented, this "bent" rutile was a fun oddity as it also

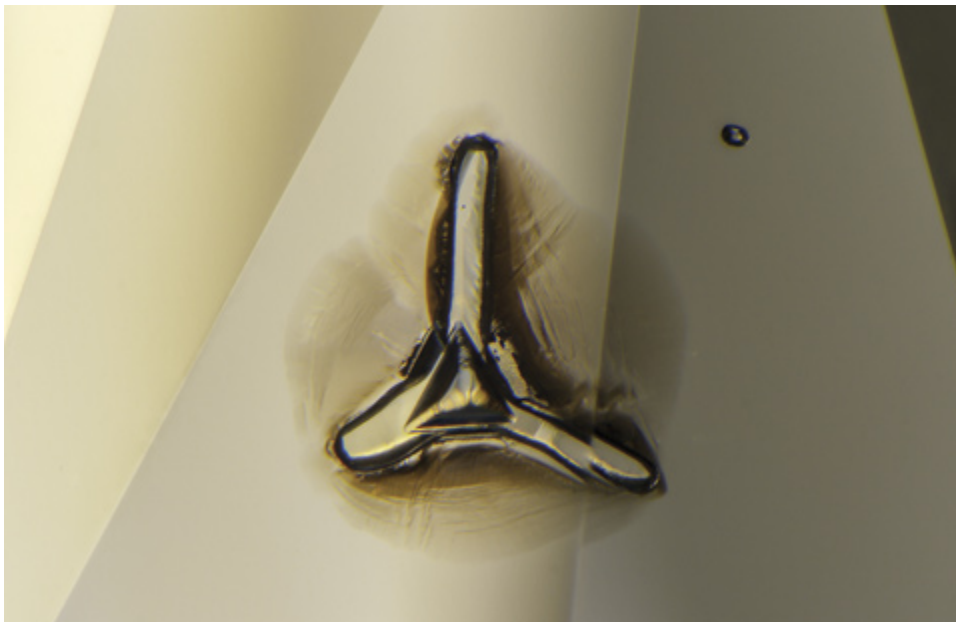


Figure 6. This three-spoke radial inclusion of olivine owes its unique morphology to the extreme temperature and pressure applied to it. This mineral inclusion forced to adopt the shape of its host is an example of xenomorphism. Photomicrograph by Nathan Renfro; field of view 2.25 mm.

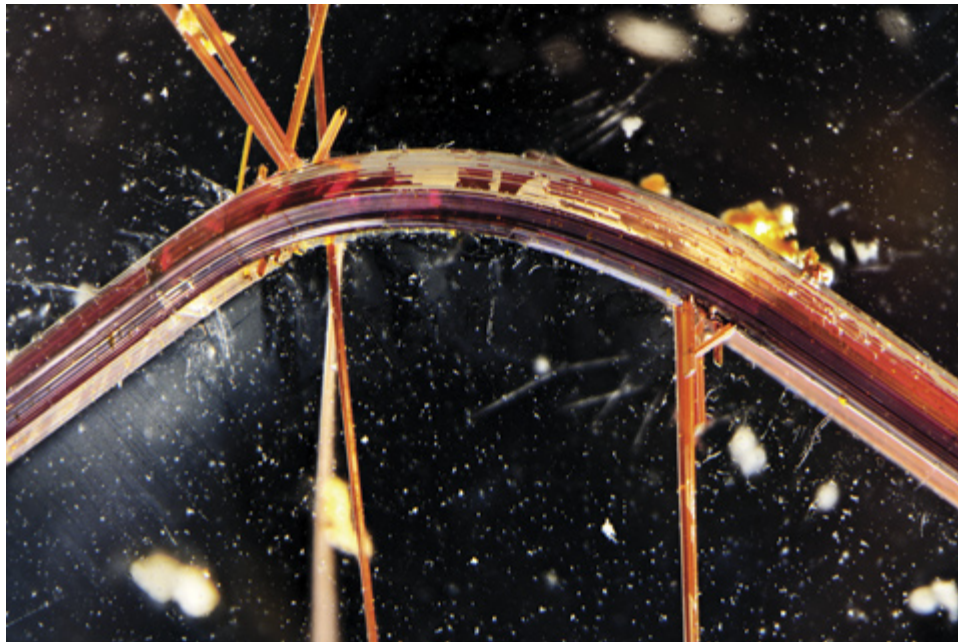


Figure 7. Brownish red “bent” rutile with additional orangy needles displaying sagenitic twinning. Photomicrograph by Nathan Renfro; field of view 11.28 mm. Courtesy of Mike Bowers.

contained small orangy sagenitic twinned rutile needles extending from the primary bend in the rutile needle. Rutile is most often seen as fine, straight needles (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 2, 2005, Opinio-Verlag Publishers, Basel, Switzerland, pp. 627 and 630). Rutile can play many roles as an inclusion and may contribute to phenomenal effects as well as to the bodycolor of an overall transparent colorless quartz (figure 8). While the exact cause of the bent nature of this rutile inclusion is unknown, the stone is a fascinating example of the unusual formation of inclusions in gems.

Amy Cooper and Nathan Renfro

Yellow Fluid Inclusions in Transparent Sodalite

The authors recently examined a 7.17 ct transparent, near-colorless sodalite submitted for identification service (figure 9). Sodalite is typically encountered as a semitransparent to opaque, violetish blue stone with white calcite veining resembling lapis lazuli.

Hackmanite is the sulfur-bearing variety of sodalite exhibiting tenebrescence (D. Kondo and D. Beaton, “Hackmanite/sodalite from Myanmar and Afghanistan,” Spring 2009 *G&G*, pp. 38–43). Tenebrescent minerals reversibly change color when exposed to UV light—from light purple to saturated purple, in the case of hackmanite. While this stone showed the strong orange fluorescence reportedly found in hackmanite, no change in color was observed. This was perhaps due to the short exposure time during testing.

Microscopic observation revealed greenish yellow two-phase fluid inclusions reminiscent of petroleum in quartz (figure 10). Unlike petroleum in quartz, the fluid inclusions were inert to long-wave UV light. Raman spectra of the gas bubble and surrounding liquid were matched to gaseous

hydrogen sulfide and hydrogen sulfide in solution, respectively. Methane-related peaks were also present in the liquid phase. These sulfur-rich fluid inclusions provided

Figure 9. This 7.17 ct colorless sodalite was remarkably transparent and contained interesting fluid inclusions. Photo by Sean-Andrew Z. Pyle.





Figure 8. The polished transparent rock crystal quartz containing the bent rutile inclusion. Photo by Robert Weldon.

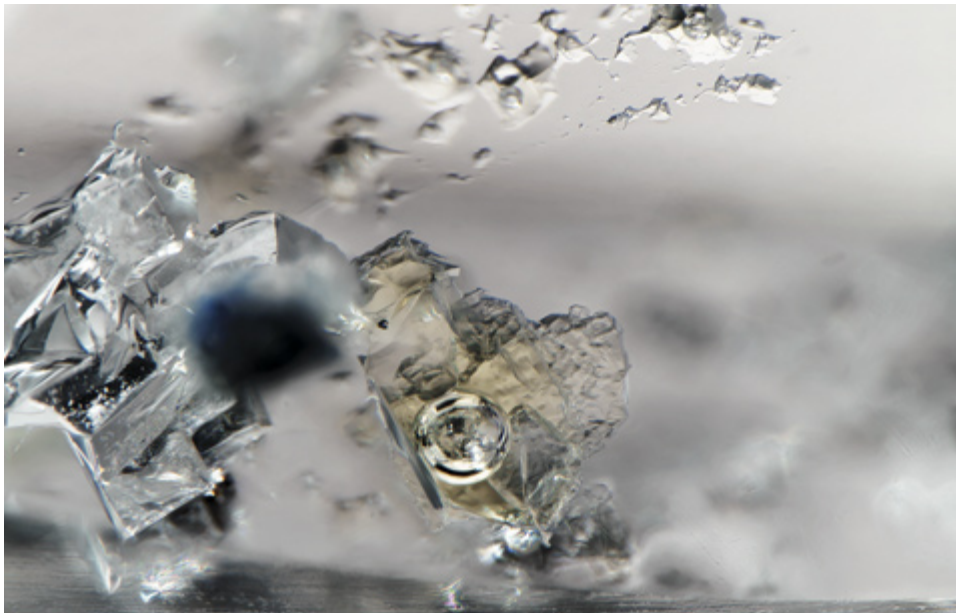


Figure 10. These greenish yellow fluid inclusions were identified as hydrogen sulfide in solution. The gas bubble was matched to hydrogen sulfide gas. Photomicrograph by Tyler E. Smith: field of view 1.99 mm.

interesting geological evidence of the stone's formation, making this rare sodalite even more exceptional.

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Quarterly Crystal: Heavily Etched Blue Beryl Crystals Reportedly from Pakistan

In previous Micro-World columns, the Quarterly Crystal entry has showcased exceptional crystalline specimens mas-

terfully crafted by geological forces. In some cases, however, it is the darker destructive forces of nature that produce a fine mineral specimen. In 2018, Raza Shah (Gems Parlor, Fremont, California) began unearthing heavily etched dark blue beryl crystals from Khyber Pakhtunkhwa in northern Pakistan. Bryan Lichtenstein (3090 Gems, San Francisco, California) submitted three of these crystals to GIA's Carlsbad lab for identification services (figure 11; see also B.M. Laurs and G.R. Rossman, "Dark blue beryl from Pakistan," *Journal of Gemmology*, Vol. 36, No. 7, 2019, pp. 583–584).



Figure 11. Three blue beryl crystals showing the heavily etched and corroded appearance typical of this material. The largest crystal is 236.8 g, while the other two weigh 16.1 g (left) and 13.8 g (right). Photo by Diego Sanchez.

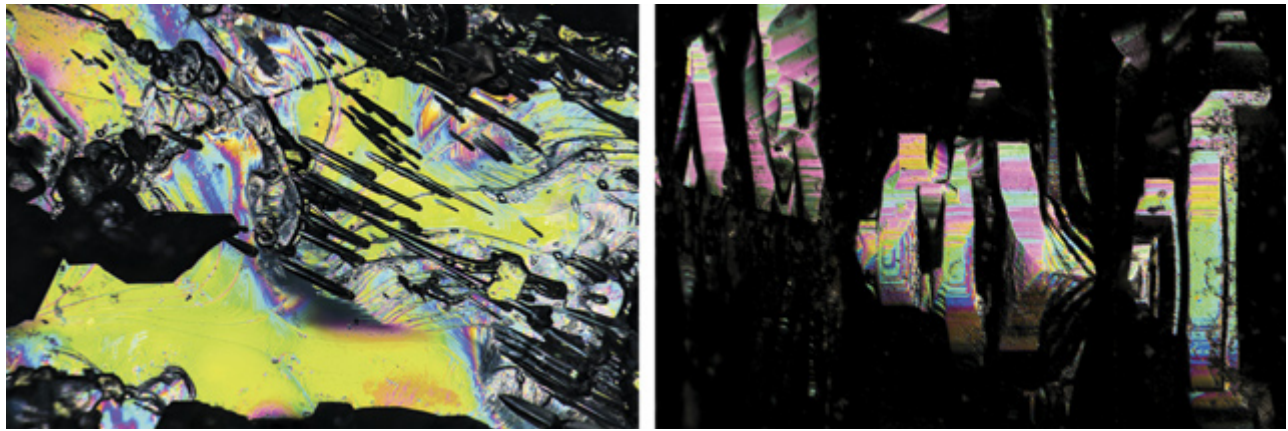


Figure 12. The use of differential interference contrast imaging illustrates the complex growth and subsequent etching processes that lent the beryl crystals their unique appearance. These views are essentially parallel to the *c*-axis (left) and perpendicular to the *c*-axis (right). The left image shows terraced, stepped patterns created during crystal growth that are crosscut by oriented, elongate etch pits. Photomicrographs by Aaron Palke; field of view 2.88 mm.

The hexagonal barrel shape that must have characterized the crystals in their initial state is still apparent despite the heavy etching. The geological conditions responsible for beryl growth apparently persisted long enough for many of these crystals to grow to extreme sizes; the largest recovered so far weighs 236.8 g. At some point, these crystals appear to have fallen out of equilibrium with their natural environment and the beryl started dissolving back into the earth. Microscopic observation of the corroded surfaces shows how the dissolution process is con-

trolled by the beryl crystal structure, with dissolution pits and the skeletal remnants of the beryl constrained by the underlying crystal lattice. Differential interference contrast (DIC) microscopy can be used to highlight both growth and dissolution features in the same image (figure 12). While Pakistan is an important source of aquamarine crystals and gems, this heavily etched dark blue aquamarine is truly a unique find.

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