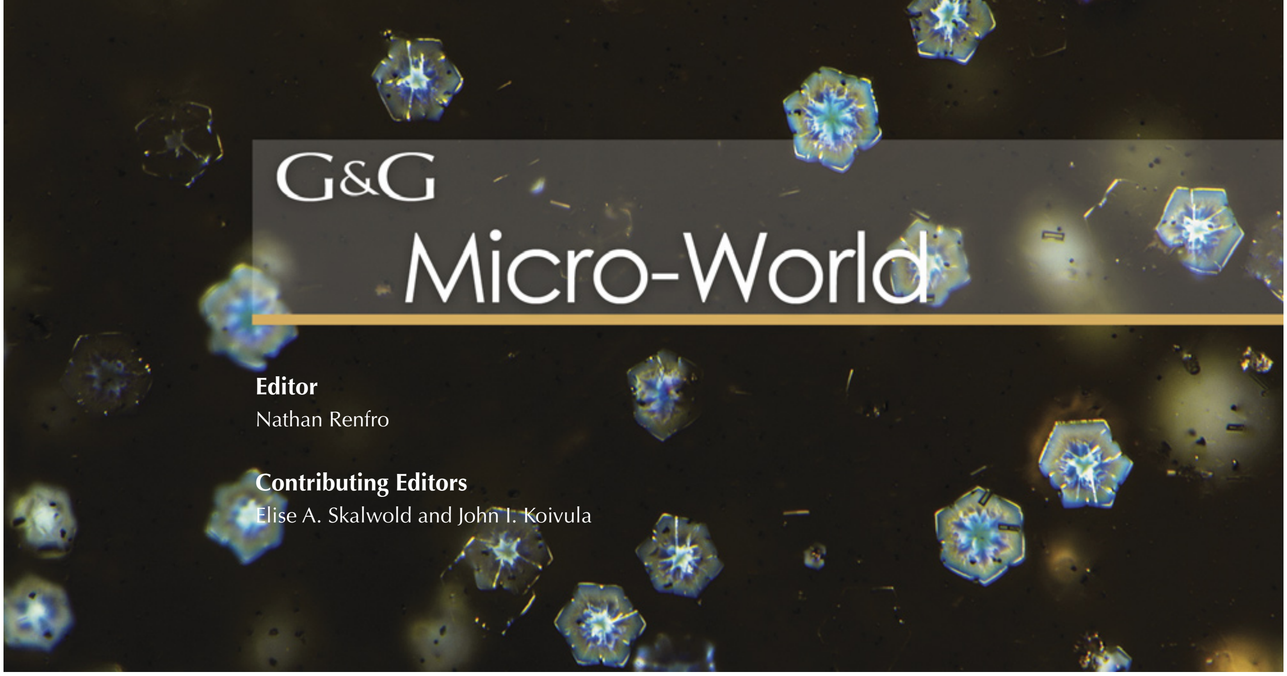


Unusual Composite Apatite-CO_2 Inclusions in Sapphires from Ohn Bin Yee Htwet, Myanmar

Routine investigation of a parcel of sapphires from Ohn Bin Yee Htwet near Mogok in Myanmar revealed something unexpected. Unusual composite inclusions were observed where one part of the inclusion exhibited flat, crisp, angular planes, while the other part showed an irregular and rough surface (figure 1). Raman spectroscopy identified the two phases as apatite (the flat, crystalline-looking area) and CO_2 (the rough and irregular surface).

The rough and irregular part of the inclusion also showed a gas bubble within the fluid CO_2, which disappeared when warmed in the well light of the microscope as the gas and liquid homogenized. These inclusions generally sit atop a dense nest of rutile silk. The rutile silk is tightly clustered in the core of the sapphire crystals and terminates rather abruptly. A myriad of inclusions is often found at the boundary between the dense, silky core and the unincluded rim (figure 2).

Figure 1. Composite apatite/CO_2 inclusion in a sapphire from Ohn Bin Yee Htwet. Photomicrograph by Aaron Palke; field of view 1.99 mm.

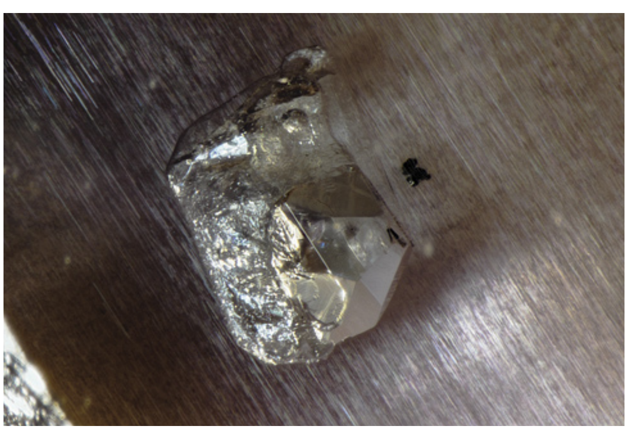


Figure 2. A myriad of inclusions at the boundary between the dense, silky core and the unincluded rim. Photomicrograph by Jonathan Muyal; field of view 1.76 mm.

While both apatite and CO_2 are routinely observed in sapphires from a variety of sources, finding both phases in a single inclusion is unexpected and has not been previously reported, to the author's knowledge. It is hypothesized that these inclusions formed when apatite was

About the banner: Numerous hexagonal flakes of hematite and ilmenite are scattered throughout this obsidian from the Jemez Mountains, New Mexico, causing a silvery aventurescence. Photomicrograph by Nathan Renfro; field of view 2.04 mm.

Gems & Gemology, Vol. 57, No. 4, pp. 382–389.

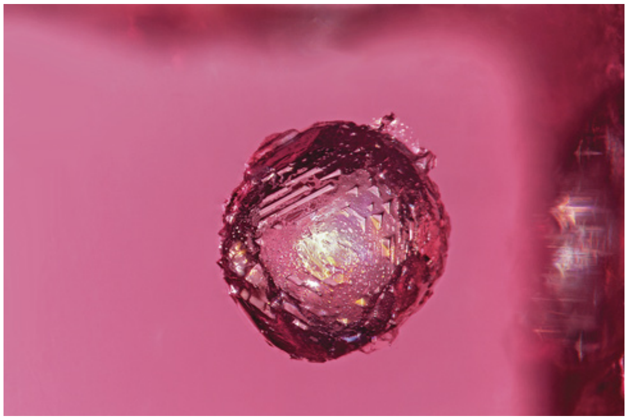


Figure 3. Chondrodite crystal in a red spinel from Mogok viewed under darkfield, diffuse, and fiber-optic illumination. Photomicrograph by Charuwan Khowpong; field of view 1.05 mm.

trapped within the sapphire and created a growth blockage, thus allowing the fluid present (CO_2) to adhere to the surface of the apatite and sapphire to become included as well.

Aaron C. Palke
GIA, Carlsbad

Chondrodite in Red Spinel from Mogok, Myanmar

Myanmar, formerly known as Burma, is one of the world's leading sources of gemstones. This includes red spinel with remarkable color, clarity, and appearance. A 1.507 ct red spinel collected from the Thit Saint Kone mining area in Mogok is part of GIA's research collection. Its inclusion scene is dominated by a single round crystal with small trigons and a rough surface texture (figure 3). The crystal was identified as chondrodite by Raman spectroscopy. Chondrodite is a magnesium-rich variety within the humite mineral group. This mineral requires relatively high temperature and pressure conditions to form, which are found in the Mogok Metamorphic Belt. Chondrodite forms during contact metamorphism of magnesium-rich limestones and felsic intrusions.

Since chondrodite and spinel are both found in metamorphosed Mg-rich marbles, it makes sense that they occur in association. Nevertheless, the combination of both minerals has rarely been documented in gems and, as such, is a potential indicator of Burmese origin in gem-quality red spinel (M.M. Phyo et al., "Spinel from Mogok, Myanmar—A detailed inclusion study by Raman microspectroscopy and scanning electron microscopy," *Journal of Gemmology*, Vol. 36, No. 5, 2019, p. 423).

Charuwan Khowpong
GIA, Bangkok

Natural Black Coral with Polyp Structure

The authors recently examined a large black oval cabochon that was opaque with a slight waxy luster. Microscopic examination revealed a layered concentric tree-like structure when a fiber-optic light was used, as well as round ring-like spherical structures. These observations are consistent with coral, and these individual spheres are referred to as polyps (figure 4). This is a great example of the diagnostic surface structure produced when black coral is cut and polished into a cabochon. Oblique fiber-optic lighting revealed an intense orangy brown and black pattern, also consistent with the polyp structure of natural black coral (figure 5). This was the clearest example of this polyp structure the authors have examined in black coral. For additional information and images on black coral, see E.W.T. Cooper et al.,

Figure 4. The surface of the black oval cabochon displayed a vivid example of the diagnostic polyp structure in black coral, shown using reflected light. Photomicrograph by Britni LeCroy; field of view 2.90 mm.

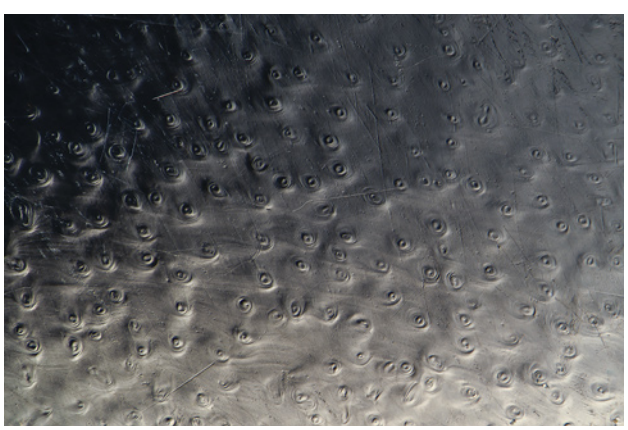
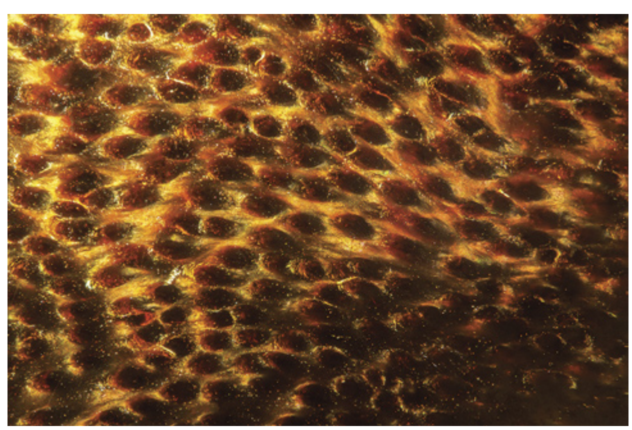


Figure 5. Using oblique fiber-optic illumination, the orangy brown color and polyp structure were clearly visible. Photomicrograph by Britni LeCroy; field of view 2.90 mm.



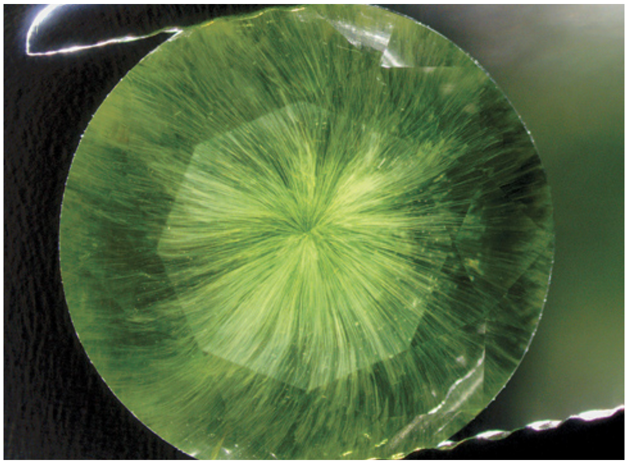


Figure 6. This demantoid was faceted to better reveal the "horsetail" inclusions. The sample is 8 mm in diameter. Photo by U. Hennebois.

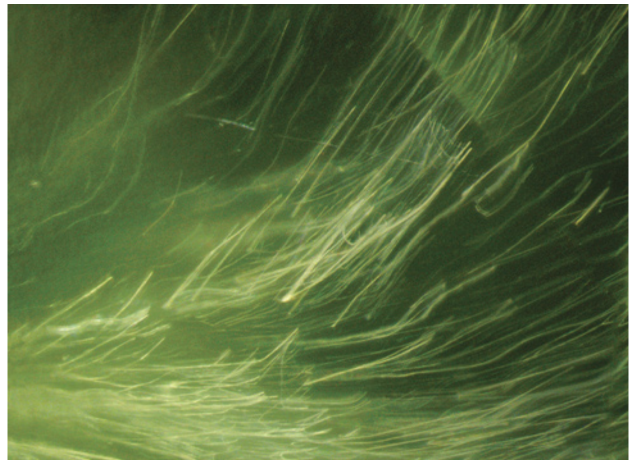


Figure 7. Fibrous inclusions in a demantoid garnet. Photomicrograph by U. Hennebois; field of view 1 mm.

Guide to the Identification of Precious and Semi-precious Corals: In Commercial Trade, World Wildlife Fund, Vancouver, Canada, 2011.

Amy Cooper and Britni LeCroy
GIA, Carlsbad

Faceted Demantoid Garnet with Spectacular "Horsetail" Inclusions

The Laboratoire Français de Gemmologie (LFG) received for analysis an example of the yellowish green variety of andradite garnet known as demantoid. The gem was cut in such a way that spectacular "horsetail" inclusions are anchored at the center of the table (figure 6). These inclusions are actually fibers (figure 7), which are present in some demantoids from the Ural Mountains (Russia) but also from Val Malenco (Italy), Baluchistan (Pakistan), as well as from Kerman (Iran) (W.R. Phillips and A.S. Talantsev, "Russian demantoid, czar of the garnet family," Summer 1996 *G&G*, pp. 100–111; Spring 2007 Gem News International, pp. 65–67; I. Adamo et al., "Demantoid from Val Malenco, Italy: Review and update," Winter 2009 *G&G*, pp. 280–287; I. Adamo et al., "Demantoid from Balochistan, Pakistan: Gemmological and mineralogical characterization," *Journal of Gemmology*, Vol. 34, No. 5, 2015, pp. 428–433).

The exact origin and composition of the "horsetail" inclusions in demantoids are still under discussion. Those in demantoids from Russia, Italy, and Pakistan were reported to be chrysotile, and those from Iran calcite. On the other hand, a recent study of these inclusions in some demantoid garnets from the Ural Mountains showed that these might be hollow channels, sometimes containing minerals from the serpentine group, possibly the result of superficial weathering (A.Y. Kissin et al., "'Horsetail' inclusions in the Ural demantoids: Growth formations," *Minerals*, Vol. 11, No. 8, 2021, article no. 825). Thus, the exact mechanism of formation of the "horsetail" inclusions in demantoid garnets is again open for discussion.

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Radioactive Green Diamond

The rarity of naturally colored green diamonds has created the demand for artificially irradiated green diamonds. One 2.42 ct green diamond recently examined by the author showed signs of radiation treatment by the use of radioactive salts (figure 8). Microscopic analysis revealed telltale green mottled and shallow radiation stains over large areas

Figure 8. Green diamond treated with radioactive salts. Photo by Diego Sanchez.

Figure 9. A mottled green appearance was visible on the table facet of the green diamond treated with radioactive salts. Photomicrograph by Nathan Renfro; field of view 4.70 mm.

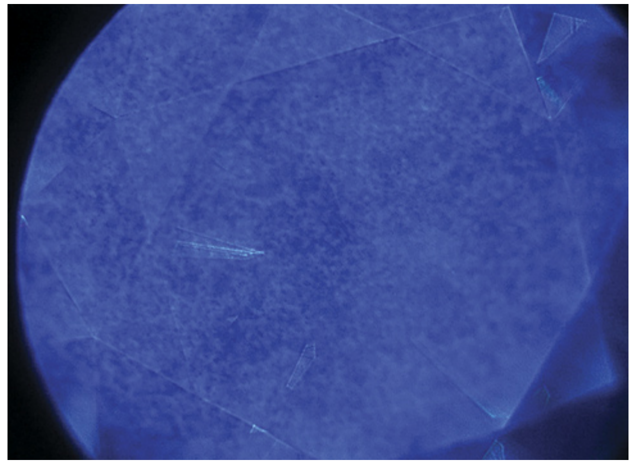


Figure 10. This diamond's blue fluorescence provides strong contrast to the inert radiation stains, as shown by the DiamondView. Image by Michaela Stephan; field of view 8.265 mm.

of the stone, causing its green bodycolor (figure 9). These radiation stains were produced by exposing a cut and polished diamond to radioactive salts for an extended period. The inert to ultraviolet light radiation stains were easily visible against the diamond's blue fluorescence seen in the DiamondView (figure 10).

Treatment using radioactive salts (such as radium) is not often used anymore, as this method may produce dangerously radioactive diamonds. Today, most artificially irradiated diamonds are treated with a low-energy electron beam (Spring 2013 Lab Notes, pp. 46–47). When tested with a Geiger counter, this stone was revealed to be weakly radioactive.

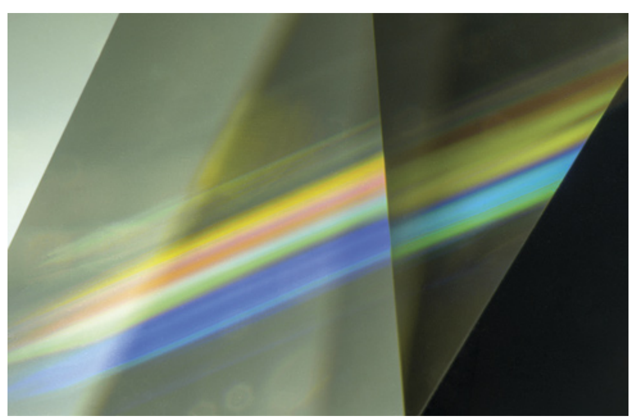
Michaela Stephan
GIA, Carlsbad

Rainbow Graining in Diamond

One of the more subtle inclusion scenes gemologists sometimes observe in natural diamonds is the presence of crystallographically oriented structural defects known as "internal graining." Often resulting from octahedral and cubic growth sectors of a diamond crystal competing for space during growth, these structural disconformities present as colorless, whitish, reflective, colored, and rarely rainbow varieties of graining (J.I. Koivula, *The Microworld of Diamonds*, Gemworld International, Northbrook, Illinois, 2000). Colorless graining is the most common type encountered, while whitish graining is somewhat less common and shows, as the name implies, a hazy white appearance in the immediate area of the structural defect zone. Colored graining often occurs when plastic deformation along the cleavage direction results in color causing defects in the diamond crystal lattice. If the defects are numerous enough, they can impart a bodycolor, which in the case of pink and red diamonds greatly enhances their value. Reflective graining occurs as a result of excess strain buildup from the crystallographic defects. The diamond's accumulated strain is released by separating along cleavage planes, leaving a reflective, mirror-like separation as the most obvious characteristic of this type of graining. The rarest of all types is known as "rainbow graining." In these remarkable stones, the structural defects in the diamond's crystal lattice are ordered layers, which act as a diffraction grating to reveal a vibrant display of spectra colors (Summer 2007 Lab Notes, p. 155).

Recently, the author had the opportunity to examine a spectacular example of a yellow diamond containing prominent rainbow graining (figure 11). When the stone was rocked and tilted, the rainbow colors would appear and disappear (see the video at https://www.gia.edu/gems-gemology/winter-2021-microworld-rainbow-graining-

Figure 11. This yellow diamond displayed a remarkable example of rainbow graining that appears and disappears as the stone is tilted. Photomicrograph by Nathan Renfro; field of view 4.64 mm.



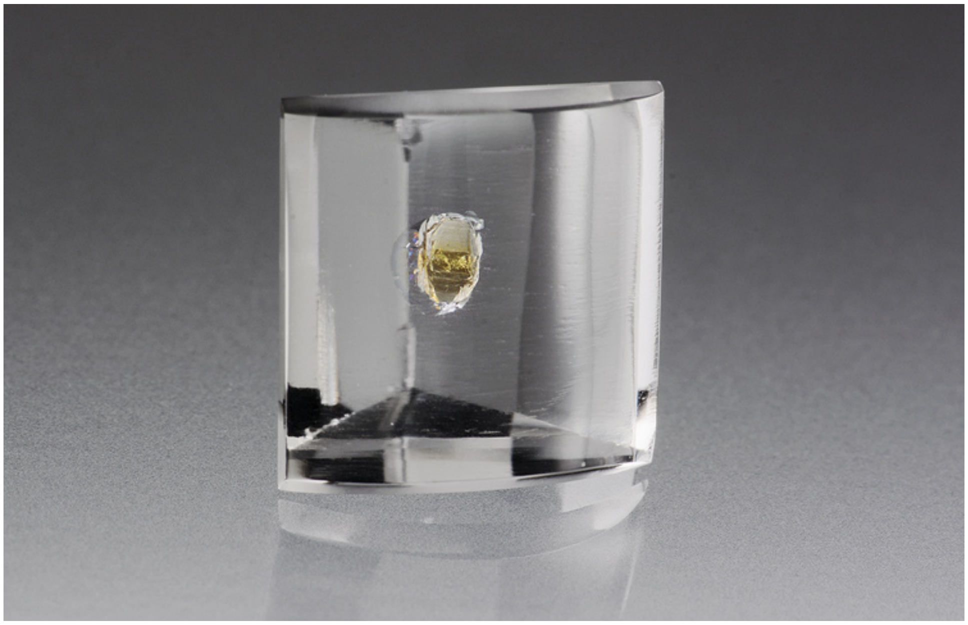


Figure 12. This 10.54 ct rock crystal quartz is host to a transparent yellow mineral inclusion. Photo by Annie Haynes.

diamond). The elusive beauty of this type of graining and the difficulty with which it is observed make this type of graining a rare and welcome sight in natural gem diamonds.

Nathan Renfro
GIA, Carlsbad

Monazite (?) in Quartz

We recently examined an interesting 10.54 ct transparent, colorless, square modified step cut with a slightly convex table facet (figure 12). The faceted rock crystal quartz host, measuring 11.82 × 11.77 × 9.57 mm, is from Itinga in Minas Gerais, Brazil, and came to us from Luciana Barbosa at the Gemological Center in Asheville, North Carolina.

The gem played host to an eye-visible transparent yellow crystal located near its center, which was visible from several directions. On examination with a gemological microscope, we observed a transparent yellow angular crystal of what appeared to be monazite, with a skirt of small stress cracks, suspended in the quartz (figure 13).

Laser Raman microspectrometry was not able to identify the inclusion because it was too deep in the host; all it

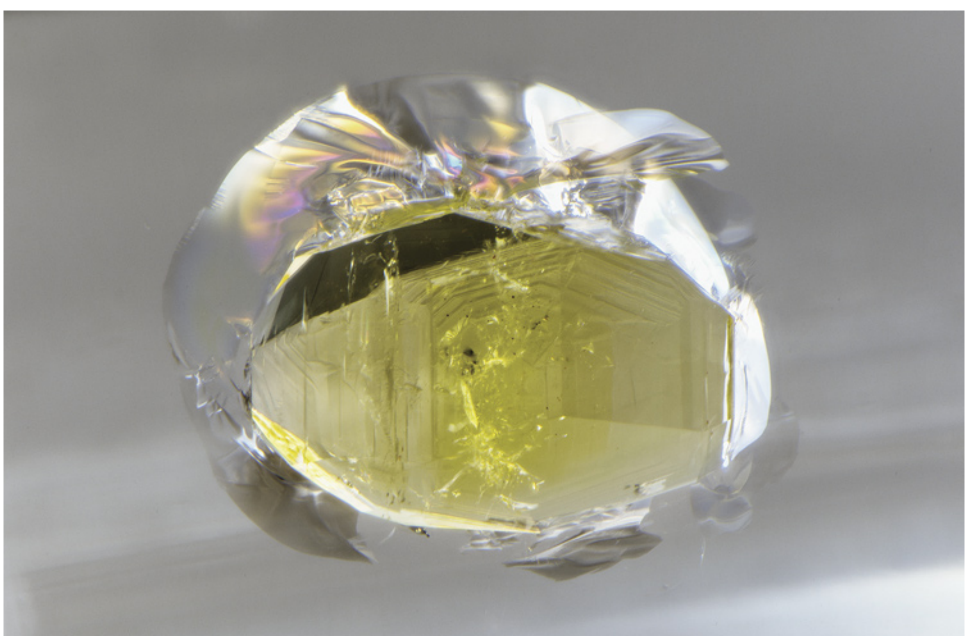


Figure 13. The transparent yellow monazite (?) inclusion in the rock crystal quartz and the stress cracks immediately surrounding it are both clearly visible in this image. Photomicrograph by Nathan Renfro; field of view 4.86 mm.

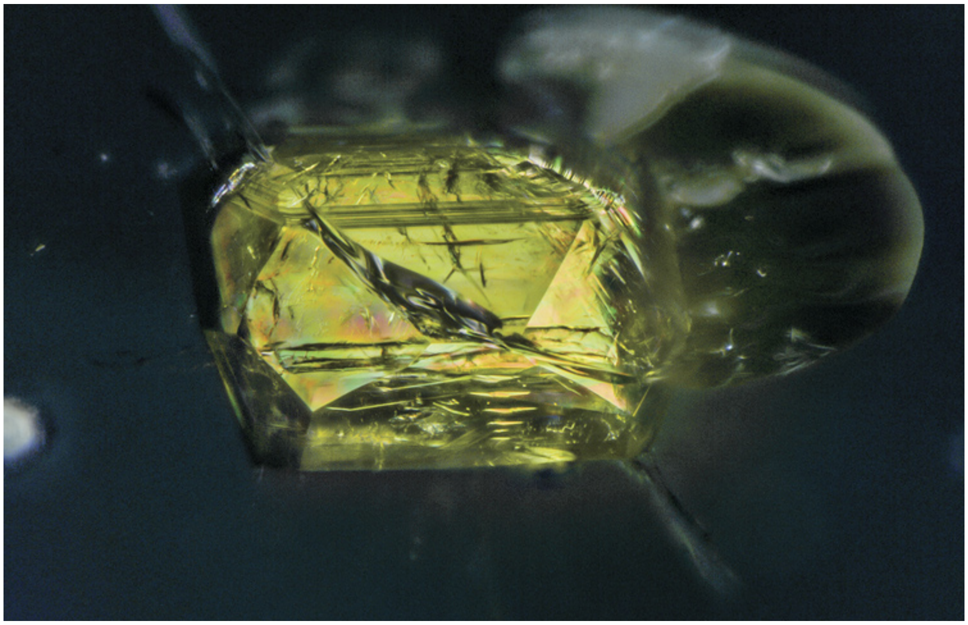


Figure 14. The monazite (?) inclusion shows its birefringent (anisotropic) nature with bright interference colors in polarized light. Photomicrograph by Nathan Renfro; field of view 3.06 mm.

returned were quartz peaks. Energy-dispersive X-ray fluorescence (EDXRF) also failed to produce hints of unusual chemistry on the inclusion. After several attempts at Raman and EDXRF, we realized that destructive analysis would be needed to clearly identify the yellow crystal, but destructive analysis was not possible.

As a result, we turned to optical mineralogy and the crystal habit shown by the well-formed inclusion. Morphologically, the inclusion looked like monazite crystals we have encountered in the past, and it appeared to be monoclinic. The yellow color also suggested monazite. The inclusion showed its birefringent (anisotropic) nature with bright interference colors in polarized light (figure 14). A small condensing lens was used to pull a partial biaxial interference figure from the inclusion. The crystal had weak pleochroism, and a Becke line test showed that the inclusion had a higher refractive index than the surrounding host quartz. All of these findings could lead to its identification as monazite. But there is still a nagging uncertainty, so we are left with "monazite (?)."

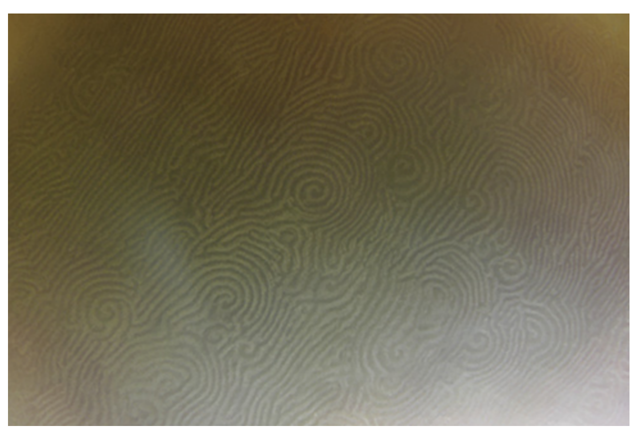
John I. Koivula and Nathan Renfro
GIA, Carlsbad

Spiral Nacre in Natural Pearl

Nacreous pearls are known to have platelet growth resembling fingerprints or topographic maps, but a less common appearance is nacre with a concentric spiral pattern. The feature is sometimes seen in small patches in unprocessed saltwater pearls. One recent example was exceptional as it showed spiral formations throughout its entire surface (figure 15). The pearl was determined to be a natural saltwater pearl from the *Pinctada* genus. Nacre is composed of aragonite crystals and conchiolin protein, with the crystals acting like bricks and the protein acting like mortar. The explanation for spiral patterns is complex and involves the development of screw dislocation defects during nacre formation as predicted by the Burton-Caberra-Frank theory (J.H.E. Cartwright et al., "Spiral and target patterns in bivalve nacre manifest a natural excitable medium from layer growth of a biological liquid crystal," *PNAS*, Vol. 106, No. 26, 2009, pp. 10499–10504).

Britni LeCroy

Figure 15. Concentric spiral nacre formations seen on a natural saltwater pearl. Photomicrograph by Britni LeCroy; field of view 2.34 mm.



Windmill Zoning in Tourmaline

Tourmaline often displays color zoning. Popular examples include parti-color tourmaline (color zoning perpendicular to the c-axis) and watermelon tourmaline (pink and green color zoning parallel to the c-axis). A more peculiar type of

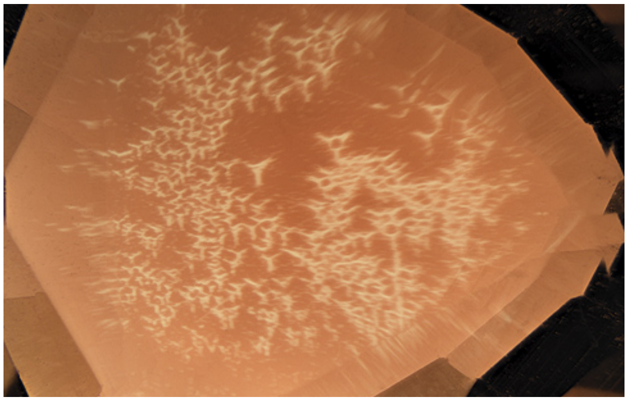


Figure 16. Colorless windmill-shaped zoning in tourmaline, as seen with diffused light. Photomicrograph by Britni LeCroy; field of view 9.60 mm.

abundant colorless zoning with windmill structures (figure 16) was seen by the author in a 8.55 ct pink faceted tourmaline. The table was cut perpendicular to the length of the crystal to reveal the windmill zoning as parallel to the c-axis, terminating at the crown and pavilion. This characteristic was visible with or without the use of a microscope. However, diffused transmitted light was necessary for observation in both cases. The stone did not possess any other visible inclusions, but some areas showed fully formed colorless hexagonal zoning following the c-axis. This feature bore a mild resemblance to windmill inclusions seen in sphalerite (Summer 2020 *G&G* Micro-World, p. 295).

Britni LeCroy

Quarterly Crystal: Rutile on Hematite

When we think of the micro-world of gems and minerals, we usually think of transparent to translucent host materials. However, there are also a number of opaque minerals used as gems that are composed of chemical elements such as copper, iron, and titanium. One of these is hematite.

Recently we had the opportunity to study an unusual hematite crystal sent by Ali Shad of Shad Fine Minerals in Gilgit-Baltistan, Pakistan. The geographic source for the hematite crystal pictured in figure 17 is the Yangslo mine, located in the Basha Valley of Gilgit-Baltistan. At 178.33 ct and 39.83 mm in the longest direction, this "floater"

Figure 17. Measuring 39.83 mm and weighing 178.33 ct, this Pakistani hematite crystal is host to a geometric outer skin of sagenitic rutile. Photo by Diego Sanchez.

Figure 18. The sagenitic epitaxial structure of the acicular rutile crystals on the surface of this hematite gives the substrate an otherworldly appearance. Photomicrograph by Nathan Renfro; field of view 11.28 mm.

hematite crystal (with no points of attachment to the surrounding rock) plays host to a sagenitic network of epitaxial, surface-oriented, opaque dark gray acicular rutile crystals as large as 4 mm in length.

Using laser Raman microspectrometry, the identification of the sagenitic crystals was confirmed as rutile. Energy-dispersive X-ray fluorescence (EDXRF) analysis showed the dominant presence of iron and titanium, with a trace of manganese. As shown in figure 18, the euhedral rutile crystals were situated on the hematite crystal in the form of a geometric sagenitic boxwork.

John I. Koivula and Nathan Renfro

Rainbow Graining in Diamond

To see video of a yellow diamond containing spectacular rainbow graining, go to www.gia.edu/gems-gemology/winter-2021-microworld-rainbow-graining-diamond or scan the QR code on the right.