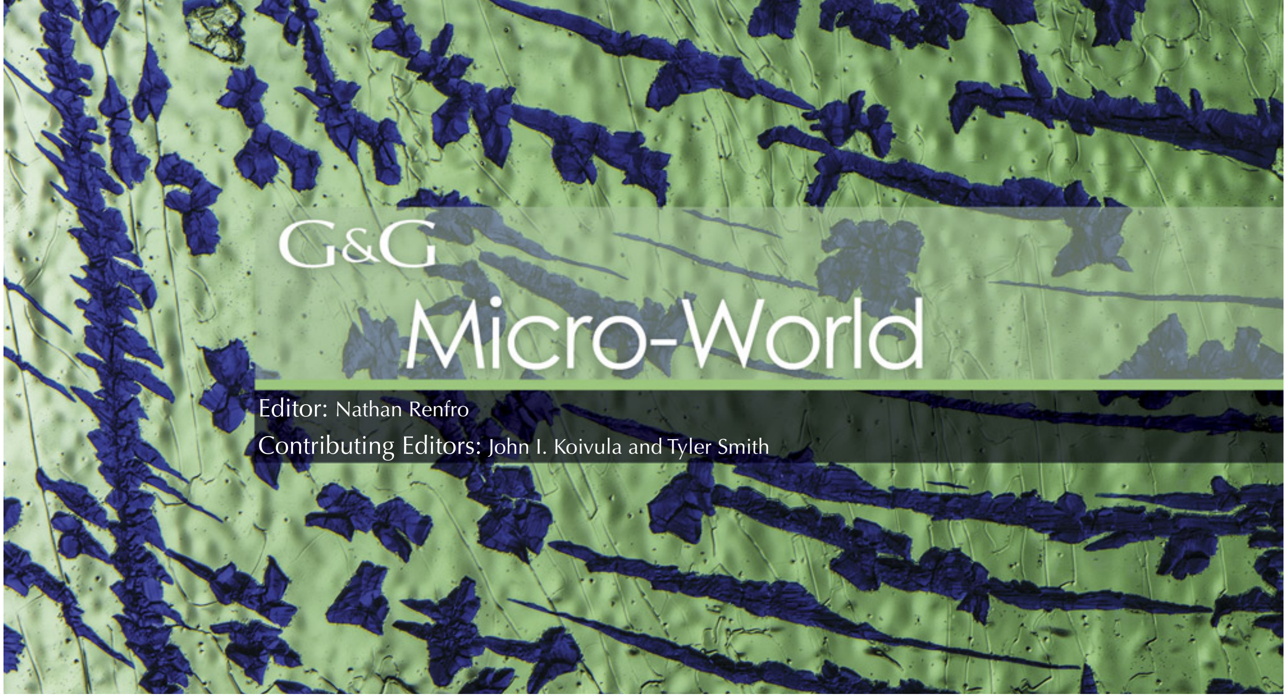

G&G Micro-World

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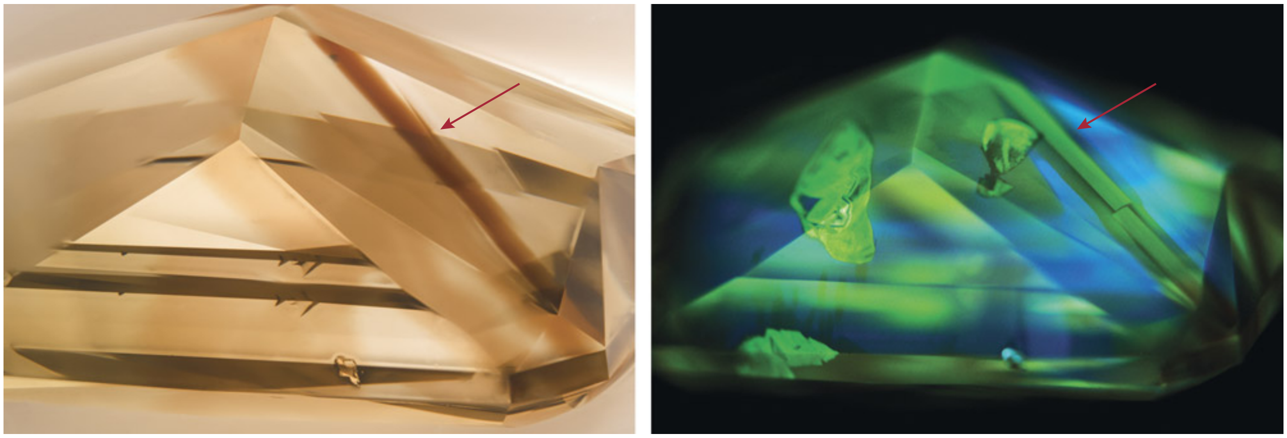

Figure 1. Left: The strong linear brown zoning (arrow) of the 2.21 ct Fancy Dark yellow-brown diamond was best viewed under diffused light, also revealing the stone's patchy bodycolor. Photomicrograph by Britni LeCroy and Jeffrey Hernandez; field of view 7.19 mm. Right: The associated DiamondView image shows a vibrant mixture of fluorescence patterns, with the brown zone displaying dull yellow-green fluorescence while retaining its linear structure (arrow). Image by Jeffrey Hernandez.

Brown Zoning in Diamond

The author recently encountered a 2.21 ct Fancy Dark yellow-brown rectangular diamond with unusually strong eye-visible linear brown zoning (figure 1, left). This stone provided a unique opportunity to document crystallographic defects coloring a diamond with various instrumentation and tools in separate lighting conditions. The diamond's ultraviolet/visible/near-infrared absorption spectra revealed a 480 nm absorption band, a defect gemologists know little about due to the complex mantle environment these diamonds come from (C.M. Breeding et al., "Naturally colored yellow and orange gem diamonds: The nitrogen factor," Summer 2020 *G&G*, pp. 194–219). Prior research has shown that the 480 nm band defect coincides with dull yellow-green fluorescence (M.Y. Lai et al., "Spectroscopic characterization of diamonds colored by the 480 nm absorption band," *Diamond and Related Materials*, Vol. 142, 2024, article no. 110825). Deep UV fluorescence imaging of this diamond showed several regions with dull yellow-green fluorescence corresponding with brown zoning. This defect was present not only in the brown band of

About the banner: The surface of this flame-fusion sapphire is decorated with unknown cobalt-colored dendrites. Photomicrograph by Nathan Renfro; field of view 12.82 mm.

Gems & Gemology, Vol. 60, No. 3, pp. 382–391.

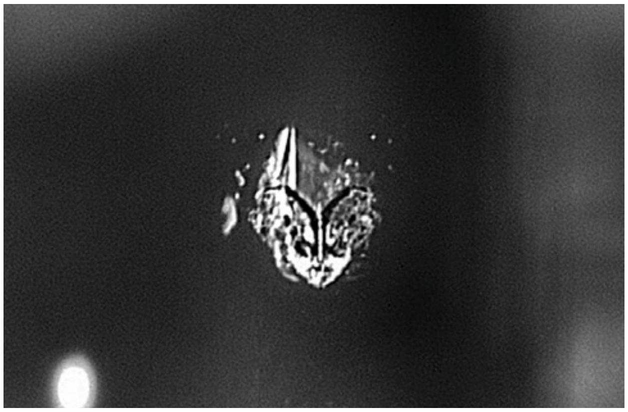

Figure 2. The mirroring of a feather inclusion in diamond, viewed through the step-cut facets of the pavilion, creates an apparent theater mask in a close-up view captured in monochrome. Photomicrograph by Kaivan Shah; field of view 3.00 mm.

color but also in the other areas of the stone that showed a dull yellow-green fluorescence (figure 1, right).

Figure 1 (right) also shows regions with blue fluorescence that are associated with the N3 defect (three substitutional nitrogen atoms adjacent to a vacancy). The bright green blocky color zones are associated with a concentrated H3 defect (two nitrogen atoms adjacent to a vacancy). Although the DiamondView image unveiled previously hidden defects, inert areas between the growth zones were not so easily explained. These images juxtaposed with one another provide a visually intriguing example of how defects in diamond can influence color.

Jeffrey Hernandez
GIA, Carlsbad

Mask Inhabiting a Natural Diamond

While diamond graders spend a good deal of time looking at inclusions, rarely do we see a clarity feature staring back at us, such as the example in figure 2. The 0.90 ct F-color type Ia natural diamond with VS_2 clarity contained a feather that reached the surface of the table. When viewed through the pavilion, the mirror image caused by the faceting created an effect resembling a distinctive theater mask. This striking inclusion showcases the wide variety of inclusions that are possible in diamond and leaves a memorable, almost haunting impression.

Kaivan Shah
GIA, Mumbai

Sally Eaton-Magaña
GIA, Carlsbad

Kaleidoscope of Butterflies and Tiny Fish in Diamonds

The author recently encountered two natural diamonds with interesting feather inclusions: a 1.55 ct round with G-color and I_1 clarity and a 0.30 ct round with F-color and VS_2 clarity.

The more heavily included diamond appeared to contain a swarm of butterflies. A feather breaking the pavilion surface was observed face-up through the crown, with mirror and prism images creating the appearance of a white butterfly (figure 3). Since the inclusion was visible through the upper half and bezel facets of the diamond, five prism images were formed, befitting the word "kaleidoscope" occasionally used to describe a group of butterflies.

The other diamond housed a small feather in the table with a mirror reflection (figure 4). The reflection along with

Figure 3. Mirrored and reflected fissures in a diamond take the form of a kaleidoscope of butterflies. Photomicrograph by Yash Jhaveri and Bijal Shah; field of view 4.20 mm.

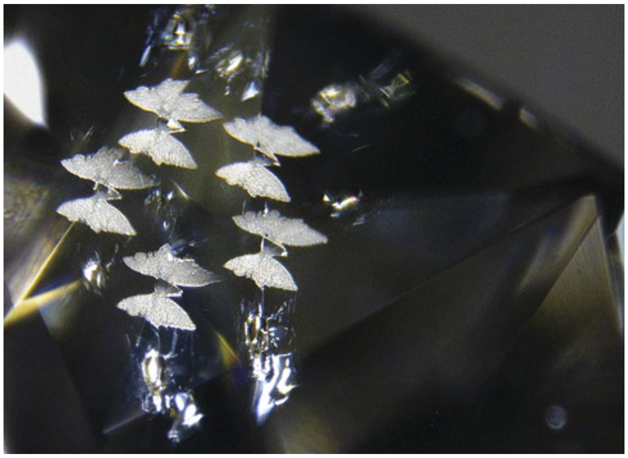

Figure 4. A mirrored feather in diamond resembles a small fish swimming through sunlit waters. The image was captured in monochrome. Photomicrograph by Russel Carvalho; field of view ~8 mm.

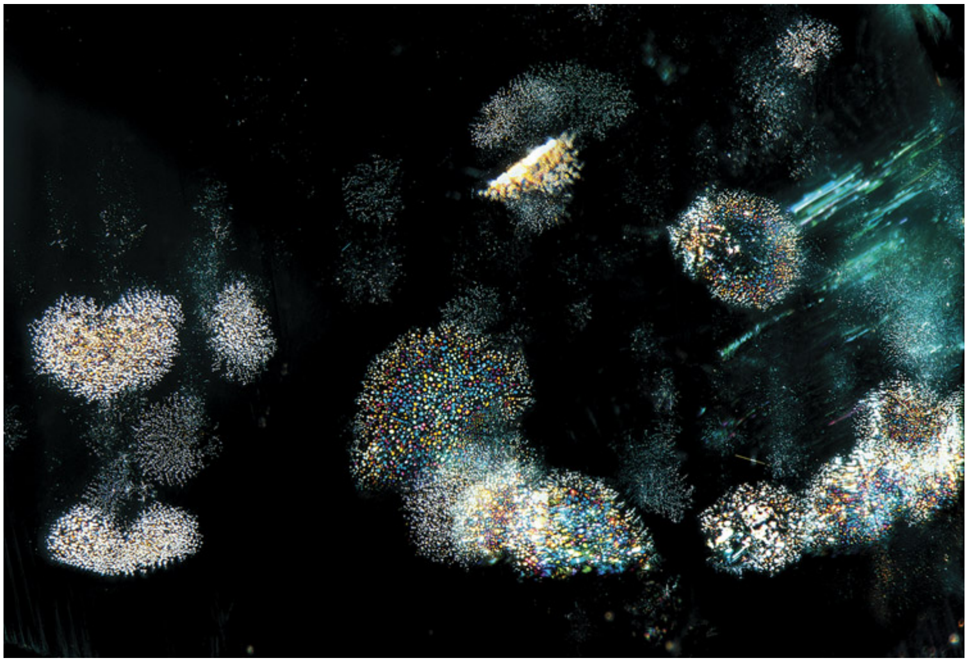

Figure 5. Interference thin films in Russian emerald resembling a sky filled with fireworks. Photomicrograph by Ungkhana Atikarnsakul; field of view 3.60 mm.

the actual inclusion resembled a tiny fish swimming under the warm rays of the sun. Feathers are commonly seen in diamonds, but such unique and precise shapes of fish and butterflies are uncommon.

Tejas Jhaveri
GIA, Mumbai

Fireworks Display in Russian Emerald

Russian emeralds can harbor unique inclusion scenes. Iridescent thin films that lie parallel to the basal pinacoid are considered conclusive evidence of this geographic origin. Microscopic observation of a 1.21 ct faceted emerald revealed multiple planes of interference thin films aligned parallel to the table (figure 5). Viewed under fiber-optic lighting, the scene was reminiscent of fireworks lighting up the night sky. Internal graining, fluid fingerprints, needles, and particles were also found in the stone, combining to form a visually interesting pattern.

Ungkhana Atikarnsakul
GIA, Bangkok

Unusual Hematite Lattice Pattern in Plagioclase Feldspar

Lattice patterns formed by hematite and magnetite platelets where the elongated blades intersect at an angle of 60° are well documented in orthoclase feldspars (S. Jin et al., "Iron oxide inclusions and exsolution textures of rainbow lattice sunstone," *European Journal of Mineralogy*, Vol. 34, 2022, pp. 183–200; J. Liu et al., "Revisiting rainbow lattice sunstone from the Harts Range, Australia," *Journal of Gemmology*, Vol. 36, No. 1, 2018, pp. 44–52). However, the author recently discovered a sample of plagioclase feldspar with similar hematite inclusions where the angle of intersection was closer to 90°. Thin-film interference caused the attractive rainbow colors of the hematite on display in this sunstone cabochon (figure 6). Chemical analysis using laser ablation–inductively coupled plasma–mass spectrometry revealed an oligoclase composition between $Ab_{82.5}An_{16.6}Or_{0.9}$ and $Ab_{83.6}An_{15.5}Or_{0.9}$. The cause of this unusual structure is unknown, as this type of inclusion would typically form as randomly oriented hexagonal platelets.

Rosie Young
Gemmological Certification Services, London

Figure 6. Elongated hematite platelets form a lattice pattern in a sunstone cabochon. Photomicrograph by Rosie Young; field of view 4.97 mm.

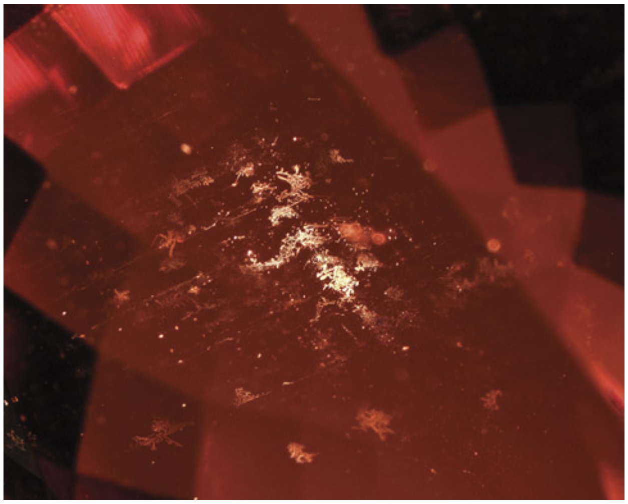

Figure 7. Skeletal formations of natural metallic reflective thin films in an 18.67 ct pinkish orange morganite. Photomicrograph by Taku Okada; field of view 8.10 mm.

Interesting Metallic Platelets in Morganite

Reflective thin films were observed in an 18.67 ct pinkish orange morganite (figure 7). Since morganite's subtle color is caused by traces of manganese, these films may have been natural metallic manganese, similar to the skeletal formations of natural metallic copper in Paraíba tourmaline (Summer 2023 *G&G* Micro-World, p. 229). Like many gems found in pegmatites (such as aquamarine, another beryl variety), morganite can form large crystals and usually does not contain eye-visible inclusions. Pegmatite is an igneous rock formed deep in the earth's crust from the fluids that remain after solidified crystals break away from hot granitic magma as it gradually cools. The fluids have low viscosity and contain many elements that are important components for gems. The elements can move quickly in the fluids, so pegmatites contain many large and clean gems.

At first glance, this morganite appeared to be eye clean. However, when the planar thin films aligned between the microscope objective lens and the fiber-optic light satisfied a total reflection condition, the skeletal platelets appeared. When examining gemstones through a microscope, gemologists are often surprised to discover unexpected inclusions.

Taku Okada
GIA, Tokyo

Written Characters in Black Opal

Opal sometimes contains play-of-color patches with unique and attractive patterns, such as an impressive 8.13 ct black opal measuring 15.93 × 10.88 × 7.52 mm recently examined by the author. Based on its gemological properties, microscopic observations, and strong phosphorescence to long-wave ultraviolet light, the stone was natural opal with no signs of assembled features.

Interestingly, blade-like play-of-color patches with a striking brushstroke pattern were present within the common (nonphenomenal) opal area on the back side (figure 8). Some of the patches intersected at nearly 90° and resembled Chinese characters. This pattern is rarely seen in precious opal and is known as a "Chinese writing pattern" in the trade. On the other side of the stone, the play-of-color formed another unique pattern, this one resembling the Latin letter "A" (figure 9). Brightfield il-

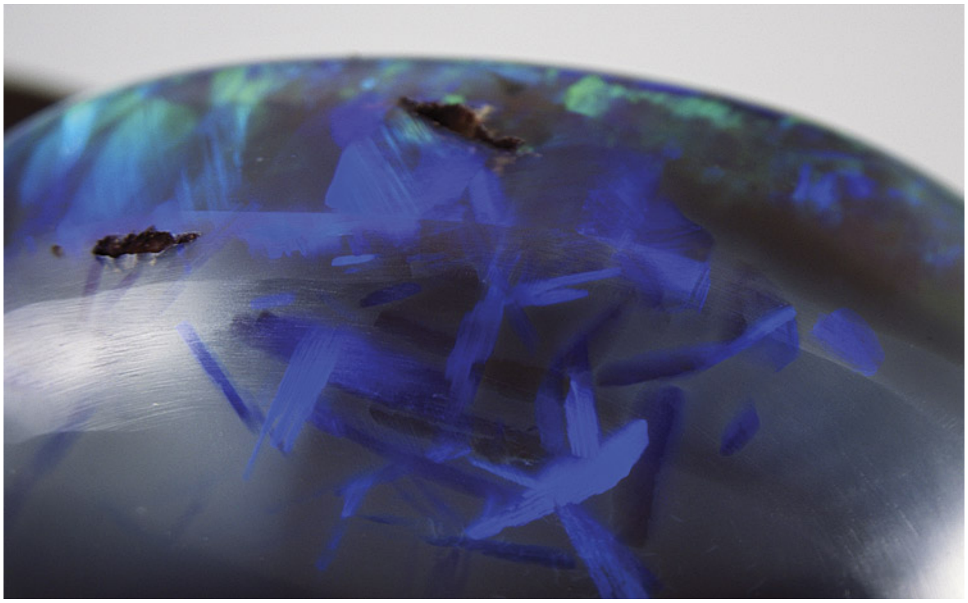

Figure 8. A pattern resembling Chinese characters in an 8.13 ct black opal. Note that blade-like play-of-color patches exist within common opal. Photomicrograph by Makoto Miura; field of view 12.06 mm.

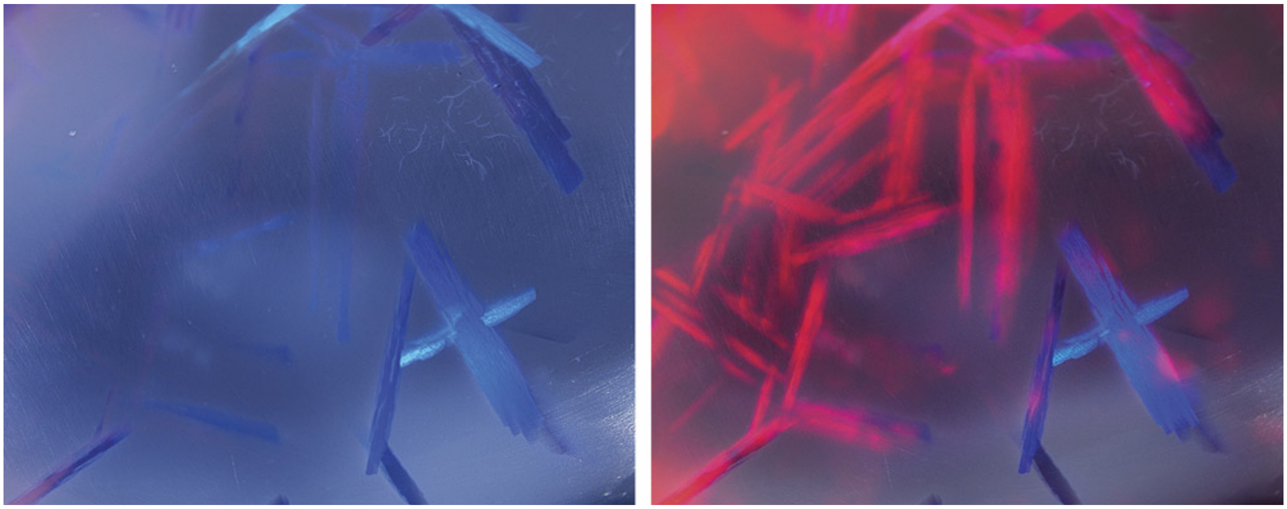

Figure 9. A pattern resembling the letter "A" was observed on the other side of the black opal. The left image was taken using fiber-optic illumination with a white diffuser, while the right image used a combination of fiber-optic and brightfield illumination. Photomicrographs by Makoto Miura; field of view 2.96 mm.

lumination revealed that these blade-like play-of-color patches were also contained within the common opal area (figure 9, right). The combination of reflected light with fiber-optic illumination and brightfield illumination caused the patterns to look like a natural inscription within precious opal. It is interesting to consider how play-of-color patches and common opal were both created from hydrothermal fluids.

Makoto Miura
GIA, Tokyo

"Frozen River" on the Surface of an *Atrina* Pearl

The author recently examined a group of dark-colored pearls reportedly produced by an *Atrina*-species mollusk from the Pinnidae family (known as "pen pearls"). The majority of pen pearls have nacreous surfaces and display characteristic linear-looking nacre under high magnification (N. Sturman et al., "Observations on pearls reportedly from the Pinnidae family (pen pearls)," Fall 2014 *G&G*, pp. 202–215). Some of the pearls examined in the group exhibited a near-colorless translucent frosted surface on certain areas. This structure is seldom observed on nacreous pearls from other mollusk species. Raman spectroscopy using 514 nm laser excitation revealed that the areas were composed of aragonite. A 0.62 ct dark brown pearl displayed the most interesting surface, composed of layered aragonite crystals in various sizes, resembling ice on a frozen river (figure 10).

Kwanreun Lawanwong
GIA, Bangkok

Anatase in Brazilian Quartz

Anatase crystals in quartz can be a fascinating sight. Their dipyramidal or acute pyramidal crystallographic habit and adamantine shine often create interference colors due to the inclusion's high refractive index compared to the host crystal. One notable example was recently observed in a 27.21 ct Brazilian quartz cabochon (figure 11). The blue interference color visible from every angle was remarkable, since isolated anatase crystals typically have a black, brown, reddish brown, or brownish yellow color. Anatase (along with

Figure 10. A "frozen river" caused by an overlay of aragonite crystals on the surface of a nacreous pearl from an Atrina mollusk. Photomicrograph by Kwanreun Lawanwong; field of view 1.80 mm.

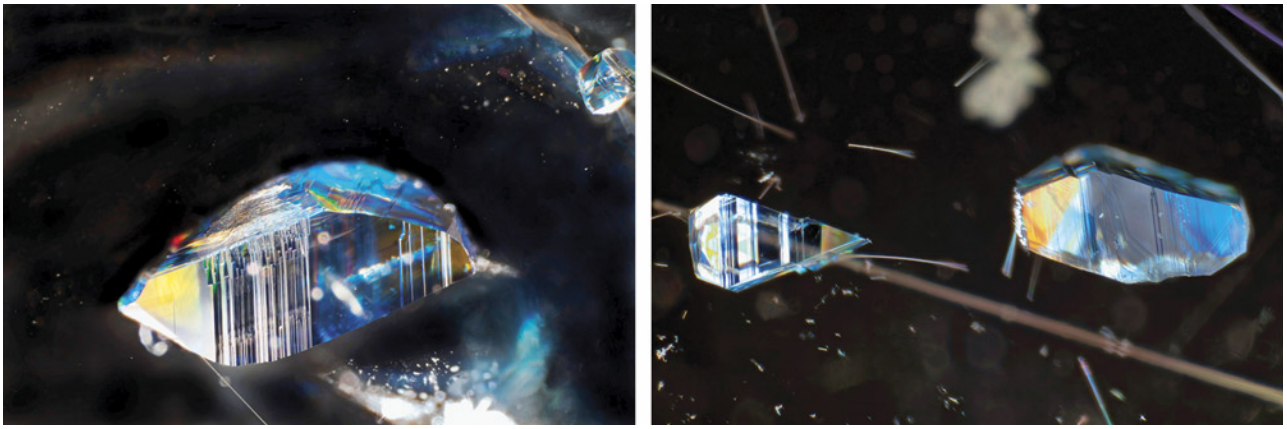

Figure 11. Left: This anatase crystal with a well-formed tetragonal habit in a Brazilian quartz shows adamantine luster and diffraction colors due to its high refractive index. Right: The crystals of anatase, one of the polymorphic forms of titanium dioxide, are associated with rutile needles shown in darkfield and oblique fiber-optic illumination. Photomicrographs by Liviano Soprani; field of view 1.8 mm.

rutile, brookite, akaogiite, and riesite) is one of the five polymorphic forms of titanium dioxide (TiO_2) found in nature and is almost always associated with rutile as an inclusion in quartz. However, rutile forms at high pressures and temperatures and is often found in igneous and metamorphic rocks, while anatase forms in hydrothermal phases at pressures and temperatures much lower than rutile (D.A.H. Hanaor and C.S. Sorrell, "Review of the anatase to rutile phase transformation," *Journal of Materials Science*, Vol. 46, 2011, pp. 855–874). The disordered orientation of the acicular rutile crystals and the relative distance from the euhedral anatase crystals suggest the protogenetic formation of rutile and the formation of anatase in a subsequent hydrothermal phase.

Liviano Soprani
Ravenna, Italy

Hedenbergite in Quartz

Quartz is known to host a wide variety of inclusions. In a large group of polished quartz samples recently examined, the authors observed groups of dark crystal inclusions that took the shape of a sea urchin. In some samples where the dark crystal reached the surface, the cross section of the crystal habit was rhomboid, indicating they were monoclinic. Under magnification, the inclusions were transparent to translucent and dark green to brownish green (figure 12). Raman spectra identified the inclusions as hedenbergite, confirmed by comparison with the RRUFF database. Hedenbergite, $CaFe^{2+}Si_2O_6$, is a member of the pyroxene group. Based on previous work (Winter 2023 *G&G* Micro-World, pp. 503–504), we realized that the material known in the trade as "urchin quartz" might contain inclusions other than hollandite.

Figure 12. These dark green acicular aggregates in quartz were identified as hedenbergite. Photomicrographs by Liyan He; fields of view 9.20 mm (left) and 8.30 mm (right).

Figure 13. A sphalerite crystal in quartz. Photomicrograph by Liyan He; field of view 11.40 mm.

Figure 14. Weighing between 3.07 and 10.53 ct, these four small transparent colorless spheres of rock crystal quartz each hosted an opaque black inclusion (one sphere contained two inclusions). Photo by Annie Haynes.

In the samples that contained hedenbergite, we also identified a translucent yellow to light brown inclusion in these samples (figure 13). The crystal was identified by Raman spectroscopy as sphalerite, consistent with the RRUFF database.

Liyan He
Guangdong Gemstones & Precious Metals Testing Center
Guangzhou, China
Wingtak Lui
Min De Minerals & Gem Research Co., Ltd.
Nanjing, China

"Rose" Quartz

The authors recently examined four small marble-sized colorless polished spheres of rock crystal quartz. Each sphere hosted a tiny, opaque black inclusion (figure 14), a feature that was the subject of this entry. The spheres weighed between 3.07 and 10.53 ct, with corresponding measurements ranging from 7.61 to 11.49 mm. They were supplied by Luciana Barbosa of the Gemological Center in Asheville, North Carolina, and were reported to have come from Zambia.

As shown in figure 15, microscopic observation of the four polished spheres revealed that the opaque black inclu-

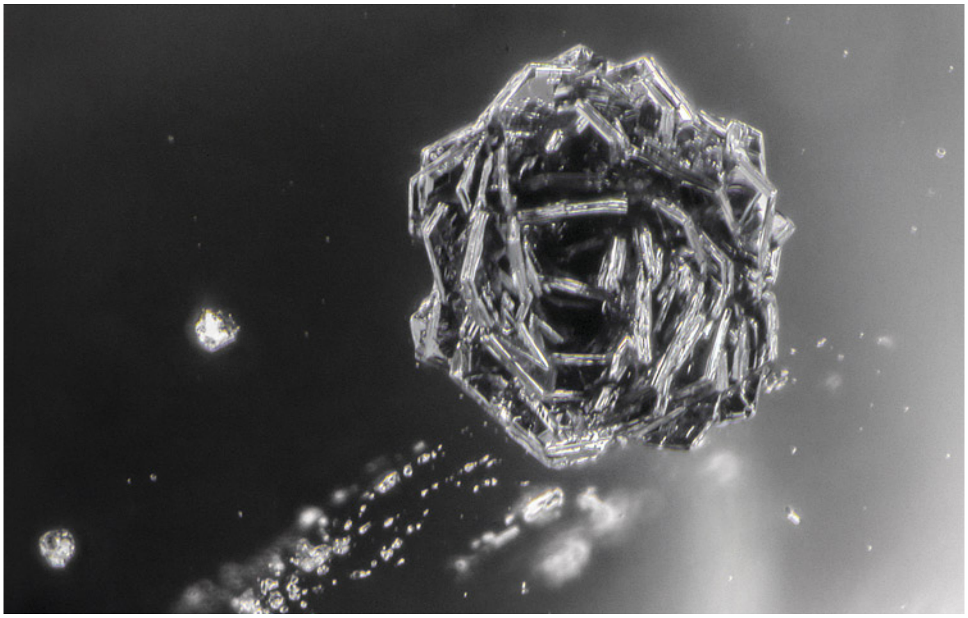

Figure 15. This opaque black hematite inclusion in one of the quartz spheres is composed of numerous platy inclusions arranged in the shape of a rose. Photomicrograph by Nathan Renfro; field of view 2.40 mm.

sions were actually composed of numerous platy euhedral crystals arranged in the shape of a rose. These inclusions were identified by Raman analysis as hematite. The roses' positioning along growth planes in the spheres shows that the hematite inclusions are syngenetic with their rock crystal quartz hosts.

John I. Koivula, Nathan Renfro, and Maxwell Hain
GIA, Carlsbad

Rainbow-Colored Partially Healed Fissure in Blue Sapphire

Thin-film interference caused by inclusions occasionally produces attractive scenes. In a 4.13 ct untreated blue sapphire from Sri Lanka, a partially healed fissure displayed vibrant iridescent colors due to this phenomenon under fiber-optic illumination (figure 16).

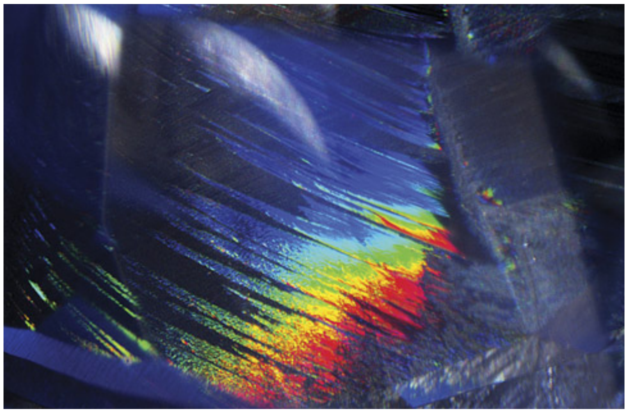

Figure 16. Iridescent partially healed fissure observed in a 4.13 ct blue sapphire. Photomicrograph by Kanako Otsuka; field of view 2.12 mm.

Healed fissures, known as fingerprints or feathers in gemology, are created by the natural healing process of surface-reaching fractures in the host gem material. Generally, when fluid involved in the healing process is trapped, fluid-filled inclusions such as negative crystals or thin internal fissures are formed (e.g., E. Roedder, "Ancient fluids in crystals," *Scientific American*, Vol. 207, No. 4, 1962, pp. 38–47). When the trapped fluid is thin enough, the difference in refractive index between the fluid and the host material causes thin-film interference and may result in vibrant colors.

Healed fissures are common in various gemstones and sometimes display iridescence (e.g., Spring 2021 *G&G* Micro-World, p. 68; Summer 2023 *G&G* Micro-World, p. 227). In this sapphire, the combination of a brushstroke-like texture and rainbow colors in a gradation from red to indigo produces a spectacular scene.

Kanako Otsuka
GIA, Tokyo

Rare Musgravite Crystal in Green Sapphire

A 6.59 ct faceted green stone, identified by standard gemological testing as sapphire, contained various inclusions such as needles, fingerprints, and a cluster of colorless and green crystals. The colorless crystals were identified as feldspar, and a transparent green prism-like crystal breaking the surface of the sapphire (figure 17) was confirmed as musgravite (magnesiotaaffeite) by Raman spectroscopy.

Musgravite, $(MgFe,Zn)_2BeAl_6O_{12}$, crystallizes in the trigonal system and is part of the taaffeite group. Musgravite

Figure 17. Green musgravite crystals observed in a faceted green sapphire. Darkfield and fiber-optic illumination. Photomicrograph by Titapa Tanawansombat; field of view 1.8 mm.

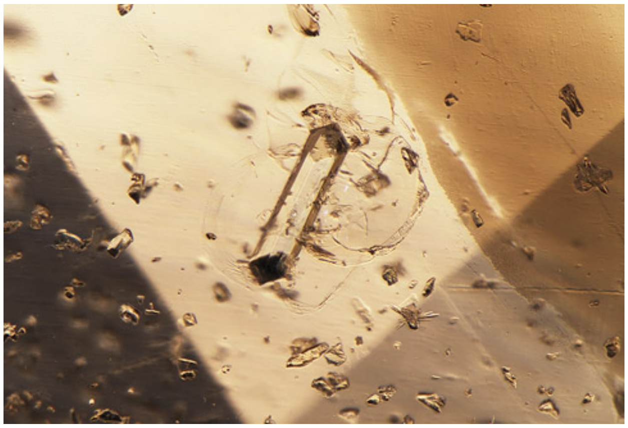

Figure 18. Prismatic diopside among a sea of diopside and danburite crystals in a rare orange sodalite. Photomicrograph by Joseph Hukins; field of view 1.56 mm.

Figure 19. The 2.83 ct orange sodalite exhibited short-lived tenebrescence after brief exposure to long-wave UV. Photos by Towfiq Ahmed.

is rarely found as an inclusion in corundum, making these crystals a unique observation for gemologists.

Titapa Tanawansombat
GIA, Bangkok

Diopside and Danburite in Rare Orange Sodalite

A rare orange sodalite was recently examined by the authors. The 2.83 ct stone, identified by Raman spectroscopy along with standard gemological testing, revealed a variety of unique inclusions upon microscopic examination.

A field of transparent crystals identified by Raman was found to consist of mostly diopside with a few intermixed danburites, which can be seen surrounding a larger euhedral, prismatic diopside in figure 18. Transparent facet-grade orange sodalite is uncommon, both for its color and high diaphaneity, as the complex tectosilicate sodalite is typically blue or colorless. The stone exhibited a short-lived reversible photochromism known as tenebrescence, changing from orange to pink after brief exposure to long-wave ultraviolet light and reverting to its stable orange color in a matter of minutes after removal of the long-wave UV (figure 19). Similar material reportedly from Afghanistan has been previously documented (M. Krzemnicki and C. Rochd, "Orange sodalite from Badakhshan, Afghanistan," *Journal of Gemmology*, Vol. 39, No. 1, 2024, pp. 20–22).

To the authors' knowledge, this is the first documented instance of diopside and danburite recorded as

Figure 20. This 46.32 ct color-change magnesioaxinite crystal from Tanzania contained interesting negative crystals. Photos by Rhonda Wilson; courtesy of Bill Vance.

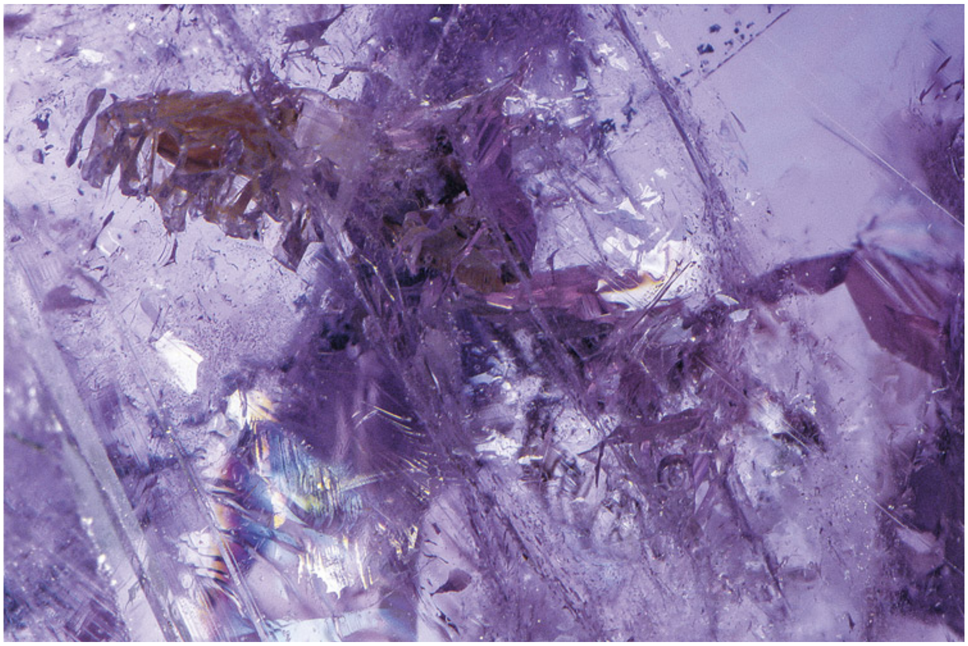

Figure 21. The irregular negative crystals in the magnesioaxinite crystal are filled with either epigenetic brown residue or liquid and gas components. Photomicrograph by Nathan Renfro; field of view 7.19 mm. Courtesy of Bill Vance.

inclusions together in sodalite and the second instance of prismatic transparent diopside (F. Blumentritt et al., "Properties and coloration of orange hackmanite from Afghanistan," *Journal of Gemmology*, Vol. 39, No. 2, 2024, pp. 160–168).

Joseph Hukins and Tyler Smith
GIA, New York

Quarterly Crystal: Magnesioaxinite

Gem-quality magnesioaxinite was first reported in 1975 (A. Jobbins et al., "Magnesioaxinite, A new mineral found as a blue gemstone from Tanzania," *Journal of Gemmology*, Vol. 14, No. 8, 1975, pp. 368–375). That report also noted a blue-to-violet color change. Magnesioaxinite is a member of the axinite group with the chemical formula $Ca_2MgAl_2BSi_4O_{15}OH$.

The authors recently examined a beautiful twinned 46.32 ct crystal with a blade-like morphology and an interesting inclusion scene (figure 20). A relatively large complex negative crystal containing a light brown epigenetic residue was observed, along with another negative crystal filled with a liquid and a mobile gas bubble (figure 21). Numerous colorful iridescent cracks were scattered throughout the crystal as well.

Magnesioaxinite is a desirable collector stone but quite scarce in the gem trade. It is also sometimes sold under the trade name "Vanceite" after gem dealer Bill Vance, who has been fascinated by this rare material since 2005, when he first encountered it mixed in a parcel of tanzanite. In addition to the color-change variety examined here, magnesioaxinate can also be pink or orange or zoned as a mixture of these colors.

Nathan Renfro and John I. Koivula