G&G Micro-World

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Cleavage System in Pink Diamond

A 0.29 ct natural Fancy Intense purplish pink diamond with a microscopically interesting geometric feature (figure 1) was recently examined at GIA's Carlsbad laboratory. A network of planar cracks, oriented in three octahedral directions, was observed at the surface of a pavilion facet (figure 2). These linear cleavage cracks were caused by localized strain on an octahedral plane.

The octahedral plane in diamond has the weakest atomic bonding, which means that when a diamond is strained, this is the direction that will be most affected. This stone offers the perfect example of strain products in pink diamond. The purplish pink color results from plastic deformation along octahedral planes. Also present along the octahedral plane is a zone where the strain was so great that it was relieved by cracking, creating the cleavage network seen in figures 2 and 3.

The cleavage network in this diamond is the most aesthetic one encountered by the author to date due to its finely textured geometric pattern. Interestingly, the clue to

Figure 1. This Fancy Intense purplish pink 0.29 ct diamond was host to a complex cleavage network. Photo by Robison McMurtry.

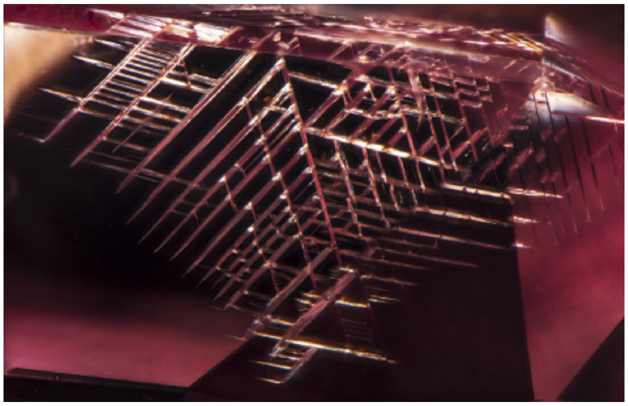

Figure 2. Three directions of cleavage along octahedral planes are seen in this pink diamond. Photomicrograph by Jonathan Muyal; field of view 1.22 mm.

About the banner: Modified Rhineberg illumination provides high contrast to etch features on the prism face of a beryl crystal. Photomicrograph by Nathan Renfro; field of view 2.86 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.

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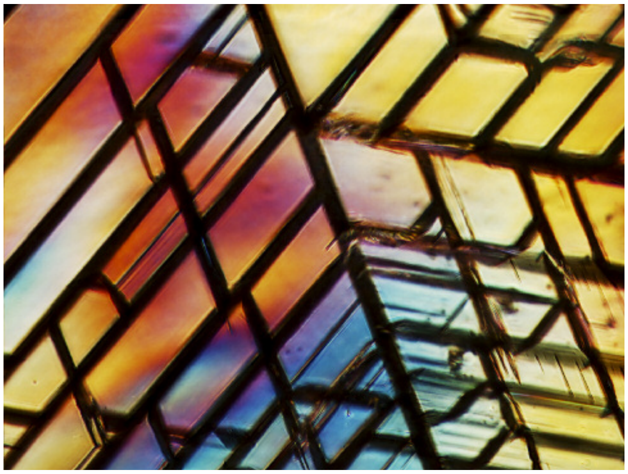


Figure 3. Between crossed polars the diamond shows high-order interference colors consistent with the strain causing the cleavage network along the octahedral planes. Photomicrograph by Jonathan Muyal; field of view 0.62 mm.

the planar cleavage network lies in the bodycolor of the stone, which indicates significant strain. This high-order strain is easily revealed between crossed polars. If a cleavage network is present in a diamond such as this, it may have a strain-induced bodycolor as well.

Jonathan Muyal
GIA, Carlsbad

Rough Diamond Fragment with a Large Green Cleavage Surface

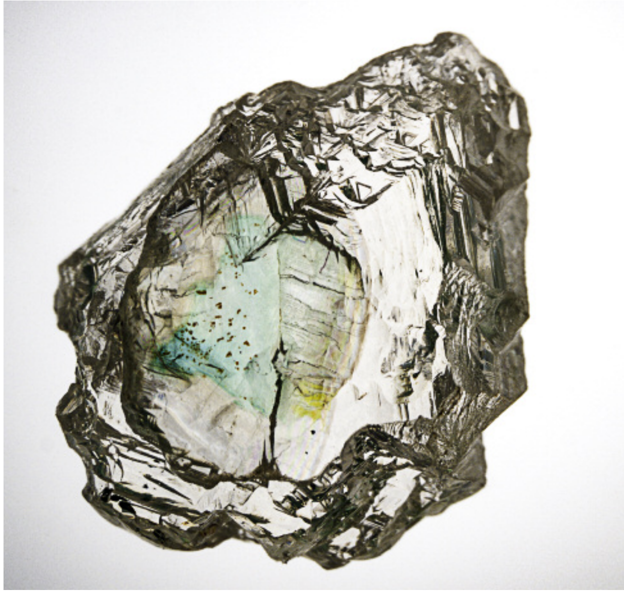
A colorless 2.02 ct flattened diamond crystal fragment (figure 4), from Rowan Beach of San Francisco, was examined at GIA's Carlsbad lab. The fragment exhibited a large bluish green internal surface that was readily visible without magnification. Initially thought to be a colorful mineral inclusion, it proved to be a radiation-induced coloration along the internal surface. When a diamond is irradiated (during laboratory color treatment or occasionally in nature), carbon atoms are removed from their normal position in the diamond lattice; this creates what scientists call the "GR1" optical defect (i.e., a vacant atom position in the lattice). The presence of this defect causes the diamond to selectively absorb light toward the red end of the visible spectrum, while the remaining portions are transmitted through the diamond and, when recombined, seen as a green or bluish green color. The GR1 optical defect can be removed in the lab by heating the diamond to over 600°C; this heating changes the green color to yellowish brown. The added energy allows a carbon atom to again occupy the vacant lattice position.

Green or bluish green color in diamonds is most often the result of exposure to a source of radiation in a geologic environment near the earth's surface. The source of exposure could be a nearby grain of a radioactive mineral that gives rise to a small "radiation spot" on the outer surface. Conversely, the source could be a radioactive solution that was able to penetrate surface-reaching cleavages in the diamond. In both cases, the source produced alpha-particle radiation, which has a limited penetrating distance in diamond. As a result, the radiation spot or stain is confined to a zone close to the radioactive material. Such radiation stains are not uncommon in diamonds, though they are often removed by the faceting process.

The presence of a large green internal radiation stain indicates that this diamond was irradiated in a near-surface geological environment where temperatures high enough to modify the GR1 were unlikely. This means that the irradiation took place in the crust after the diamond was transported up from the mantle by the kimberlite magma eruption. Although the geographic origin of this rough diamond is uncertain, it is one of the more intriguing examples of a natural "radiation-stained" diamond we have seen.

James Shigley
GIA, Carlsbad

Figure 4. This 2.02 ct rough diamond displays prominent green coloration along an internal cleavage surface. Such coloration is thought to result from the presence of a natural radioactive solution within the cleavage. Photo by James Shigley.



Blue Gahnite Inclusions in Cat's-Eye Heliodor

Four golden oval cabochons (figure 5) were submitted to the Carlsbad laboratory by L. Allen Brown (All That Glitters, Methuen, Massachusetts) for scientific examination. Standard gemological testing revealed that the stones were beryl. Under incandescent fiber-optic illumination, the stones showed a very sharp cat's eye, caused by growth

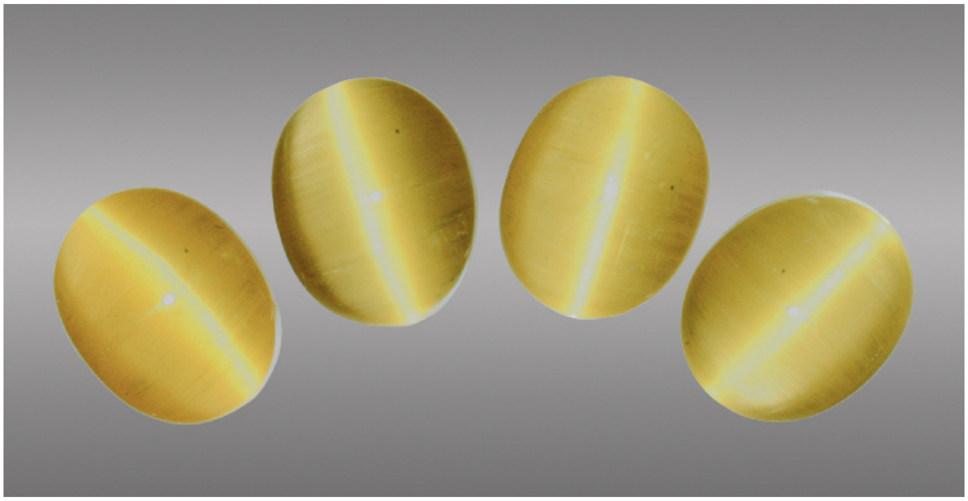
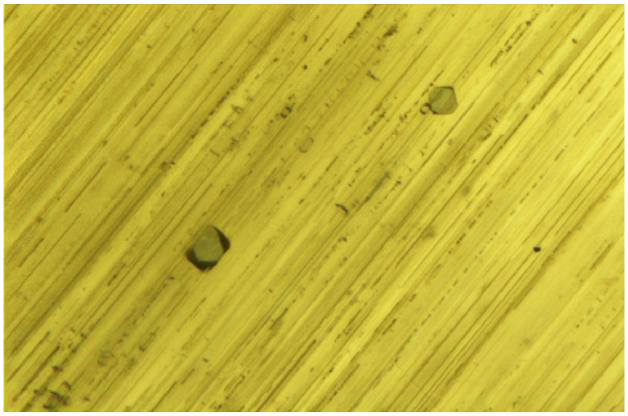


Figure 5. These four heliodor cabochons display sharp eyes under incandescent fiber-optic illumination. Photo by C.D. Mengason.

tubes and fine needle-like inclusions oriented parallel to the c-axis. Under magnification, blue crystals with octahedral morphology (figure 6) were the most distinctive internal characteristic.

Raman microspectroscopy was used to identify the blue octahedral inclusions as gahnite, a zinc-rich end member of the spinel group with the general formula $ZnAl_2O_4$. It occurs most commonly as an accessory mineral in granitic pegmatites, usually associated with almandine-spessartine garnet, muscovite, beryl, tourmaline, and nigerite (D.R. Soares, et al., "Chemical composition of gahnite and degree of pegmatitic fractionation in the Borborema Pegmatitic Province, northeastern Brazil," *Anais da Academia Brasileira de Ciências*, 2007, Vol. 79, No. 3, pp. 395-404). According to Brown, the stones were purchased in Tucson in 2010 and were represented as being from Brazil. These are the first beryls with gahnite inclusions that GIA has examined to date. Since gahnite is a diagnostic inclusion in sapphires from Sri Lanka (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Verlag, Basel, Switzerland, 2008, p. 290), detailed study of gahnite may also provide some indication of the geographic origin of heliodor.

Figure 6. Diffused fiber-optic illumination reveals well-formed blue octahedral crystals in addition to the hollow tubes that cause the chatoyancy. The black needle-like inclusions may be hematite. Photomicrograph by Nathan Renfro; field of view 1.10 mm.



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Pezzottaite Debuts as the Newest Trapiche Gem Mineral

Since the first enigmatic six-spoked emeralds were sent to GIA in the mid-1960s for analysis (H.L. McKague, "Trapiche emeralds from Colombia," Fall 1964 *G&G*, pp. 210–213, 223), the family of trapiche-type gem minerals has grown to include a variety of species and morphologies. One of the latest mineral varieties to exhibit the rare trapiche form is a relatively new and rare mineral itself: pezzottaite.

Following its appearance at the 2003 gem shows in Tucson, pezzottaite has quickly become an item coveted by gem and mineral collectors around the world. A member of the beryl group and with trigonal symmetry (the beryl *species* has hexagonal symmetry), it was approved by the International Mineralogical Association in September 2003 as a unique species and named after mineralogist Dr. Frederico Pezzotta (see B.M. Laurs et al., "Pezzottaite from Ambatovita, Madagascar: A new gem mineral," Winter 2003 *G&G*, pp. 284–301).

In 2004, while working in the gem markets of Mae Sai and Mae Sot along the border of Thailand and Myanmar, Elaine Rohrbach of Gem-Fare obtained a small collection of pale pink trapiche crystals and crystal fragments reported to be of Burmese origin. Laboratory analysis later proved these crystals to be the cesium-containing mineral pezzottaite (previously confirmed localities include Madagascar and Afghanistan).

A doubly terminated, well-developed crystal obtained by one of the authors (JIK) exhibits the tabular prismatic habit characteristic of the species, but with a complete six-

Figure 7. As viewed through the pinacoid face, strong oblique fiber-optic lighting illuminates the six-legged trapiche structure emanating from the c-axis of this doubly terminated 2.33 ct pezzottaite crystal. Photo by Kevin Schumacher.

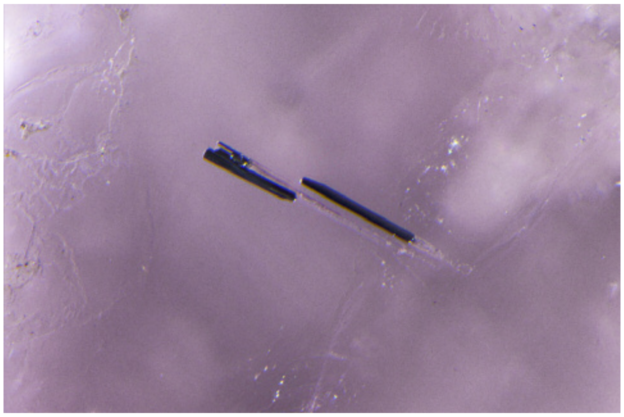

Figure 9. Eye-visible dark needles were seen throughout the pezzottaite crystal with diffused transmitted illumination. Despite a clear Raman signal, the features could not be conclusively identified. Photomicrograph by Nathan Renfro; field of view 1.10 mm.

spoke trapiche structure that is clearly visible in both reflected and transmitted light (figure 7). Another doubly terminated crystal obtained by author EAS from the same parcel shows secondary crystals growing out of each pinacoid face, each of which are also trapiche crystals (figure 8). Similar to trapiche crystals of other mineral species, each of the spokes radiates from the central c-axis toward the prism faces and in a plane parallel to the basal pinacoid. Exploring the former crystal's inner world revealed not only the details of the white spokes and a spray of golden brown needles and eye-visible black needles, but also a delightful surprise: minute euhedral blue crystals (figures 9 and 10). Unfortunately, the black needles were not identifiable despite their distinct Raman spectrum. Due to their depth within the host, the brown needles and blue crystals remain mysteries as well. Let this be a lesson that nondestructive

Figure 8. Another well-developed, doubly terminated pezzottaite crystal from the same locality, weighing 6.17 ct and measuring 11.19 × 10.71 × 8.61 mm, has separate crystals growing at random angles on each pinacoid face. Each of these smaller crystals also exhibits trapiche growth. The white trapiche growth reaches all six prism faces in both of the tabular crystals, as well as those faces on the secondary growth crystals. Photo by Elise A. Skalwold.

Figure 10. Using diffused transmitted and oblique fiber-optic illumination, a golden-brown spray of needles is shown deep in the crystal, along with a bright blue crystal to its right. Their depth precluded analysis by Raman spectroscopy. Photomicrograph by Nathan Renfro; field of view 0.91 mm.

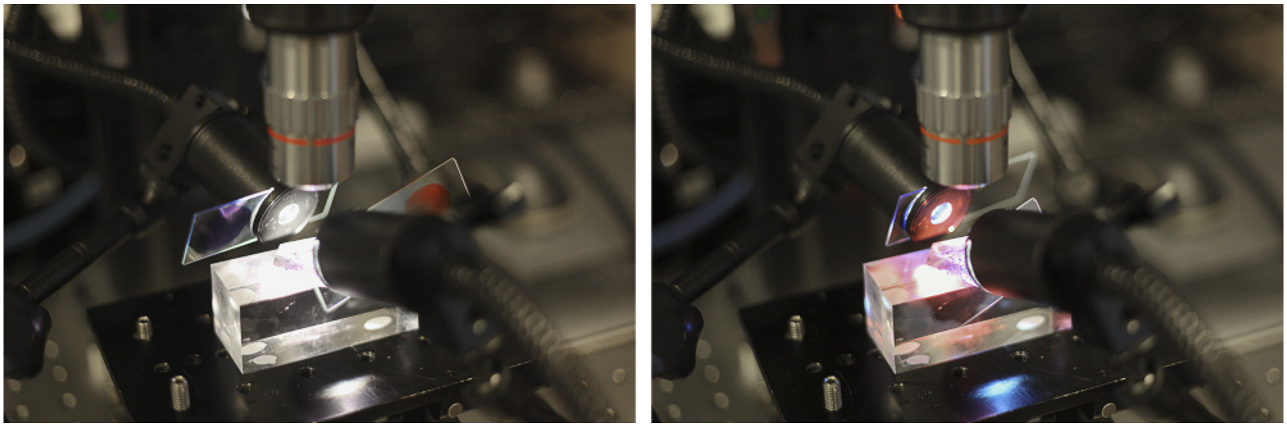

Figure 11. In one method of applying Rheinberg-type illumination, glass slides are fitted to the end of two fiber-optic illuminators and painted with red and blue ink (left) to create a filter that is easily positioned by moving the colored portion of the glass slide into the light path (right). Photos by Danny J. Sanchez.

testing cannot always provide answers, but we can be content with exploring the beauty of the micro-world while leaving some mysteries for the future.

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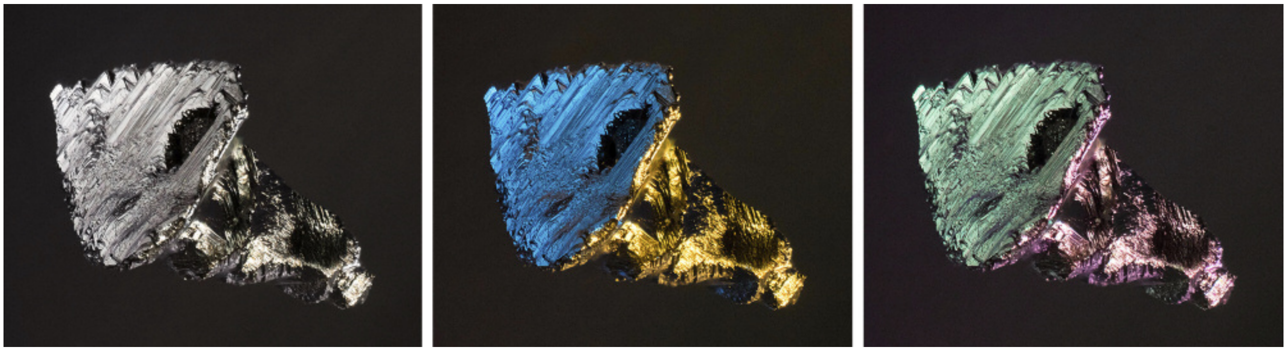
Modified Rheinberg Illumination

Lighting control is one of the most important considerations for maximizing the use of the gemological microscope; with greater control over illumination sources, more information may be gathered from observing a specimen. An interesting technique that gives the microscopist another lighting tool is modified Rheinberg illumination, also known as differential color illumination (M. Pluta, *Advanced Light Microscopy: Specialized Methods*, Vol. 2, PWN-Polish Scientific Publishers, Warsaw, 1989, pp. 113). This method, as modified for gemological microscopy, employs the use of a contrasting color filter between each illumination source and the subject (figure 11) to achieve an "optical staining" effect (figure 12). When viewing crystallographically aligned subjects such as negative crystals or inclusions with well-defined, reflective crystal faces, each illumination source highlights areas that have the same crystallographic orientation (figure 13). This provides dramatic false-color contrast to an otherwise low-contrast

Figure 12. This silvery metal sulfide inclusion in fluorite shows angular crystal faces, but the low contrast in the image on the left makes it difficult to resolve the orientation of the faces from different sections of the inclusion. Rheinberg illumination provides stark contrast between differently oriented regions by using two colored illumination sources that reflect their independent color off of crystallographically aligned crystal faces, as seen in the center and right images. This allows the microscopist to easily observe the different orientations of the crystal faces in the metal sulfide inclusion, as evidenced by the dramatic boundary of the two contrasting colors. Photomicrographs by Danny J. Sanchez; field of view 1.66 mm.



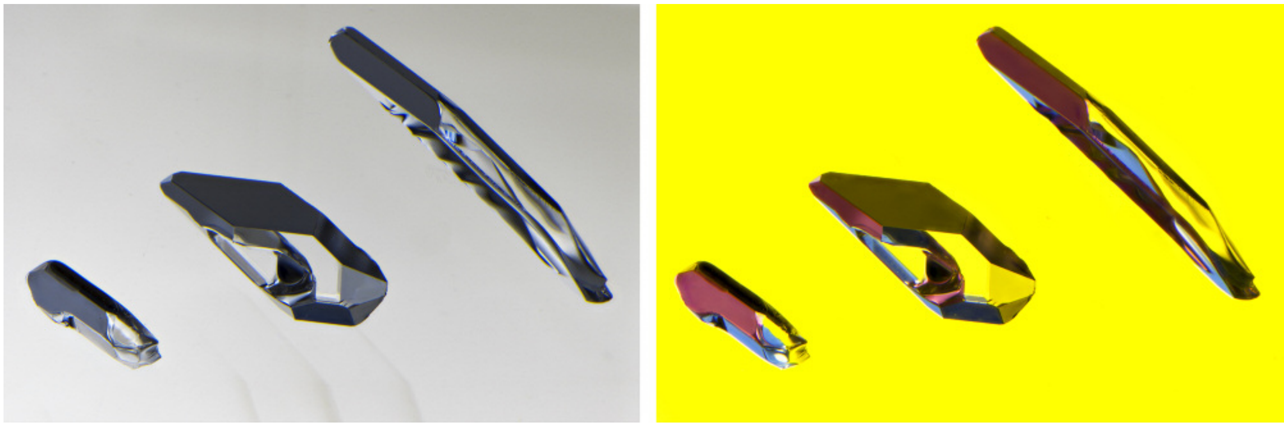


Figure 13. With modified Rheinberg illumination to impart contrasting color on some of the crystal faces, the negative crystals in the rock crystal quartz (left) prove to be crystallographically aligned (right). Photomicrographs by Nathan Renfro; field of view 7.34 mm.

subject. This enhanced contrast makes it easier to observe the relationship between areas in an inclusion scene with identical and also differing crystallographic orientations.

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Glassy Melt Inclusions in Sapphires from Montana

Two-phase inclusions are common in many sapphires. Physical and chemical analysis of the gas and liquid phases present in these inclusions can shed light on the formation conditions of alluvial sapphires, even in the absence of evidence of source rock lithology. We report here some initial observations of a different type of two-phase inclusion, seen in alluvial sapphires from the Rock Creek and Missouri River deposits in the state of Montana.

At first glance, these inclusions appeared to be ordinary gas-liquid inclusions (figure 14, left); however, polishing through the inclusions demonstrated that the "liquid" component was actually a glassy solid. The identification of the solid as a glass rested with the phase's optically isotropic nature and the lack of an identifiable Raman spectroscopic signal attributable to any crystalline phase. Glassy melt inclusions in Montana sapphires were previously documented by John Koivula (R.W. Hughes, *Ruby & Sapphire*, RWH Publishing, Boulder, Colorado, 2007, pp. 468–469). Electron microprobe analysis (EPMA) of glass inclusions from several samples showed them to be dacitic to trachydacitic in composition. In this sense the inclusions are ordinary two-phase inclusions in which the original liquid phase was a silicic magma that quenched to form a silicate glass. The gas phase is presumed to have originally been dissolved in the silicate magma. Later exsolution produced a separate gas phase as volatile solubility

Figure 14. Left: A two-phase glassy melt and gas inclusion and a glass-filled discoid fracture in a sapphire from the Rock Creek deposit in Montana. Center: A two-phase glassy melt and gas inclusion and a glass-filled discoid fracture in a sapphire from the Rock Creek deposit. Right: A two-phase glassy melt and gas inclusion, in a sapphire also from the Missouri River, showing the surrounding discoid fracture. This fracture presumably filled with a silicate liquid and partially healed, leaving an impression in some places of the corundum host's trigonal crystallographic orientation. Photomicrographs by Aaron Palke; field of view 1.24 mm (left) and 0.62 mm (center and right).

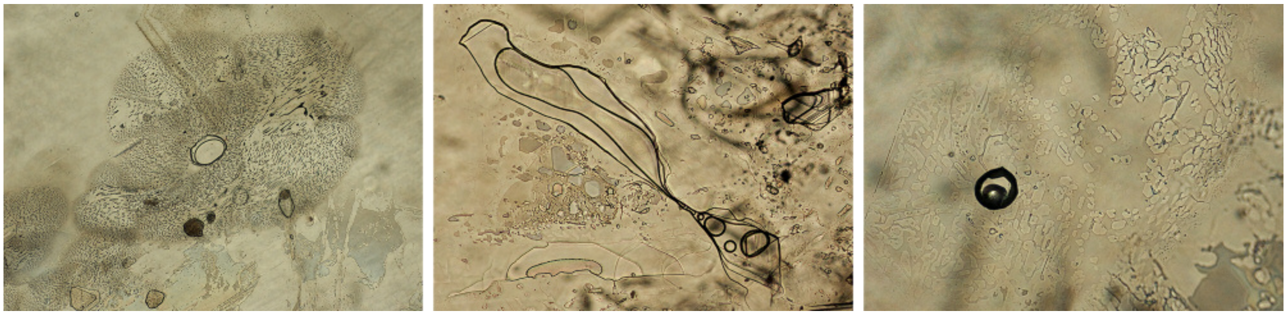

Figure 15. This 4.71 ct Brazilian colorless topaz hosts a cluster of hexagonal molybdenite crystals. Photo by Kevin Schumacher.

in the magma decreased due to falling pressure and/or temperature. Volatile exsolution likely also led to the discoid fractures commonly seen around melt inclusions, which are filled with silicate liquid and/or the volatiles themselves (again, see figure 14, left). Figure 14 (center) captures a snapshot of the process of volatile exsolution and the "bursting" of the two-phase inclusions, in which multiple gas bubbles seem to have precipitated instantaneously as the inclusion exploded out into the surrounding corundum. Due to the high relief of the silicate glass, these discoid fractures often have a "flux"-like appearance. In some cases, the fractures seem to have partially healed, leaving hexagonal geometric patterns as evidence of the crystallographic orientation of the sapphire host (figure 14, right). Further work is being carried out to characterize these inclusions and to decipher the story they have to tell about the genesis of alluvial Montana sapphires.

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Molybdenite in Topaz

A photogenic cluster of hexagonal molybdenite crystals (MoS_2) was recently discovered in a 4.71 ct transparent colorless hexagonal step-cut topaz (figure 15). The topaz host was identified using traditional gemological testing, and the molybdenite cluster (figure 16) was identified through its metallic luster, morphology, and the presence of molybdenum, which was detected using focused EDXRF analysis.

This gem, which came from Luciana Barbosa of the Gemological Center in Ashville, North Carolina, is from Seridó, Rio Grande do Norte, Brazil. We have never seen this inclusion-host association before, and it is not previously recorded in the literature. This elegant gem is a perfect micromount of molybdenite in a faceted showcase.

John I. Koivula

Figure 16. It was a surprise to discover molybdenite crystal inclusions in topaz. Shadowed lighting reveals iridescence and surface details on the cluster, which measures 2.82 mm in length. Photomicrograph by Nathan Renfro.