



G&G

# Micro-World

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## Thin-Film Fluid Inclusions in Aquamarine

The author recently examined a faceted aquamarine from Brazil that showed two-phase (liquid and gas) thin-film inclusions of different sizes and shapes. When observed using oblique fiber-optic illumination, the inclusions revealed a kaleidoscopic play of interference colors. The most diagnostic beryl inclusions, yet barely noticeable in brightfield illumination are ultra-thin-film fluid inclusions. The planar surface of these inclusions is oriented parallel to the basal pinacoid of their host (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Volume 2, Opinio Publishers, Basel, Switzerland, 2005, pp. 312–314). The presence of the bright iridescent thin-film fluid inclusions resembles colorful rainbow sprinkles.

Muzdareefah Thudsanapbunya  
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## Chromite in Emerald

The beryl species is known for its different colored varieties, such as pink morganite and blue aquamarine, which are directly influenced by the chemical composition of the stone. The emerald variety is colored green by the trace elements chromium and/or vanadium. Beryl, a beryllium aluminum cyclosilicate, has a crystal structure that readily integrates foreign elements. When an elevated amount of chromium is present in the growth environment, a beryl crystal has a chance of becoming an emerald. One inclusion that has been well documented in emeralds is the mineral chromite, an iron chromium oxide. Specifically,

*About the banner: A blue color filter using transmitted light provides high contrast to the golden yellow rutile needles in this rock crystal quartz. Photomicrograph by Nathan Renfro; field of view 7.61 mm.*

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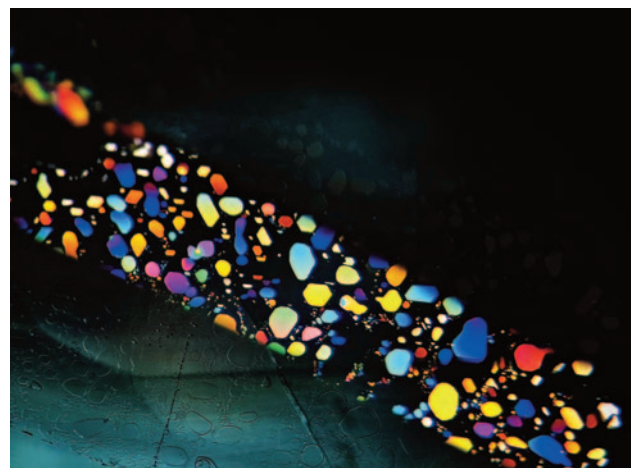


Figure 1. Thin-film fluid inclusions oriented perpendicular to the c-axis of this aquamarine display interference colors when viewed using oblique fiber-optic illumination. Photomicrograph by Muzdareefah Thudsanapbunya; field of view 2.79 mm.

this mineral is a source of chromium for some Brazilian emeralds.

The author recently examined a matching jewelry set consisting of a bracelet and ring that were decorated with emeralds from Brazil. Each stone exhibited a unique concentration of color when viewed through diffused lighting. Compared to the angular or linear color zoning generally seen in emeralds, each of these stones displayed an irregular, circular green zone with strong graining. The color zoning correlated with crystallites of chromite (figure 2). During the emerald's crystallization, chromite from the growth environment was incorporated into the stone as an inclusion. A chemical alteration along the interface of the chromite and the beryl occurred due to the presence of chromium from the crystallites. The altered chemistry of the beryl led to the green bodycolor adjacent to the

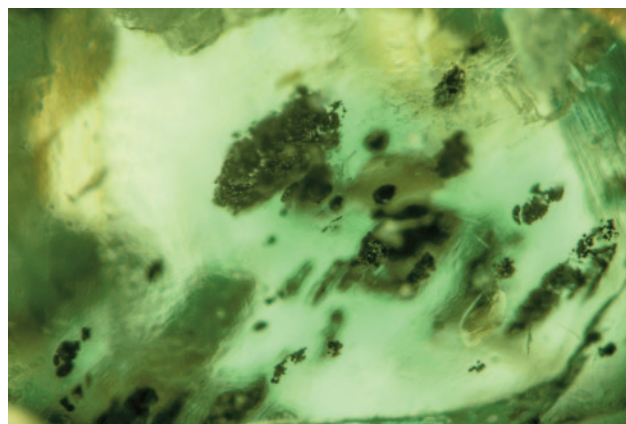


Figure 2. A Brazilian emerald with green color zoning and strong graining surrounding clusters of chromite. Photomicrograph by Nicole Ahline; field of view 1.58 mm.

chromite crystals. The strong graining is the result of the difference in refractive index in the green-colored area from the elevated chromium in contrast to the host beryl.

While chromite is regularly seen in emeralds from Brazil, it is not common to see such a strong correlation of color with the mineral inclusion.

Nicole Ahline  
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### Diamond-Shaped Cloud in Diamond

Diamonds can show some interesting surprises when examined by microscopy. Recently, the authors examined a D-color, 0.53 ct round brilliant diamond with an intriguing cloud inclusion that bore a remarkable resemblance to the profile view of a faceted round brilliant (figure 3). Due to the prominent diamond-shaped cloud under the table, the clarity grade of the stone was SI<sub>2</sub> (figure 4).

Photomicrography was used to chronicle the depth of the cloud, which indicated that it was three-dimensional and part of its center reached the diamond's surface. When focusing through the inclusion beginning at the surface of the table facet, the cloud spanned ~320 microns of focal distance. This is not the first instance of a faceted diamond showing a cloud inclusion with diamond-related geometry. Gemologists have shown other natural diamonds with clouds resembling diamond octahedra (Winter 2015 Lab Notes, pp. 428–429; Renfro et al., Winter 2018 *G&G*, pp. 428–429). However, this is the first cloud with such a shape the authors have encountered.

The infrared absorption spectra showed a type Ia diamond with saturated concentrations of nitrogen. Photoluminescence maps were collected with 532 nm and 455 nm excitation. A false-color map corresponding with the normalized intensity of a peak at 700 nm (figure 5A) was detected almost solely within the cloud. This peak at 700 nm has been ascribed to nickel and can be seen in hydrogen-

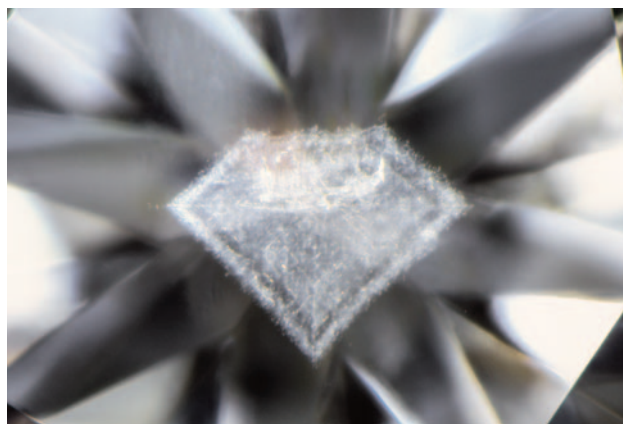


Figure 3. This 0.53 ct round brilliant diamond contained a unique cloud that resembled the profile view of a diamond. Photomicrograph by Nathan Renfro; field of view 2.60 mm.

rich diamonds, particularly within hydrogen-rich clouds (e.g., Fall 2020 Lab Notes, pp. 416–419).

In the 455 nm PL map, we detected the H3 center at 503.2 nm (figure 5B), which is identified as an A-aggregate decorated with a vacancy. The especially dense area along the “girdle” showed a distinct chemistry as that portion of the cloud had an elevated 700 nm peak intensity (figure 5A) and an elevated H3 concentration (figure 5B). Figure 5C shows the intensity of the diamond Raman peak. The Raman signal detected within the cloud shows decreased intensity; additionally, the diamond outline in this map corresponds well with the image in figure 3 (as the presence

Figure 4. The D-color, 0.53 ct round brilliant diamond has SI<sub>2</sub> clarity due to a distinctive cloud inclusion under the table facet. Photo by Marco Martinez.



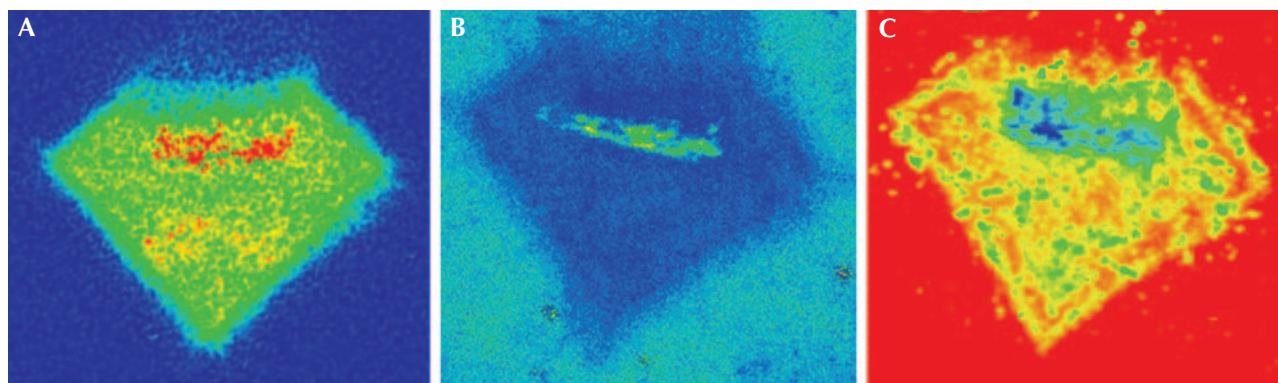
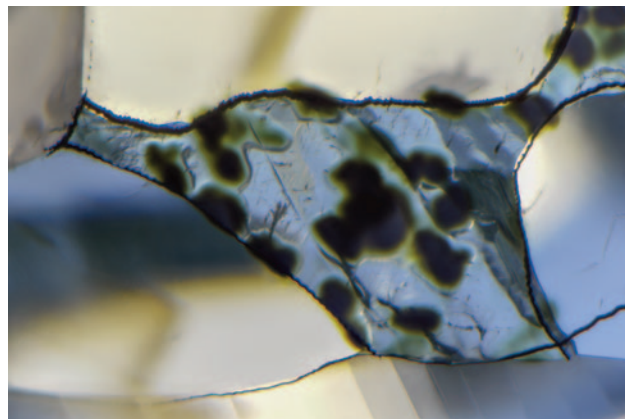


Figure 5. Photoluminescence maps were compiled from thousands of spectra (each pixel is 10 microns in size). A: Intensity of a peak centered at 700 nm (associated with nickel and often seen in hydrogen clouds). This peak intensity is normalized by ratioing to the diamond Raman peak. B: Intensity of the normalized H3 center at 503.2 nm; much of the cloud has a lower intensity than the surrounding diamond, but a portion of the “girdle” section of the cloud shows a higher H3 intensity. C: The map of the diamond Raman intensity corresponds well with the visual image, including the cloud resembling a diamond outline seen in figure 3.

of the cloud reduces the Raman signal reaching the detector). Prior research has shown that oftentimes such clouds form preferentially within the {100} growth sectors (W. Wang and W. Mayerson, “Symmetrical clouds in diamond – the hydrogen connection,” *Journal of Gemmology*, Vol. 28, No. 3, 2002, pp. 143–152).

While this diamond-shaped cloud formation may cause some concern over the natural origin of such an inclusion (see an example of a 3D subsurface laser engraving in quartz in Fall 2020 Micro-World, pp. 427–430), the cloud in this diamond appeared to be completely natural when examined in the microscope. Generally, the absence of inclusions or clarity characteristics increases the beauty and value of a diamond, but not always. In this diamond, the cloud’s presence adds beauty, value, and distinction.

Figure 6. Dark green radiation stains on a natural diamond surface. This is a partially faceted diamond with some of its natural surface bounded by laser markings, seen as dark lines in the image. Photomicrograph by Nathan Renfro; field of view 2.24 mm.



Thanks to an observant and skillful polisher, we get to see another “brilliant” example of an intriguing cloud inclusion in diamond.

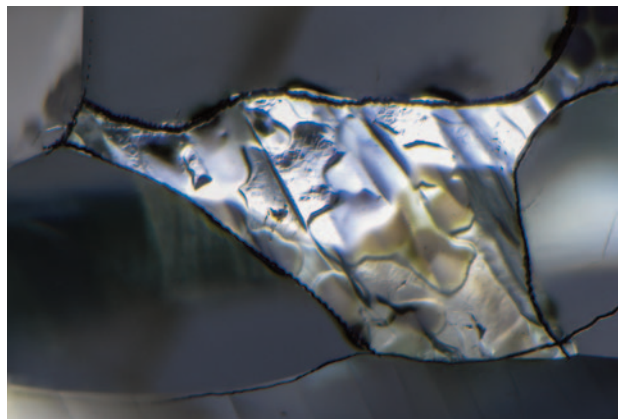
Sally Eaton-Magaña and Nathan Renfro  
GIA, Carlsbad

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### Expanded Diamond Surface Due to Radiation Staining

The author examined a 0.56 ct Fancy grayish bluish green diamond with prominent green radiation stains. Studies have shown that radiation can cause staining that expands

Figure 7. The radiation stains on a natural surface in reflected light, which highlights the smooth texture of the stained and expanded areas. Photomicrograph by Nathan Renfro; field of view 2.24 mm.



the surface of a diamond (L. Nasdala et al., "Radio-colouration of diamond: A spectroscopic study," *Contributions to Mineralogy and Petrology*, Vol. 165, 2013, pp. 843–861; S.C. Eaton-Magaña and K.S. Moe, "Temperature effects on radiation stains in natural diamonds," *Diamond and Related Materials*, Vol. 64, 2016, pp. 130–142). This can create a noticeable bump that is visible in the microscope. The effect in this diamond is so pronounced that the radiation stains appear encased in a protective plastic bubble. This expansion effect is believed to be caused by the radiation damage creating an expansion in the diamond lattice (Nasdala et al., 2013).

When viewed with transmitted light (figure 6), the raised lattice can be seen extending beyond the dimensions of the stain itself. The green-colored stains are very dark. Using reflected light (figure 7), the difference between surface textures is apparent. The surface that has been damaged and expanded by the radiation staining has a much smoother texture than the unaltered diamond surface. It is unknown why this diamond lattice was so distorted compared to typical radiation stains; they showed no unusual spectroscopic features that might provide a clue as to their formation.

*Troy Ardon  
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### Unusual Fibrous Inclusions in Blue Opal

The authors recently encountered an opal with a grayish blue bodycolor and weak play-of-color. The gem also contained some interesting fibrous inclusions (figure 8). The inclusions were generally scattered throughout a planar zone as curled bundles of chatoyant fibers. This type of opal appeared to be naturally colored and consistent in appearance and physical properties with opal from Sinaloa, Mexico (Fall 2011 Gem News International, p. 243). Raman analysis was unable to identify the inclusions, but a strong cristobalite signal was measured in areas with the

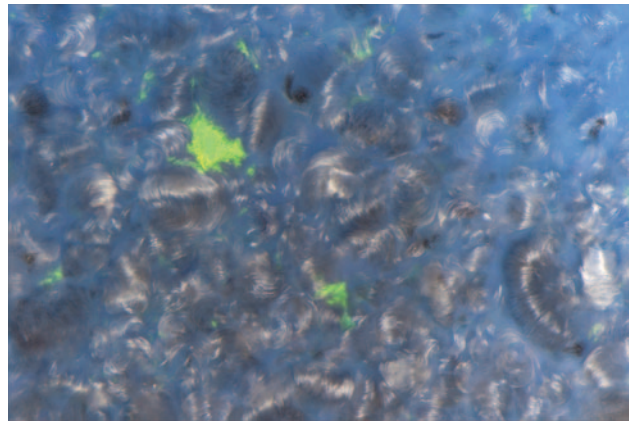


Figure 8. These unusual clusters of curled fibers were seen in a blue opal. Photomicrograph by Nathan Renfro; field of view 3.58 mm.

fibers and without them, suggesting a volcanic origin (E. Fritsch et al., "Green-luminescing hyalite opal from Zacatecas, Mexico," *Journal of Gemmology*, Vol. 34, No. 6, 2015, pp. 490–508). While the exact nature of these inclusions remains a mystery, this is the first time the authors have encountered this type of unusual coiled fibrous inclusion in blue opal.

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### Opal with Fluid Inclusion and Mobile Bubble

A Mexican opal was recently examined at the GIA laboratory in Carlsbad. The inclusion shows a euhedral void with a mobile gas bubble (figure 9). The void mimics the shape of a barite crystal that might have once been present in the opal. The barite crystal was likely dissolved during a dissolution phase during the growth of the opal, leaving behind only a fluid-filled void. Toward the end of the opal's

Figure 9. A Mexican opal containing a mobile gas bubble in the lower edge of the void (left). Tilting the stone causes the bubble to change position within the cavity (right). Photomicrographs by Jessa Rizzo; field of view 3.57 mm.





Figure 10. Large iridescent healed fissures in an oval mixed-cut sapphire. Photo by Shunsuke Nagai; field of view 12.20 mm.

formation, the temperature decreased, causing the trapped fluid to separate into liquid and gas phases. Because of the small size of the bubble relative to the void, rocking and tilting causes it to move about. Fluid inclusions in opal are generally quite rare, and one with a mobile bubble is exceptional.

Jessa Rizzo  
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### Remarkably Large Iridescent Healed Fissures Resembling Play-of-Color in Sapphire

An interesting iridescent pattern was recently observed in a blue sapphire. Gemological properties and inclusions indicated a natural sapphire, and the UV-Vis-NIR spectrum

suggested basalt-related origin (e.g., A.A. Levinson and F.A. Cook, "Gem corundum in alkali basalt: Origin and occurrence," Winter 1994 *G&G*, pp. 253–262). The characteristic inclusions of blue color concentrations surrounding exsolution particles of rutile and numerous partially dissolved needles provide evidence of heat treatment (J.I. Koivula, "Internal diffusion," *Journal of Gemmology*, Vol. 20, No. 7/8, 1987, pp. 474–477).

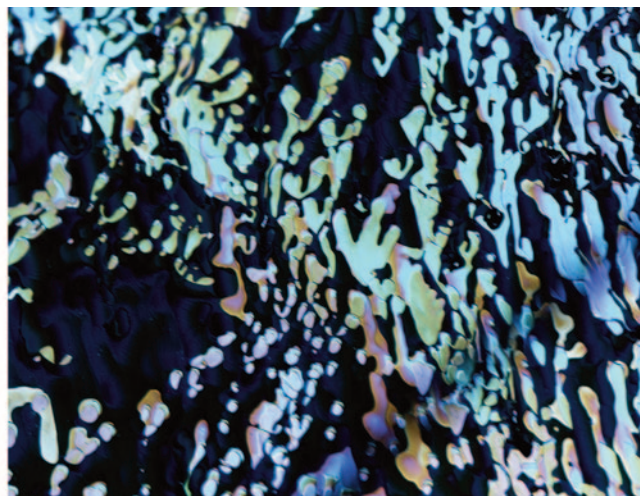
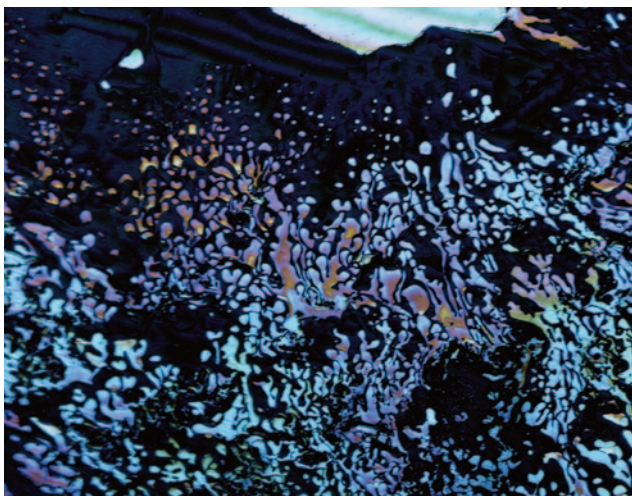
Notably, this sapphire included unique large partially healed fissures showing attractive iridescence (figure 10). Similar iridescent healed fissures in sapphires and rubies from basaltic deposits have been previously documented (e.g., E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones*, Vol. 3, Opinio Verlag, Basel, Switzerland, 2008, pp. 110 and 216–220); however, the healed fissures in this sapphire were remarkably large and visible to the unaided eye (figure 10). The fissures nearly parallel to the table facet showed variously colored iridescence with dendritic patterns (figure 11). Trapped air in a cemented plane of a doublet can also show such patterns (see Spring 2019 Lab Notes, p. 92), but this stone has no assembly feature. These attractive iridescent colors, resembling the "play-of-color" of precious opal, result from thin-film interference. This is a unique visual effect created by internal features in heat-treated corundum.

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### Quarterly Crystal: Topaz with Phlogopite

This issue's quarterly crystal is a gem-quality very light pinkish brown topaz (figure 12) from the Dusso mine in Pakistan. The transparent singly terminated topaz crystal measures 30.52 × 29.84 × 27.89 mm and weighs 216.56 ct. It hosts a prominent 6 mm long dark brownish orange

Figure 11. Iridescent dendritic healed fissures in sapphire. Photomicrographs by Makoto Miura; field of view 2.10 mm (left) and 1.30 mm (right).





*Figure 12. This 216.56 ct topaz crystal is from Dusso, Pakistan. Photo by Diego Sanchez.*

phlogopite mica booklet that shows strong brownish orange and yellow dichroism as well as lamellar cleavage planes (figure 13). A tiny cluster of dark brownish red manganotantalite and colorless albite inclusions are also present. Small near-colorless and transparent mica and feldspar in-

clusions are randomly scattered throughout the crystal. This suite of inclusions strongly suggests that a complex granitic pegmatite was the parent rock type of this topaz.

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GIA, Carlsbad*



*Figure 13. This prominent 6 mm crystal of phlogopite mica is hosted by the Pakistani topaz. Photomicrograph by Nathan Renfro; field of view 9.09 mm.*