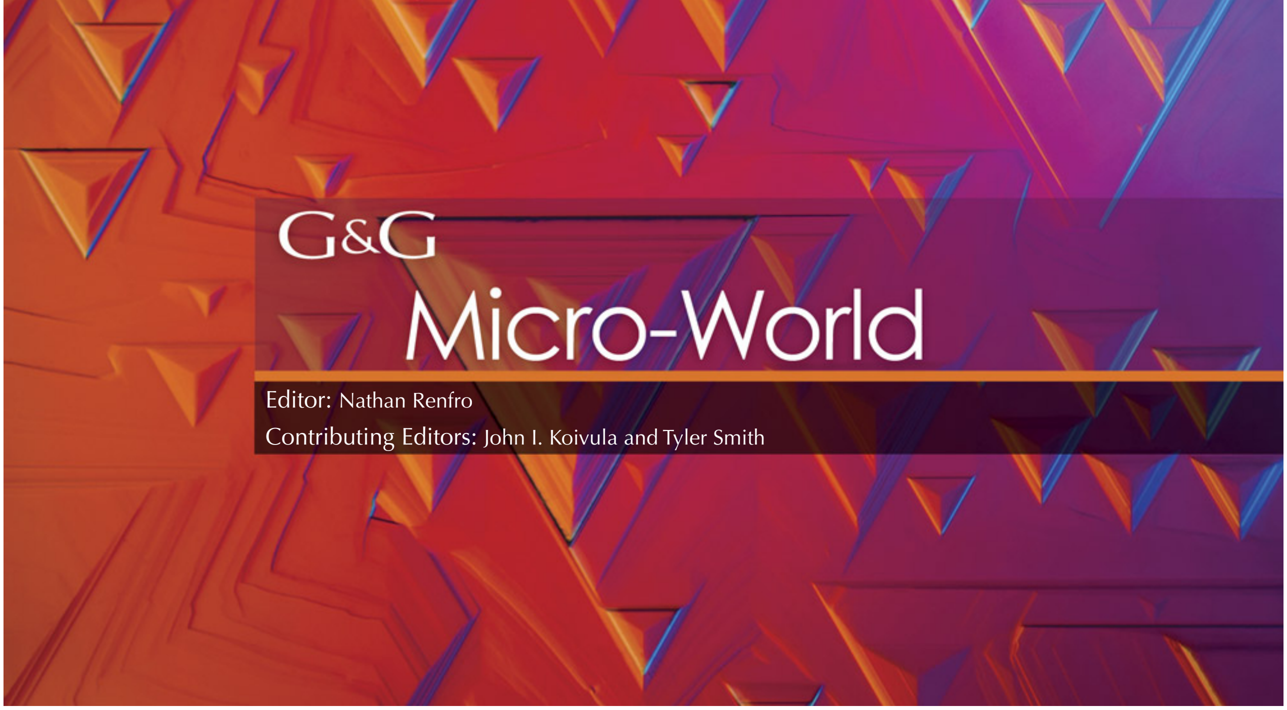


Internal World of Aquamarine from Xinjiang

The authors recently examined a batch of aquamarine samples from the Xinjiang autonomous territory of China. Microscopic observation revealed rich and colorful features.

The aquamarines contained yellow-brown to black-brown inclusions. Microscopic observation and further Raman analysis confirmed that these dot-like, flaky, and dendritic yellow-brown to black-brown inclusions were hematite. Interestingly, when observed with a microscope using LED white light illumination, the hematite inclusions appeared to extend from the center to the periphery, and the overall hexagonal shape resembled a rose floating on a calm sea (figure 1).

Colors generated by interference phenomena are very common in gemstones. A number of thin-film liquid inclusions were seen in the aquamarines, along with the spectral interference color phenomenon parallel to the *c*-axis (figure 2). Many disk-shaped inclusions (figure 3) were also found. Stress fractures were caused by solid inclusions in the middle to the surrounding areas, and tubular fractures extended in the direction perpendicular to the disk-shaped fractures. The disks were filled with thin films of

Figure 1. Hematite inclusions extend from the center of an aquamarine sample from Xinjiang, China. Photomicrograph by Yubing Chen; field of view 3.64 mm.

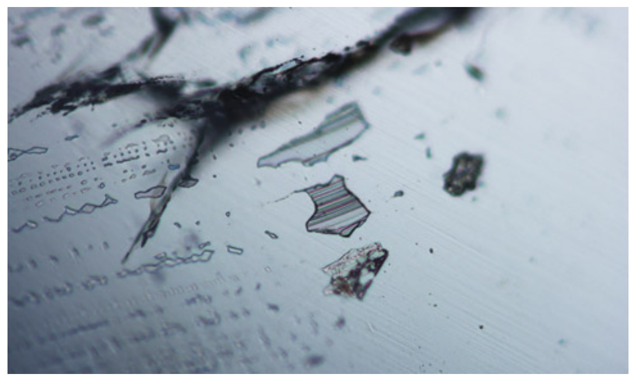


Figure 2. Thin-film liquid inclusions and visible internal tubes parallel to the c*-axis with spectral interference colors were observed in the aquamarine samples. Photomicrograph by Yubing Chen; field of view 0.70 mm.*

About the banner: Triangular etch features known as "trigons" are often seen on the surfaces of rough diamond crystals such as those shown here using differential interference contrast microscopy. Photomicrograph by Nathan Renfro; field of view 1.1 mm.

Gems & Gemology, Vol. 59, No. 2, pp. 222–231.

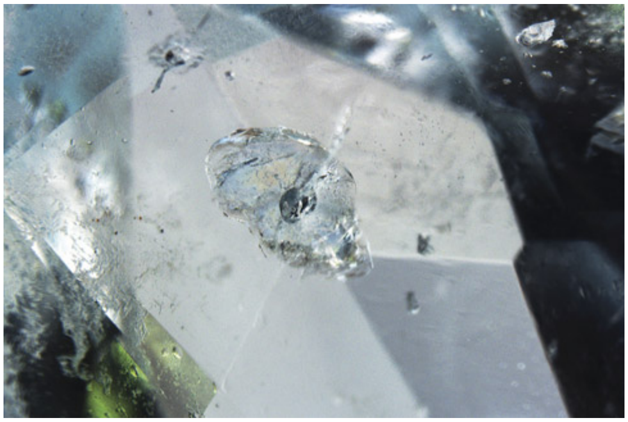


Figure 3. Disk-shaped fissures in the aquamarine were caused by solid inclusions in the middle with tubular fissures extending inward. Photomicrograph by Yubing Chen; field of view 1.50 mm.

liquid, and the interference phenomenon could be seen under the microscope using oblique fiber-optic illumination. The entire disk-shaped inclusion resembled a jellyfish floating in the sea.

Yubing Chen, Jun Shu, Yanling Wang, and Qishen Zhou
Gemmological Institute
China University of Geosciences, Wuhan

Clinochlore and Muscovite in Quartz from Colorado

Recently the author encountered a parcel of quartz with phantom layers consisting of beautiful bluish green and white spheres (figure 4). Raman analysis identified the green spheres as clinochlore (figure 5), $Mg_5Al(AlSi_3O_{10})(OH)_8$, a member of the chlorite group. Many of the white orbs appeared to be secondarily altered, presumably by fluids entering through fractures in the quartz host, though some showed no clear evidence of alteration. Raman analysis of one of the unaltered white spheres identified it as muscovite, $KAl_2(AlSi_3O_{10})(OH)_2$. Minute dark brown to black spheres were also present and visually consistent with hematite, but that could not be confirmed by Raman analysis.

This material is from Larimer County, Colorado, where it was collected in 2020 by Nico Jackson. So far, three pockets of material have been discovered, with a total production of about 10 kg. While chlorite-group minerals are relatively common inclusions in quartz, the soft texture and greenish blue color of these clinochlore spheres are less common in the author's experience. These green clinochlore spheres with contrasting white muscovite spheres are a striking addition to the possible minerals seen in the micro-world of quartz.

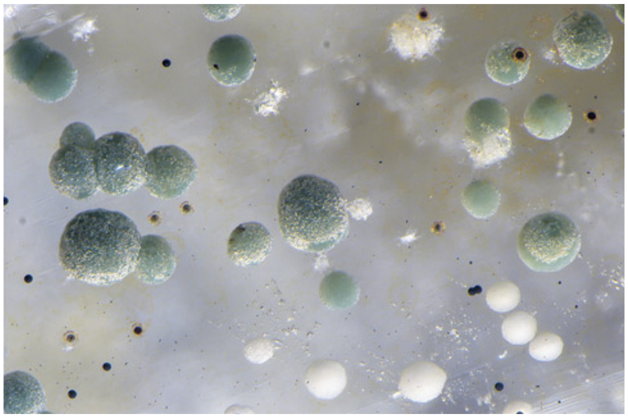
Nathan Renfro
GIA, Carlsbad

Figure 4. This quartz crystal cluster from Larimer County, Colorado, contains numerous bluish green and white spherical inclusions on phantom growth planes. Photo by Annie Haynes; courtesy of Nico Jackson.

An Iridescent "Insect Wing" in Diamond

Diamond is very resistant to scratching and is often referred to as the hardest mineral on Earth due to its compact crystal structure. However, diamond is not indestructible,

Figure 5. These bluish green spheres in the quartz crystal were identified as clinochlore, and the white spheres were identified as muscovite. Photomicrograph by Nathan Renfro; field of view 4.23 mm.



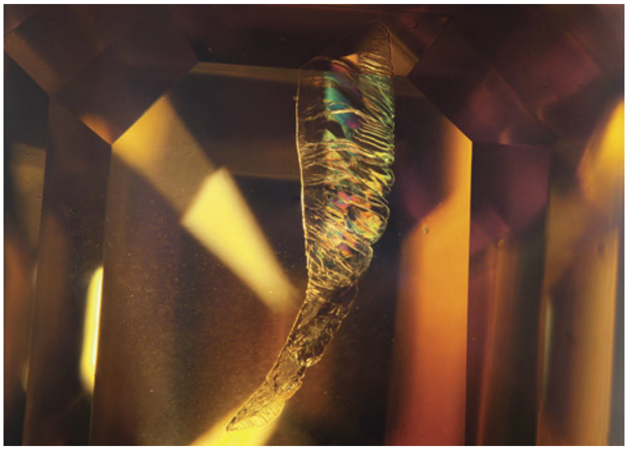


Figure 6. A subsurface feather in diamond resembling an insect wing, with visible iridescence caused by thin-film interference. Photomicrograph by Matthew Hardman; field of view 2.90 mm.

and it can be fractured or even broken apart during ascent from the mantle to the earth's surface through fast, violent kimberlite eruption. Collision with rocks in high-energy rivers also results in percussion marks on the surface of alluvial diamonds (e.g., J.W. Harris et al., "Morphology of monocrystalline diamond and its inclusions," *Reviews in Mineralogy and Geochemistry*, Vol. 88, No. 1, 2022, pp. 119–166). Surface cracks extending into the interior of a diamond are referred to as "feathers" in the gem trade, and these often have a negative effect on the clarity grade.

Fractures within diamond can cause fascinating optical phenomena on rare occasion. The authors recently examined a 0.39 ct Fancy Deep brownish yellowish orange type Ib/IaA diamond containing multiple feathers and graded as I_2 clarity. These natural features had not been filled with a clarity-enhancing material. The largest feather located on the table facet of the diamond resembled an iridescent insect wing (figure 6).

Iridescence is an optical phenomenon caused by interference of light, typically seen in gemstones with cleavage or repeating submicroscopic structures (e.g., X. Lin and P.J. Heaney, "Causes of iridescence in natural quartz," Spring 2017 *G&G*, pp. 68–81). In this diamond, the feather's iridescence was due to thin-film interference caused by a thin film of air with a thickness similar to the wavelength range of visible light. As diamond and air have very different refractive indices, there is a phase difference between the incident light reflected from the upper and lower boundaries of the thin film, resulting in constructive and destructive interference. When viewed using a broadband light source (light consisting of a wide range of wavelengths), constructive or destructive interference intensifies or attenuates certain wavelengths (colors), respectively, producing a rainbow-like interference pattern.

Mei Yan Lai and Matthew Hardman
GIA, Carlsbad

Patchy Yellow Trigon

Occasionally, diamonds show irregularity in their color related to heterogeneous distribution of atomic-level defects. "Yellow-skin" diamonds are evidence of this. Seen in figure 7 is the rough surface of a 0.98 ct diamond that shows a trigon with patchy yellow coloration. The yellow color is caused by isolated nitrogen that is confined to the outer surface of the rough stone, making it look like the rough diamond has a "yellow skin."

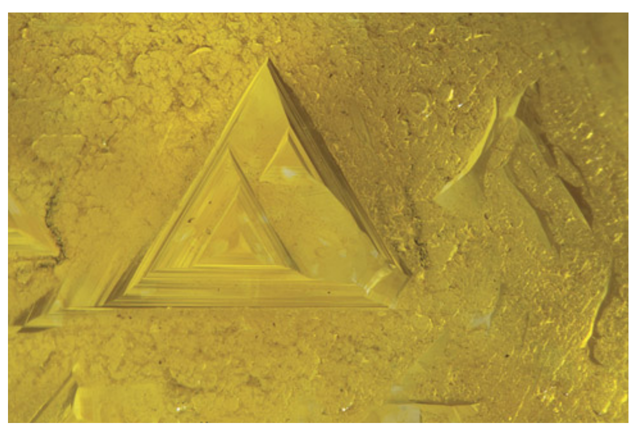
Yellow diamonds colored by isolated nitrogen are known to have uniform to patchy or irregular color zoning (more information on naturally colored yellow and orange diamonds can be found in C.M. Breeding et al., "Naturally colored yellow and orange gem diamonds: The nitrogen factor," Summer 2020 *G&G*, pp. 194–219). The color zoning (or lack of) correlates with the distribution of the nitrogen in the diamond's crystal lattice as it grows. It is theorized that the "yellow skin" is from a subsequent growth event, making it younger than the colorless diamond it surrounds.

Nicole Ahline
GIA, Carlsbad

Rainbow Mountain in Natural Diamond

At GIA, we occasionally see diamonds with inclusions that resemble natural objects. A breathtaking example was recently observed in a 1.71 ct, H-color, I_2-clarity natural diamond. The deep feather in figure 8 (top) shows an iridescence feature resembling Montaña Arcoíris (Rainbow Mountain) in the Andes Mountains of Peru (figure 8, bottom). Thirty years ago, a diamond with a similar feature (Summer 1993 Lab Notes, pp. 123–124) was described as having iridescence due to a thin-film separation caused by a "V"-shaped dislocation.

Figure 7. Trigons creating the impression of a thin and patchy "yellow skin" on a 0.98 ct rough diamond. Photomicrograph by Nicole Ahline; field of view 2.34 mm.



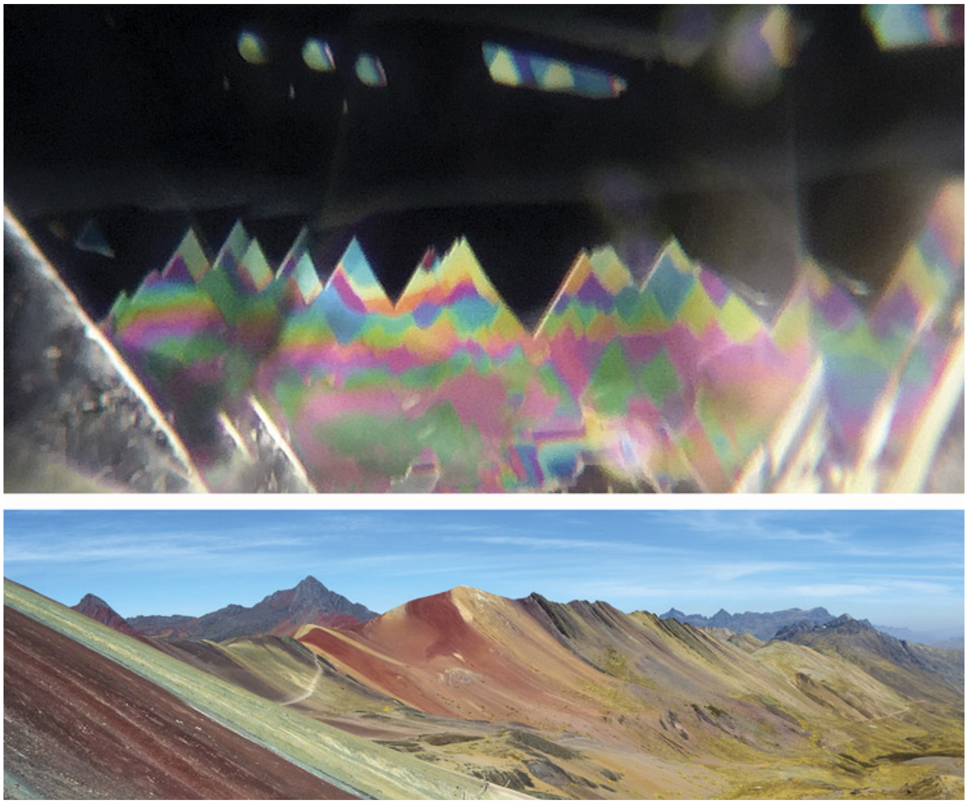


Figure 8. These iridescence features observed in a 1.71 ct natural diamond (top) were reminiscent of Rainbow Mountain in Peru (bottom). Photomicrograph by Tejas Jhaveri; field of view 2.90 mm. Bottom photo courtesy of Daniel Sánchez Ibarra (Wikimedia Commons).

As with the previously described diamond, the iridescence in this diamond is only visible at some orientations. This memorable effect showcases the beauty of the natural world within the diamond.

Tejas Jhaveri
GIA, Mumbai

Sally Eaton-Magaña
GIA, Carlsbad

Musical Diamond

Recently the author examined a 0.95 ct diamond with a special note. It only took one and a half beats to discover a dark crystal with a straight stress cleavage crack shaped like a dotted quarter note (figure 9).

Crystals, cleavages, and other inclusions are common occurrences that impact a diamond's clarity grade. This diamond received a clarity grade of SI_1, or slightly included with inclusions noticeable to a skilled grader at 10× magnification.

Michaela Damba
GIA, Carlsbad

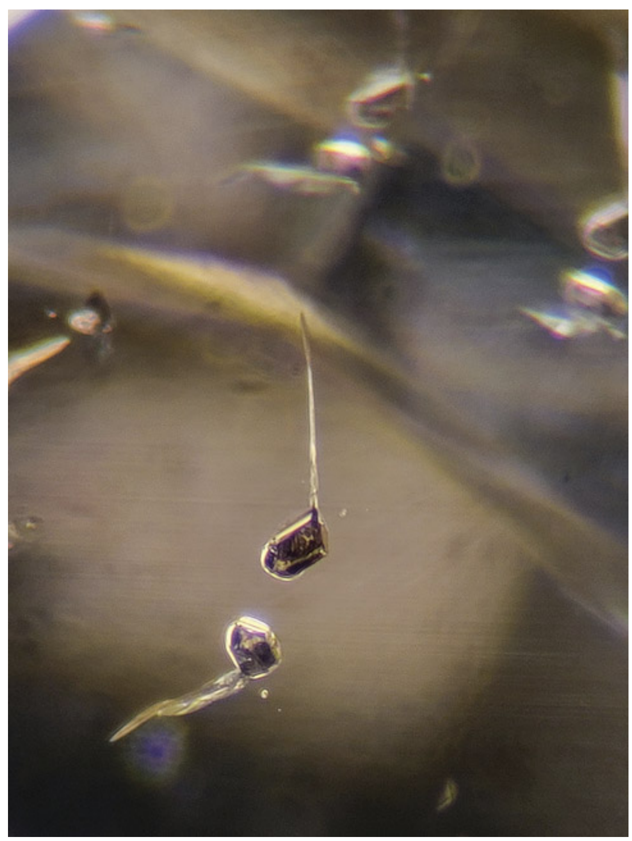


Figure 9. A crystal with a stress halo and a smaller adjacent crystal resembles a dotted quarter note. Several reflections of such crystals with stress fractures are visible. Photomicrograph by Michaela Damba; field of view 2.90 mm.

Figure 10. This "snail" inclusion was viewed through the upper half facet of a 4.00 ct near-colorless diamond. The purple-red "shell" was identified as pyrope garnet, while the green "body" was determined to be diopside. Photomicrograph by Christopher Vendrell; field of view 1.99 mm.

"Snail" in Diamond

While different types of inclusions often occur independently within diamond, it is quite rare to find more than one occurring simultaneously, let alone in contact with each other. In figure 10 we have a unique example of a purple-red pyrope garnet crystal and green diopside crystal suspended together, having been captured within this natural 4.00 ct near-colorless diamond during formation. Such inclusions can be utilized to verify what environment a diamond may have formed in. In this case, the diamond's genesis was likely in an ultramafic peridotite environment. The appearance of this unique inclusion series is playfully reminiscent of a snail.

Christopher Vendrell
GIA, New York

Guest in Garnet: Metal Sulfide?

Recently a faceted garnet containing a striking inclusion came across the author's desk. The solid inclusion was opaque with a metallic luster and had an uneven surface containing numerous sharp protrusions (figure 11). Al-

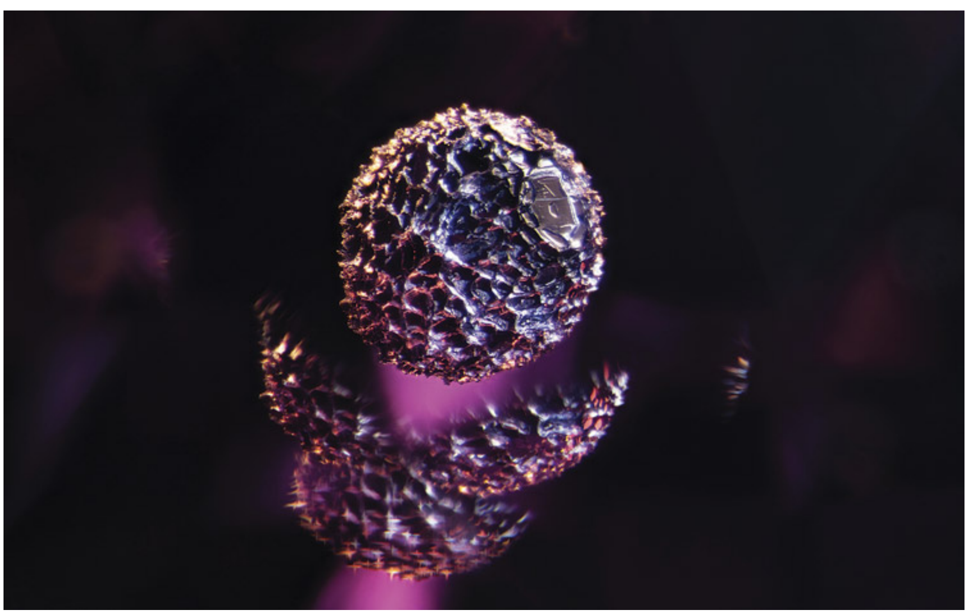


Figure 11. An opaque crystal, likely a metal sulfide, is suspended in a garnet. A combination of darkfield and oblique fiber-optic illumination makes it appear as though the crystal is hovering inside the stone. Portions of the inclusion are duplicated because of its split across several facet junctions, adding to the visual interest. Photomicrograph by E. Billie Hughes; field of view 4 mm.

though we were unable to definitively identify the inclusion, its opaque dark nature and crenulated texture were consistent with a metal sulfide crystal.

This inclusion scene inspired a variety of imaginative comparisons at our laboratory. Some thought it was reminiscent of the fire-breathing piranha plants from the Super Mario franchise, while others suggested it resembled a Ferrero Rocher chocolate. Regardless of what we might see in this piece, it is certain that we will continue to be fascinated by the delightful whimsy of Mother Nature's micro-world.

E. Billie Hughes
Lotus Gemology, Bangkok

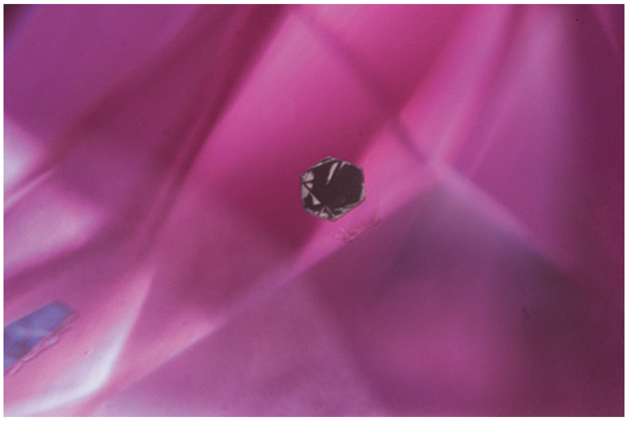


Figure 12. This pristine hexagonal platelet of graphite was seen in a pink sapphire from Sri Lanka. Photomicrograph by Jeffrey Hernandez; field of view 1.99 mm.

Pink Sapphire with Graphite Inclusion

Graphite inclusions in corundum can occur as minute bodies inside negative crystals alongside trapped diaspore and carbon dioxide. They can also appear as separate large metallic-looking hexagonal plates or jumbled clusters of small flaky crystals. Graphite in sapphire commonly occurs in those from Sri Lanka or Batakundi, Pakistan (V. Pardieu et al., "Sapphires reportedly from Batakundi/Basil area," *GIA Research News*, May 12, 2009). The author recently found a surprisingly well-formed hexagonal graphite platelet with surface etchings in a pink sapphire from Sri Lanka (figure 12). Taking into account the luster and structure of the inclusion in this particular stone, it was identified as graphite under the microscope.

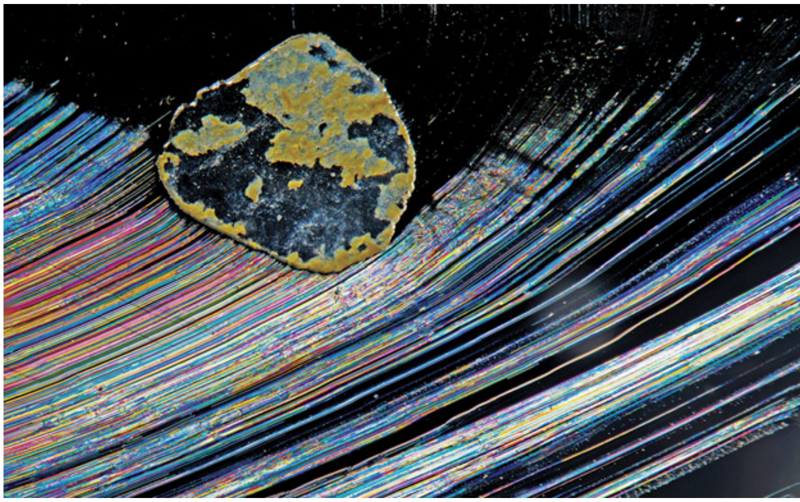
Graphite is a stable form of layered carbon occurring as a submetallic opaque mineral with a black to steel-gray color range. It typically forms in carbon-rich metamorphic rock or in pegmatite. Formation of this inclusion is dependent on the grade of metamorphism and temperature in the growth environment. It is rare to find such a clean example of a singular graphite inclusion demonstrating the crystal system it belongs to. This graphite inclusion in pink sapphire was a remarkably pristine example of this inclusion and host relationship.

Jeffrey Hernandez
GIA, Carlsbad

Night Sky in Yellow Sapphire

Fractures are usually not desired in gemstones, but in some cases they provide a great subject for photomicrography. When a 2.49 ct yellow sapphire from Ilakaka, Madagascar, was examined with a fiber-optic light, the scene in figure 13 was revealed. It is reminiscent of a long-exposure photograph of a star-filled sky with an extraterrestrial object floating in it. In reality, this is a globular iron stain in a large fracture, but the spotted iron staining evokes a faraway planet. The colorful curved lines are conchoidal patterns in the fracture. The combination of features makes the image seem as if viewed through a telescope rather than a microscope.

Figure 13. This scene of an iron stain and numerous curved lines showing rainbow colors in a fracture resembles a scene from the night sky viewed through a telescope rather than a microscope. Photomicrograph by Charuwan Khowpong; field of view 2.85 mm.



Illumination is very important for capturing the iridescence effect. Only if a strong fiber-optic light is used at the correct angle relative to the fracture will the colorful curved lines be highlighted.

Charuwan Khowpong
GIA, Bangkok

An "Eye" on a Tridacninae Pearl

The Tridacninae subfamily of giant saltwater clams consists of two genera: *Hippopus* and *Tridacna*. These bivalve

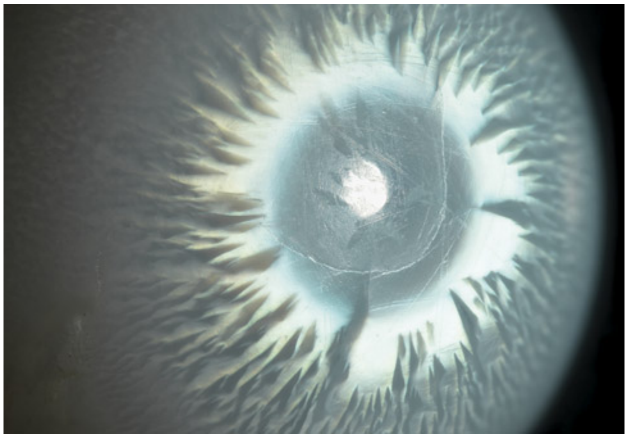


Figure 14. A 4.77 ct near-round white Tridacninae pearl exhibited an attractive sheen-like flame structure in a pattern resembling an eye when viewed in certain directions under a single white light source. Photomicrograph by Ravenya Atchalak; field of view 7.20 mm.

mollusks live only in the shallow waters of coral reefs in the tropical parts of the Indo-Pacific Ocean (E. Strack, *Pearls*, Rühle-Diebener-Verlag, Stuttgart, 2001, p. 60). They are known to produce white to cream non-nacreous pearls, with yellow or orange pearls less commonly found. Tridacninae pearls frequently exhibit a porcelain-like surface with a flame structure caused by stacked layers of aragonite lamellae in a crisscross fashion. The sheen-like effect occurs when those lamellae interact with light (H.A. Hänni, "Explaining the flame structure of non-nacreous pearls," *Australian Gemmologist*, Vol. 24, No. 4, 2010, pp. 85–88). Pearls with such characteristics are known as porcelaneous pearls.

A 4.77 ct near-round white Tridacninae pearl (figure 14) recently examined by the author displayed a well-arranged flame structure consisting of a wide base with spiky ends radiating outward from the apex of the pearl. Microscopic examination under fiber-optic light revealed a remarkable feature. A dramatic pseudo-chatoyancy occurred over the luminous flames, creating the appearance of an eye staring back at the observer. Pearls with prominent flame structures and high sheen often contain striking features.

Ravenya Atchalak
GIA, Bangkok

Ancient Script-Like Serpentine in Brown Peridot

Peridot is a green olivine often characterized by "lily pad" inclusions and high birefringence causing a doubling effect. Apart from its familiar green hue, peridot can also possess a brown color, though these gems receive little attention.

Recently, the author found a xenocryst of peridot from southeast Vietnam that appeared black in daylight and brown through a transmitted light source. Standard gemological testing of a cabochon (2.51 ct) and two faceted stones (2.35 and 4.65 ct) that were cut from this xenocryst indicated peridot, but the specific gravity and refractive index gave higher results than the values for green peridot. Finally, the Raman spectra confirmed the identification as peridot.

Microscopic examination did not reveal any typical "lily pad" inclusions. Instead, there were innumerable fascinating thread-like inclusions (figure 15). Some formed closed loops with round, oval, and distorted shapes measuring from a few nanometers to a millimeter. Others stretched or twisted together like tangled threads up to 2 mm long. The display was reminiscent of an ancient script.

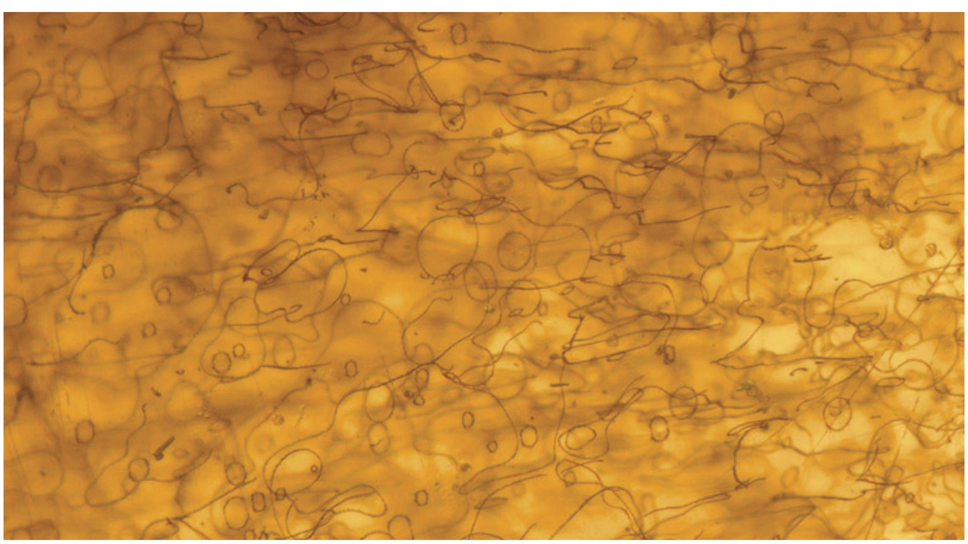


Figure 15. Thread-like inclusions of serpentine resembling an ancient text. Photomicrograph by Le Ngoc Nang; field of view 2.50 mm.

Figure 16. A 2.52 ct oval modified brilliant Paraíba tourmaline. Photo by Adriana Gudino.

Micro-Raman spectral analysis revealed these thread-like inclusions were serpentine.

Examination of this brown peridot revealed an unexpected inclusion scene quite different from the common inclusions found in green peridot.

Le Ngoc Nang
University of Science, Vietnam National University Ho Chi Minh City
Liu Gemological Research and Application Center

Interesting Metallic Platelets in a Brazilian Paraíba Tourmaline

The authors recently examined the 2.52 ct saturated green oval modified brilliant shown in figure 16. The gemological properties, as well as trace element analysis using laser ablation–inductively coupled plasma–mass spectrometry, confirmed this gem was a Paraíba tourmaline from Brazil.

Microscopic observation revealed interesting metallic dark gray dendritic inclusions (figure 17). The metallic inclusions were similar in shape to previously documented native copper inclusions in Paraíba tourmaline (E.J. Gübelin and J.I. Koivula, *Photoatlas of Inclusions in Gemstones, Volume 1*, 2008, Opinio-Verlag Publishers, Basel, Switzerland, p. 167). Metallic inclusions with a dendritic pattern and similar brassy color in a Brazilian Paraíba tourmaline were previously identified as native copper (F. Brandstätter and G. Niedermayr, "Copper and tenorite inclusions in cuprian-elbaite tourmaline from Paraíba, Brazil," Fall 1994 *G&G*, p. 181). Because the inclusions in figure 17 are different in color from those previously documented, they are probably not copper. However, Raman analysis was unsuccessful in identifying them. Based on their morphology and color, the authors speculate they could be ilmenite, which has been observed as skeletal inclusions of a similar color in gems such as emerald. These are the first examples of dark gray skeletal metallic inclusions the authors have encountered in a Paraíba tourmaline.

Shiva Sohrabi and Amy Cooper
GIA, Carlsbad

Triplite Inclusions in Quartz from Yaogangxian, China

Quartz is host to a wide variety of inclusions. Recently, the authors examined a 30.80 ct transparent faceted quartz with several pinkish orange crystal inclusions, from the town of Yaogangxian in Hunan Province, China (figure 18). This quartz was cut from a rough stone collected by a local miner. In this quartz, the pinkish orange inclusions were unique and attractive.

Figure 17. Left: The skeletal formation that usually indicates very rapid growth of the mineral. Right: Skeletal formations showing a cross-hatch pattern. Photomicrographs by Shiva Sohrabi; fields of view 1.26 mm (left) and 2.95 mm (right).

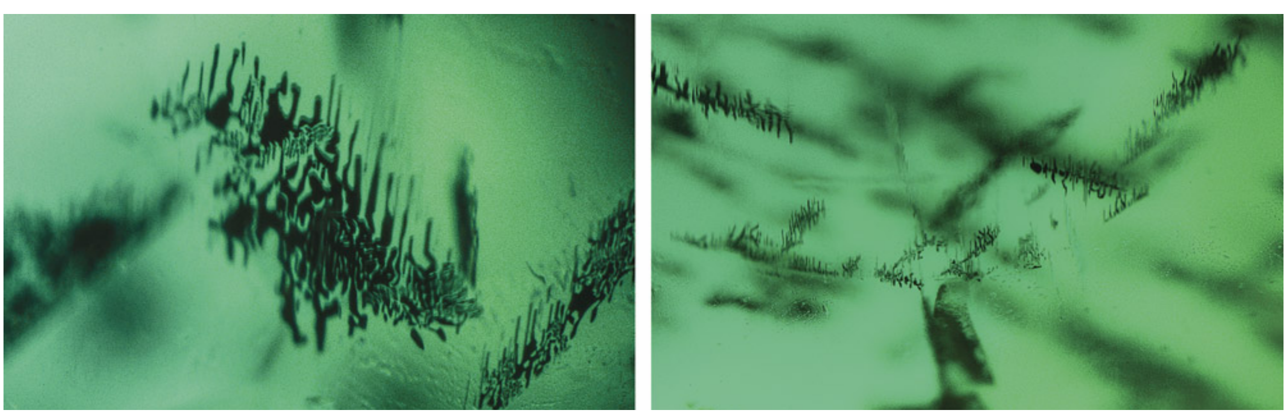


Figure 18. A 30.80 ct faceted quartz containing pinkish orange inclusions. Photo by Hongtao Shen; courtesy of Jinrui Dong.

Figure 19. Magnification of pinkish orange triplite in a transparent quartz from Yaogangxian in Hunan Province, China. Photomicrograph by Hongtao Shen; field of view 11.15 mm.

After grinding, one of these inclusions was exposed to the surface (figure 19). Raman spectroscopy and energy-dispersive X-ray fluorescence were used to identify the inclusion as triplite.

Triplite, $(Mn^{2+},Fe^{2+})_2PO_4(F,OH)$, is a rare phosphate mineral that can be found as either a gem material or an inclusion. Most triplites are produced in pegmatite, as with quartz. Triplite inclusions have been reported in topaz (Summer 2016 *G&G* Micro-World, p. 205) and beryl (Spring 2020 *G&G* Micro-World, p. 145). To the best of our knowledge, this is the first discovery of triplite as an inclusion in quartz.

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Gemmological Institute
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Hongtao Shen
State Key Laboratory of Geological Processes and Mineral Resources
China University of Geosciences, Wuhan

Quarterly Crystal: Geocronite in Fluorite

A tight crystal cluster of bright apple-green fluorite and opaque silvery gray geocronite, $Pb_{14}(Sb,As)_6S_{23}$, was recently examined for this edition of Quarterly Crystal. The specimen shown in figure 20 measured 29.60 × 23.84 × 18.35 mm, and the fluorite portion played host to several small, well-formed monoclinic crystals, all situated near the surface. The crystals appeared to be geocronite, a very rare sulfide containing lead, antimony, and arsenic.

The specimen was obtained from Luciana Barbosa of Barbosa Minerals (Asheville, North Carolina). It came from a recent discovery at the Milpo mine in the Atacocha mining district of Pasco Province, Peru. The Milpo mine is known to produce fluorite crystals with inclusions of various sulfides. Since the fluorite and geocronite are intimately intergrown, the opaque silvery gray bodycolor of the inclusions in the fluorite, together with their monoclinic appearance shown in figure 21, strongly suggested geocronite.

The next logical step was laser Raman microspectrometry. Using this technique, we conclusively identified the inclusions as geocronite, thereby confirming our suspicions. It should be noted that, to the authors' knowledge, this is the first time geocronite has been identified as an inclusion in any mineral.

John I. Koivula and Nathan Renfro
GIA, Carlsbad

Figure 21. A combination of optical microscopy and Raman analysis identified the opaque silvery gray monoclinic inclusions as the very rare sulfide geocronite. Photomicrograph by Nathan Renfro; field of view 2.39 mm.

Figure 20. This 29.60 × 23.84 × 18.35 mm cluster of well-formed isometric fluorite and monoclinic geocronite crystals was recently discovered at the Milpo mine in Peru. Photo by Annie Haynes.