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Unusual Multicolored ASSEMBLED STONE

Although in some cases (such as backed opal) an assembled stone is created to increase the durability of a gem material, the more common purpose of manufacturing assembled stones is to deceive. Green synthetic spinel and synthetic quartz triplets have long imitated emeralds. Likewise, doublets consisting of natural green sapphire crowns and synthetic sapphire or synthetic ruby pavilions have fooled many buyers, as the natural inclusions in the crown mask the synthetic inclusions in the pavilion.

Rarely, however, do we see assembled stones created for other, more artistic purposes. It was therefore very surprising to receive for identification the nearly 6 mm transparent multicol-

ored square tablet in figure 1. This specimen was composed of six thin sections, each of a different color—red, orange, yellow, green, light blue, and light purple—joined with colorless cement. The client told us that he had purchased this “rainbow stone” with the intent to market it for use in commitment ceremonies for members of the Rainbow Coalition, a prominent civil rights organization.

The client wanted to verify the identification of each of the six sections. Due to the nature of the assemblage, the individual refractive indices were easy to obtain. The light purple, green, yellow, and orange sections had R.I.’s of 1.54. The red section had an R.I. of 1.76, and the light blue section had an R.I. of 1.72. A combination of standard and advanced gemological testing identified the red section as

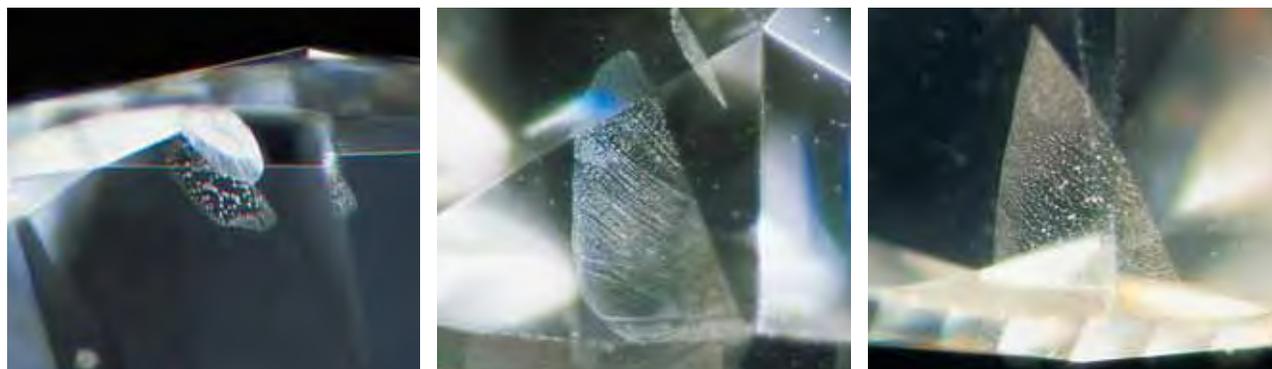


Figure 1. This unusual specimen was assembled from slices of synthetic ruby, synthetic quartz, and synthetic spinel.

synthetic ruby, the light blue section as synthetic spinel, and the remaining four sections as synthetic quartz.

Wendi M. Mayerson

Figure 2. Fingerprint-like inclusions such as these have been reported in several colorless to near-colorless diamonds known to have been HPHT treated (from figure 10 in T. M. Moses et al., Fall 1999 *Gems & Gemology*, pp. 14–22). From left to right, magnified 32×, 18×, and 13×.



DIAMOND

With “Fingerprint” Inclusions

Fingerprint-like inclusions are common features in many colored stones, such as ruby and sapphire, but they are extremely rare in diamonds. In corundum, these “fingerprint” patterns are formed by fluid-assisted partial healing of pre-existing fractures. However, in the case of diamond, much higher pressures and temperatures are necessary to promote partial healing of fractures and, at these conditions, fluids are usually not present. A few instances of fingerprint-like patterns produced by groups of tiny inclusions in natural-color blue and colorless diamonds have been reported, but the interconnected channel-like structure that is common to sapphire “fingerprints” was not observed in these stones (see Lab Notes: Spring 1968, pp. 278–279; Spring 1993, pp. 47–48).

In recent years, fingerprint-like inclusions seen in colorless to near-colorless diamonds are most often associated with high pressure, high temperature (HPHT) treatment (figure 2; see also T. M. Moses et al., “Observations on GE-processed diamonds: A photographic record,” Fall 1999 *Gems & Gemology*, pp. 14–22). Similar to the HPHT-treated stones described in Moses et al., a small “fingerprint” extending from a graphitized inclusion was recently seen in an F-color, 4.79 ct, type IIa heart-shaped brilliant that was found to have been HPHT treated (figure 3).

Over the past few months, the West Coast laboratory has had the opportunity to examine three natural-color diamonds with a range of fingerprint-like inclusions. A pattern con-

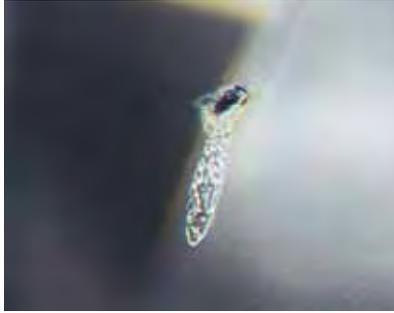


Figure 3. This fingerprint-like inclusion extends from a graphitized crystal in a colorless diamond that was recently proved to have been HPHT treated. Magnified 45 \times .

sisting of several groups of tiny crystals, very similar to those described in the 1968 and 1993 Lab Notes referenced above, was observed in a Light blue, 0.64 ct, type IIb marquise brilliant (figure 4). However, the most intriguing discoveries were two colorless type IIa diamonds (a 2.28 ct D-color round brilliant and a 1.00 ct F-color pear shape) that contained inclusions with an appearance remarkably similar to the “fingerprints” seen in rubies and sapphires (figure 5). The diamonds were tested very carefully and determined to be of natural color. The channel-like patterns (not composed of tiny crystals) very strongly suggested that these were partially



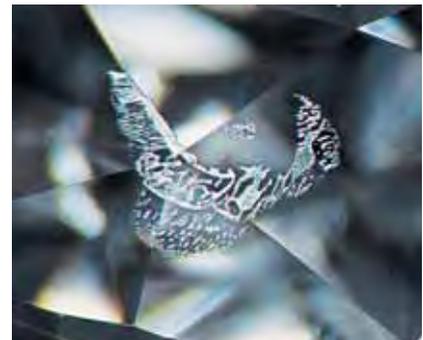
Figure 4. A fingerprint-like inclusion seen recently in this 0.64 ct natural-color Light blue diamond actually consists of groups of many tiny crystals. Magnified 45 \times .

healed fractures in natural, untreated diamonds.

The geologic environment in which these two diamonds may have been heated to the temperatures necessary to cause partial healing of fractures remains a mystery. The heating must have occurred very deep in the earth (i.e., at high pressures), in that the clarity of these relatively large gem-quality diamonds did not show any evidence of the intense graphitization that occurs in diamonds heated at lower pressures. These samples also serve as a caution to gemologists that fingerprint-like features in colorless or near-colorless diamonds do not always mean the stones have been HPHT treated.

Christopher M. Breeding

Figure 5. These fingerprint-like inclusions seen in two natural-color type IIa colorless diamonds show a channel structure that is remarkably similar to the “fingerprints” commonly found in ruby and sapphire. Magnified 45 \times (left), 30 \times (right).



Editor's note: The initials at the end of each item identify the editor(s) or contributing editor(s) who provided that item. Full names are given for other GIA Laboratory contributors.

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Pink Diamond with Etch Channels at the Intersections of Glide Planes

Pink graining and pink glide planes are the main causes of a pink-to-red body-color in natural diamond. In contrast to pink graining, which is usually rather irregular in morphology, the glide planes typically occur as a set of well-defined, parallel, and highly color-concentrated planes that extend through the entire stone or a large part of it. In our experience, only a few percent of pink diamonds are colored by glide planes, and pink stones of this type usually have only one set. However, the East Coast laboratory recently examined a pink diamond that had *two* sets of glide planes (figure 6), as well as etch channels that occurred at the intersections of the planes. This feature is not only rare among pink diamonds, but it also supplied an opportunity to examine the mechanism by which etch channels form in diamond.

The 0.77 ct round brilliant cut ($5.87 \times 5.76 \times 3.61$ mm) was color graded Light pink. Two large fractures were present at the girdle. The diamond displayed a weak blue fluorescence to long-wave ultraviolet (UV) radiation and was inert to short-wave UV, with no phosphorescence. Consistent with other diamonds with sim-

Figure 6. In this 0.77 ct Light pink diamond, the pink color is clearly concentrated in two sets of glide planes, which are nearly perpendicular to each other. Magnified 38 \times .

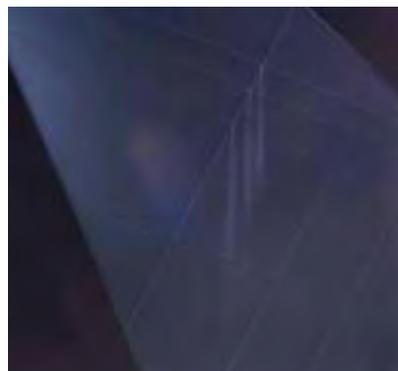


ilar pink glide planes, it contained a high concentration of nitrogen, mostly in the A-form aggregation, and a relatively weak platelet peak around 1365 cm^{-1} in the infrared absorption spectrum. As expected, the UV-visible absorption spectrum displayed moderately strong and sharp absorptions at 316, 330, and 415 nm (N3), and a broad band centered at ~ 550 nm.

The distance between individual planes varied from about 0.2 to 1.0 mm. The two sets of planes were nearly perpendicular to each other (again, see figure 6), and etch channels were observed where the two sets intersected. All the channels were likewise straight and parallel. Depending on the development of the glide planes, the dissolution channels varied from less than 1 mm to over 2 mm deep. The shape and diameter of the channels were too small to be determined with a regular gemological microscope, but the diameter appeared to be less than $50\text{ }\mu\text{m}$. Nevertheless, the channels were readily seen with proper lighting (figure 7).

The physics of the crystalline defect that generates the ~ 550 nm broad absorption band is not well understood. However, it is widely believed to be related to plastic defor-

Figure 7. As can be seen here, etch channels developed at the intersections of the two sets of glide planes in the 0.77 ct Light pink diamond. With reflected light, the planes appear as distinct lines on the polished faces. Magnified 98 \times .



mation of the diamond lattice (see, e.g., A. T. Collins, "The colour of diamond and how it may be changed," *Journal of Gemmology*, Vol. 27, 2000, pp. 341–359). A glide plane is a distortion of the crystal lattice, with the carbon atoms shifted away from their normal, stable positions. This distortion would be significantly intensified where the two sets of glide planes intersect, since it is occurring in two separate directions. The carbon atoms in these strongly distorted regions would not have a normal diamond structure, and thus they would not be chemically as stable. As a result, dissolution or etching could selectively occur in these regions.

Etch channels are a common sight in natural diamonds, though their formation mechanisms are not fully understood (see, e.g., T. Lu et al., "Observation of etch channels in several natural diamonds," *Diamond and Related Materials*, Vol. 10, 2001, pp. 68–75). This unusual pink stone revealed that intersections of plastic deformation planes are chemically less stable, so they are one of the localities where etching can selectively occur.

Wuyi Wang, Vinny Cracco,
and TMM

Two Diamonds from the Same Octahedron

Typically a diamond cutter will fashion at least two stones from a single octahedral crystal; however, these stones rarely remain together for long. One is commonly larger than the other, so the diamonds tend to get distributed in different lots. Certain spectroscopic methods can sometimes be used to detect similarities in once-contiguous stones, but natural zoning of impurities and lattice defects in colored diamond crystals often makes it difficult to match spectroscopic data from different parts of the crystal. Other techniques such as X-ray topography may have more potential (see I. Sunagawa et al., "Fingerprinting of two diamonds cut from the same rough," *Winter 1998 Gems &*



Figure 8. High-energy DiamondView UV fluorescence patterns from these two diamonds (left, 0.38 ct; right, 2.39 ct) are nearly perfect mirror images of each other, strongly suggesting that they were at one time part of the same crystal.

Gemology, pp. 270–280; R. Diehl and N. Herres, “X-ray fingerprinting routine for cut diamonds,” Spring 2004 *Gems & Gemology*, pp. 40–57).

The West Coast laboratory recently examined two partially polished colored diamonds that appeared to have been cut from the same piece of rough. The stones had been submitted at the same time, but for separate origin-of-color reports. One (0.38 ct) consisted of the rough top of a brownish yellow octahedron with only the cut base polished. The other was much larger (2.39 ct) and had been blocked into a yellow cut-cornered rectangular modified brilliant. Unpolished surfaces on both diamonds showed abundant brown radiation stains. The diamonds exhibited similar strain patterns with cross-polarized light, and both showed greenish yellow fluorescence to long- and short-wave UV lamps. Infrared spectroscopy revealed that both stones were type Ia with abundant nitrogen impurities; the spectra were almost identical. These similarities suggested that at one time these two diamonds might have been part of the same crystal.

In an effort to confirm this speculation, the diamonds were examined with a Diamond Trading Company (DTC) DiamondView, which uses a high-energy UV source to reveal differences in the fluorescence of diamond growth zonations. Distinctive fluorescence patterns were present in both

stones (figure 8). Furthermore, the high-energy fluorescence pattern from the base of the smaller diamond was almost a mirror image of that seen in the larger, blocked stone. The correlation of their DiamondView images, gemological observations, and spectroscopic data indicates that these two diamonds were indeed cut from the same octahedron.

Christopher M. Breeding

Unusual Translucent Brown-Orange Diamond

Micro-inclusions in diamond, such as water and carbonates, are useful in

Figure 9. This translucent 1.58 ct brown-orange diamond (7.20 × 7.09 × 4.76 mm) appears to owe its unusual hue to large amounts of carbonate micro-inclusions.



studying the formation and evolution of the fluids/melts that are essential for diamond formation in the upper mantle. These inclusions usually occur in the fibrous coatings on some octahedral diamond crystals. Although such coated diamonds from the DRC/Zaire and Botswana have been described previously (O. Navon et al., “Mantle-derived fluids in diamond micro-inclusions,” *Nature*, Vol. 335, 1988, pp. 784–789), and we have recently reported on a colorless diamond and a Fancy Dark brown-greenish yellow diamond with carbonate micro-inclusions (Lab Notes: Winter 2004, pp. 325–326; Summer 2005, pp. 165–167), it is still extremely rare to see a faceted gem diamond with these inclusions throughout the entire crystal.

The 1.58 ct translucent brown-orange round brilliant in figure 9 was submitted to the East Coast laboratory for identification and origin-of-color determination. Upon examination, we saw fractures that appeared to have orange color concentrations. With the microscope, we also observed extensive surface graining (figure 10), as well as micro-inclusions throughout the stone.

Since this diamond was translucent, we used diffuse reflectance infrared spectroscopy to study the inclusions. As seen in figure 11, absorption bands at

Figure 10. With reflected light (here, on the table facet), surface graining was observed over most of the diamond in figure 9. Magnified 40×.



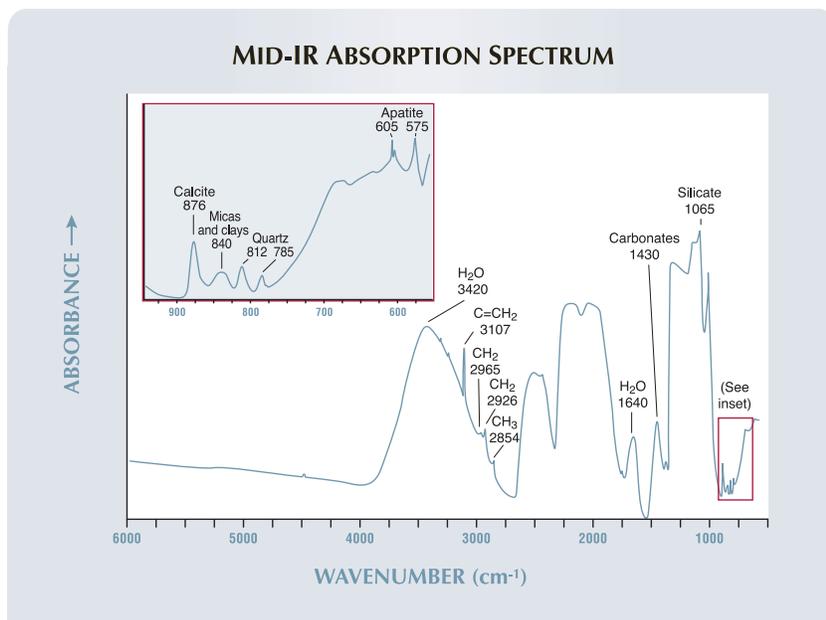


Figure 11. Diffuse reflectance IR absorption spectroscopy showed that this diamond is type Ia with carbonate and water micro-inclusions. By subtracting the spectrum of a pure type Ia diamond, the absorption bands of other micro-inclusions such as apatite and micas can be seen in detail (inset).

3420 and 1640 cm^{-1} suggested the presence of water molecules. A silicate absorption band was also seen at 1065 cm^{-1} . The two bands at 605 and 575 cm^{-1} are due to apatite (M. Schrauder and O. Navon, "Hydrous and carbonatic mantle fluids in fibrous diamonds from Jwaneng, Botswana," *Geochimica et Cosmochimica Acta*, Vol. 58, No. 2, 1994, pp. 761–771). The bands at 812 and 785 cm^{-1} are due to quartz. They are shifted from their normal positions at 798 and 779 cm^{-1} as a result of the high internal pressure within the micro-inclusions. The band at 840 cm^{-1} is characteristic of micas and clay minerals. The bands for carbonates (CO_3^{2-}) were also observed at 1430 and 876 cm^{-1} ; these are the main carbonate band and the characteristic band for calcite, respectively (again, see Navon et al., 1988).

The bands at 2965 and 2926 cm^{-1} are caused by the CH_2 group, the one at 2854 cm^{-1} by the CH_3 group, and the sharp peak at 3107 cm^{-1} is assigned to the $\text{C}=\text{CH}_2$ group (J. Lindblom et al.,

"Luminescence study of defects in synthetic as-grown and HPHT diamonds compared to natural diamonds," *American Mineralogist*, Vol.

Figure 12. High-energy Diamond-View fluorescence imaging shows that the diamond in figure 9 grew from a cube to an octahedron with multiple growth centers. This was further confirmed by a distinctive cubic growth center seen when the diamond was viewed through the pavilion.



90, No. 2–3, 2005, pp. 428–440). These peaks are observed in natural diamonds and may also be attributed to artifacts from contamination within the fractures of this diamond, so their presence is probably unrelated to inclusions.

Our examination of this unusual diamond allows us to infer some geologic conditions of its formation. The shift in the peak positions of quartz in the IR spectrum corresponds to a pressure of 1.5 GPa at room temperature (see Schrauder and Navon, 1994). Extrapolating to a typical mantle temperature of 1,000°C would correspond to a pressure of 4.5 GPa, which falls within the diamond stability field. Therefore, the micro-inclusions in this diamond appear to have crystallized from fluids that were trapped during its growth in the upper mantle. As the mantle-derived fluids in the diamond cooled during its travel to the surface, they developed into a secondary-phase assemblage that formed the micro-inclusions (i.e., water, carbonates, silicates, apatites, micas, and clays). This assemblage, with an absence of molecular CO_2 , suggests that the diamond formed under conditions that were fluid-rich and gas-poor. The inclusions correspond to both carbonatic fluids (carbonates) and hydrous fluids (water, SiO_2), which may coexist at upper-mantle temperatures and pressures.

Because this diamond was polished, there was no obvious evidence of its crystal habit. However, when it was examined with the DTC DiamondView, the fluorescence image showed that the internal morphology evolved from cube to octahedron with multiple growth centers (figure 12). It also indicated that the brown-orange color followed the growth zoning. This could be important evidence that the color was caused by micro-inclusions that were captured by different growth zones rather than along the fractures as it initially appeared. Another DiamondView image through the pavilion showed a distinctive cubic growth center, confirming that this diamond grew from multiple growth centers.



Figure 13. This emerald-in-matrix specimen was known to be assembled prior to being submitted to the laboratory, but it proved to have another, very unusual, characteristic.

This brown-orange diamond is the first we have analyzed with this variety of micro-inclusions. Advanced spectroscopic testing not only confirmed that its color was of natural origin but also provided keys to its geologic formation. An orange hue is not common in naturally colored diamonds; it is mainly due to the presence of point and/or extended defects. This diamond demonstrated that micro-inclusions may also contribute to an orange coloration.

Kyaw Soe Moe and Paul Johnson

Inscriptions Inside EMERALD Crystals

Occasionally the laboratory receives mineral specimens for identification, usually for the purpose of determining whether or not they are natural or have been assembled (see, e.g., Spring 2003 Lab Notes, p. 42). The emerald-in-matrix specimen shown in figure 13 was submitted to the West Coast laboratory, but this time the owner knew in advance that it had been assembled from Colombian material.



Figure 14. The extent of the glue used to affix the emerald crystals in the matrix became very apparent when the specimen was exposed to long-wave UV radiation. Notice how visible the writing in one of the crystals is.

The purpose of the examination was to make sure the emerald crystals were natural, as well as to document something very unusual that had been done to them.

Spectroscopic testing and microscopic examination confirmed that the crystals were natural emeralds. Close observation of the specimen at the base of the crystals revealed an adhesive that had been mixed with crushed matrix to give it a more natural appearance—a practice that is very common in the construction or reconstruction of mineral specimens. The glue was easily visible when exposed to long-wave UV radiation, as it fluoresced a strong blue (figure 14).

This was not, however, the most interesting aspect of the specimen. The two largest crystals (26.75 × 25.50 × 20.50 mm and 17.00 × 20.80 × 19.90 mm) had what appeared to be some sort of internal inscription. With a loupe, it could be seen that the writing was in Arabic and was not on the surface of the crystals. With the microscope, the answer to this mystery became clear. While out of the matrix,



Figure 15. This view through the termination of one of the emerald crystals in figure 13 reveals that a hole had been drilled down the center from the bottom without breaking the surface of the termination. Magnified 10 \times .

the crystals apparently had been core drilled from the bottom, with care being taken not to cut through the termination or any of the prism faces. What appeared to be a rolled up piece of paper or some other writing material was then inserted into each of the crystals, conforming to the cylindrical shape of the drilled holes. The holes were then filled with a resin or similar compound (figure 15), and the specimen was reassembled. We surmise that once the paper was saturated by the resin, it became transparent, leaving only the wording, in black, visible from the outside of the crystal (figure 16). Although this is not the only possible scenario, it seems the most likely.

One of our staff members at the time, Maha Calderon, was able to read most of the two inscriptions, the first of which she translated as, "To the people, guidance, and wisdom to the believers." Only part of the second inscription was legible because of inclusions in the emerald.

SFM



Figure 16. It appears that some sort of material with Arabic writing was inserted into the holes made in the two largest emerald crystals. Magnified 10 \times .

Color-Coated Star QUARTZ

Recently, the East Coast laboratory received for identification a grayish blue oval cabochon displaying asterism. The stone measured approximately 12.35 \times 10.25 \times 6.45 mm and was set in a white metal ring (figure 17). Standard gemological testing revealed a spot refractive index of 1.54 and a bull's-eye optic figure, which identified the stone as quartz.

The lab has reported on star quartz many times over the years, discussing the typical colors, cause of asterism, and sources of the material (see, e.g., Lab Notes: Winter 1981, p. 230; Spring 1985, pp. 45–46; Spring 1987, pp.

Figure 17. Although the asterism in this rock crystal quartz cabochon is natural, the color is caused by a blue coating on the back, probably to help it imitate star sapphire.



47–48). This stone contained numerous oriented needles, which caused the star, so we concluded that the asterism was natural. What was unnatural, however, was the apparent color. When the bottom of the cabochon was viewed with magnification and a combination of overhead and darkfield lighting, a slightly uneven blue coating was clearly visible. In fact, two small chips near the stone's edge revealed colorless quartz underneath (figure 18).

Coating is one of the simplest ways to change a stone's color and is frequently used on a variety of materials, including diamond, beryl, topaz, cubic zirconia, and, of course, quartz. What made this particular ring interesting was that the color of the coating on the natural star quartz cabochon created an extremely convincing imitation of a star sapphire. As noted above, this is hardly a new material. GIA reported on a nearly identical stone—a star quartz with blue backing added to imitate star sapphire—in the Summer 1938 *GeG* (p. 168), which shows that no matter how many new treatments come on the market, gemologists must still be on guard for simple ones such as this. [Editor's note: *The Summer 1938 issue is available in PDF format on the Gems & Gemology website at www.gia.edu/gemsandgemology.*]

Wendi M. Mayerson

Figure 18. A chip on the bottom of the cabochon in figure 17 reveals colorless quartz underneath the blue coating. Magnified 30 \times .





Figure 19. This 25.35 × 17.70 × 5.75 mm cabochon was one of several samples submitted to the laboratory that at first appeared to be spiderweb turquoise, but proved to be variscite. Its resemblance to true spiderweb turquoise from the Lander Blue turquoise mine in Nevada (inset) is quite striking.

VARISCITE, Resembling Turquoise

Several cabochons of a mottled green-blue material in black matrix (figure 19), represented as turquoise from Lander, Nevada, were recently submitted to the West Coast laboratory for identification. The now-inactive Lander Blue turquoise mine was noted for small pockets of nodular turquoise with black matrix (figure 19, inset) that was called “spiderweb” turquoise. The deposit has been referred to as a “hat mine” because the pockets were small enough to be covered by a hat. The deposit was discovered in 1973, and during its relatively short lifespan only 104 lbs. (47 kg) of spiderweb turquoise was mined (A. Ahmed et al., “Türkis: der

Edelstein mit der Farbe des Himmels” [Turquoise: The Jewel of the Sky], *extraLapis* No. 16, Christian Weise, Munich, 1999, pp. 34–41).

The submitted material strongly resembled this unusually textured turquoise, but the color was less saturated than we would expect from this locality. Microscopic examination revealed a structure and texture that were not typical of turquoise, but could not rule it out given the many deposits and treatments possible for this gem material. The refractive indices of the 20.16 ct piece we tested were 1.570–1.590, which are lower than the published values for turquoise. Again, however, many impreg-

nated turquoises have lower refractive indices that may fall within this range. The samples were all backed with a black material, so a meaningful specific gravity could not be obtained.

Our standard laboratory procedure is to test all turquoise for polymer impregnation using infrared spectroscopy. The IR spectrum of this material, however, did not resemble that of turquoise at all. This effectively eliminated turquoise as a possible identification, so the next step was to obtain a Raman spectrum. The results showed a very close, but not exact, match to variscite ($\text{AlPO}_4 \cdot 2\text{H}_2\text{O}$). Variscite is a mineral in the variscite group that forms a complete solid solution with strengite ($\text{Fe}_3\text{PO}_4 \cdot 2\text{H}_2\text{O}$).

The final test was X-ray diffraction (XRD) analysis. After comparing the sample to known patterns, we determined that the material was in fact variscite. Minor variations in the Raman spectrum and the XRD pattern were probably due to variations within the variscite series. This was the first time that a sample of variscite with an appearance this close to turquoise was seen in our lab. Even our most experienced gemologists would not have suspected this material to be variscite at first glance.

Eric Fritz and Kimberly Rockwell

PHOTO CREDITS

Elizabeth Schrader—1; Shane F. McClure—2 (left), 15 and 16; Shane Elen—2 (center and right); Maha Calderon—3, 5, 13, and 14; Christopher M. Breeding—4 and 8; Wuyi Wang—6 and 7; Jessica Arditi—9 and 17; Kyaw Soe Moe—10 and 12; Wendi Mayerson—18; Don Mengason—19 and 19 (inset).

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