LAB NOTES 2004

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Notable Cat's-eye ALEXANDRITE

Through the years, the lab has had the privilege of seeing several beautiful cat's-eye alexandrites. In the Spring 1983 Lab Notes (p. 43), we reported on a 4.02 ct stone that displayed exceptional transparency, as well as a very distinct change of color from red to blue-green. In the Fall issue of the same year (p. 171), we described a much larger one, a 17-mm-diameter cat's-eye alexandrite from Sri Lanka that weighed 32.69 ct. This giant was similar in its spherical shape to the previous stone and also had high diaphaneity, but its color change, though distinct, was not ideal. In 1987, both the East and West Coast laboratories examined a number of faceted alexandrites from Minas Gerais, Brazil (Fall 1987 Lab Notes, p. 164). The color change of these stones was reminiscent of fine Russian alexandrites: green to bluish green in fluorescent light and purple to reddish purple in incandescent light. Several of these stones were cat's-eyes, but—as the needles creating the eyes were not fine enough—their chatoyancy was not exceptional. In addition, the largest was only about 1 ct.

With this history, you can see why we were delighted to examine the cat's-eye alexandrite shown in figure 1. This 16.02 ct oval cabochon was transparent to semitransparent, with a sharp eye due to very fine needles that could only be seen with magnification and fiber-optic illumination. The color change was distinct, from dark bluish green in fluorescent light to very dark reddish purple in incandescent light. The proportions of this oval cabochon were particularly noteworthy. It is a common practice with high-quality chatoyant stones to leave the bottom half very deep, as was the case with the two cat's-eyes mentioned above. This is done to save as much weight as possible from the rough, but it also causes the stones to appear smaller than their weight suggests and makes them difficult to set in jewelry. With measurements of approximately 15.28 × 12.96 × 7.90 mm, this cabochon appeared nearly the same size as the 32.69 ct stone even though it had less than half its weight—a direct result of the better proportions. This also meant that it could be set more easily into a piece of jewelry. Stones like this one, which display such an unusual combination of features (two phenomena and a nice cut), are rare and truly a delight to behold.

Wendi M. Mayerson

Figure 1. This 16.02 ct cat's-eye alexandrite, seen here in fluorescent (left) and incandescent (right) light, not only has fine transparency, a sharp eye, and a distinct color change, but it has good proportions as well.

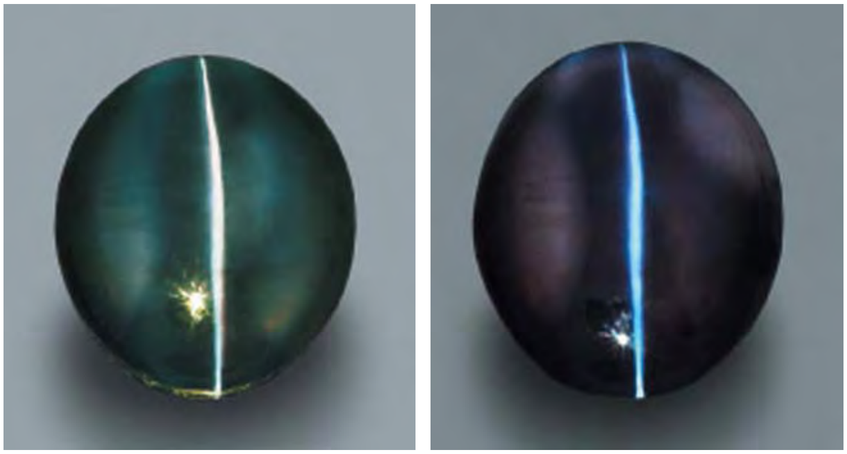

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Figure 2. This 1.02 ct diamond is colored by a pink residue in the large fractures that reach the surface through the crown. The rest of the diamond is near-colorless.

Figure 3. Closer observation shows not only pink in the fractures but also a blue flash-effect color that is typically associated with fracture filling to improve apparent clarity. Magnified 30×.

DIAMOND

Fracture Filled, to Alter Color and Enhance Clarity

While diamonds typically are fracture filled to improve their apparent clarity, we have also seen stones in which a "filler" has been used for other purposes. For example, in the Spring 2003 Lab Notes section (pp. 38–39), the East Coast laboratory reported on a 0.20 ct round brilliant diamond that was filled primarily to produce a pink appearance. This diamond showed an uneven face-up color distribution, with the pink color confined to the eye-visible fractures. No attempt had been made to reduce the visibility of the large fractures, which showed areas of concentrated pink color in a fingerprint pattern when examined with magnification.

Recently, the East Coast lab received the 1.02 ct "pink" round brilliant diamond shown in figure 2 for identification and origin-of-color determination. Like the diamond examined earlier, this stone exhibited uneven coloration, with the pink concentrated in large fractures; magnification of these fractures revealed a dried pink substance in a fingerprint pattern. However, further examination also revealed the flash-effect colors typically associated with the substances used for clarity enhancement (see, e.g., figure 3). These flash-effect colors were visible in the smaller fractures and deeper parts of the large fractures, while the pink color was confined to the largest and most obvious fractures.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy indicated the presence of lead and bromine. Both of these elements, which are not found in untreated diamonds, have been identified in diamond fracture-filling materials used for clarity enhancement (see, e.g., R. C. Kammerling et al., "An update on filled diamonds: Identification and durability," Fall 1994 *Gems & Gemology*, pp. 142–177). From this evidence, we concluded that the diamond was indeed fracture filled to improve its clarity. Since the colorless filling was seen deeper in the fractures than the dye, we assume that the diamond was first fracture filled, and then dyed. This is the first diamond we have seen that showed both types of treatment.

Siau Fung Yeung and Thomas Gelb

Moon-like Surface on a Crystal

Most diamonds are subjected to at least one period of dissolution after their formation and subsequent transport to the surface of the earth. This process results in various surface features, from macro-scale modifications of the crystal morphology to micro-scale etch figures. All of these features are the result of the interaction between corrosive solutions and a diamond's crystal structure (in particular, lattice imperfections in that structure). Common dissolution features include pyramidal trigons produced at dislocation outcrops, flat-bottomed trigons related to dislocations and/or impurities, and etch figures with hexagonal or rhombic forms that are related to twin boundaries on the surfaces (see, e.g., S. Tolansky, *The Microstructures of Diamond Surface*, N.A.G. Press, London, 1955; Yu. L. Orlov, *The Mineralogy of Diamonds*, John Wiley & Sons, New York, 1973). We recently examined a very unusual rough diamond, submitted for origin-of-color determination, with a surface that not only had numerous green radiation stains but also showed a large number of round, crater-like depressions of varying sizes.

The 2.70 ct modified dodecahedron/octahedron (figure 4) measured 8.38 × 7.98 × 5.18 mm. Infrared spectroscopy established that it was a type IaA diamond, with a high concentration of nitrogen. The green

Figure 4. In addition to numerous green radiation stains, the surface of this 2.70 ct diamond crystal was seen to have many unusual round depressions of varying sizes.

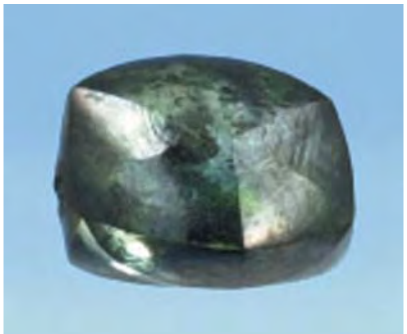


Figure 5. With magnification, the diamond shown in figure 4 revealed an unusual moon-like surface with many round depressions due to etching. The largest "crater" shown here is about 500 µm in diameter.

radiation stains covered the entire surface, forming the typical shallow green "skin" seen on diamonds that have been subjected to natural irradiation. The interior of the stone, as viewed through polished "windows," appeared to be near-colorless. Examination with a microscope revealed that the crater-like depressions (figure 5) occurred randomly over approximately half of the diamond's surface, with no specific relationship to crystal orientation observed. All were almost perfectly round, with the maximum depth estimated at less than 10 µm. Some depressions overlapped one another, and some small "craters" were present within larger ones. They varied significantly in diameter, from ~500 µm to less than 10 µm, with most of them smaller than 100 µm. These features constituted a very interesting phenomenon that called to mind the surface of the moon, with its many round meteorite impact craters. There was no clear corresponding relationship between these depressions and the green radiation stains, although some stains were observed in the flat bottoms of certain depressions.

Judging from the curved corners, faces, and edges of the crystal, it was obvious that it had been subjected to dissolution. The round depressions possibly also formed due to etching. Unlike those etch figures that are seen more commonly, these depressions are most likely discoid sculptures (see Orlov, pp. 93–98), which have been observed on the curved surfaces of rounded crystals from certain diamond deposits. Formation of these discoid sculptures could be related to some special lattice defects in the crystal and selective dissolution processes. The spatial distribution of the green stains and round depressions indicates that the etching process took place before the natural irradiation, which would be expected since such irradiation typically occurs after diamonds have been weathered from their primary deposits.

Detailed investigation of the fine structures of these discoid sculptures and the related green stains could provide a better understanding of the interaction of dissolution and irradiation processes in diamond.

Wuyi Wang, Taijin Lu, and TMM

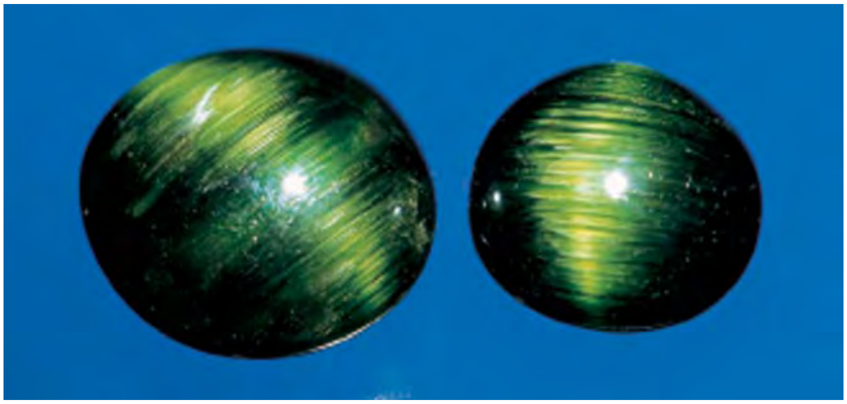
Cat's-eye Demantoid GARNETS

Two translucent to semitranslucent oval cat's-eye cabochons that appeared almost black were submitted to the West Coast laboratory for identification. Each of the cabs, which weighed 4.47 and 6.56 ct, had a broad, intense green chatoyant band (figure 6).

Their refractive indices were over the limits of a standard refractometer, and both had a hydrostatic specific gravity of 3.86. They did not fluoresce to long- or short-wave UV radiation, and they appeared red when viewed through a Chelsea filter. The visible spectrum displayed general absorption to about 510 nm and had lines in the red region at approximately 630, 650, and 680 nm; in most directions, these three lines appeared to converge into a single dark band, which made the individual lines difficult to discern. Neither showed pleochroism, which indicated that the material most likely was singly refractive. Unfortunately, due to the darkness and translucency of the cabochons, we were unable to confirm their optic nature using a polariscope.

Since the results of standard gemological testing were inconclusive, we turned to Raman analysis, which identified both stones as andradite. This was consistent with their gemological properties. Since their visi-

Figure 6. These two cat's-eye demantoid garnets (6.56 and 4.47 ct) are unusually dark with an intense green chatoyant band.



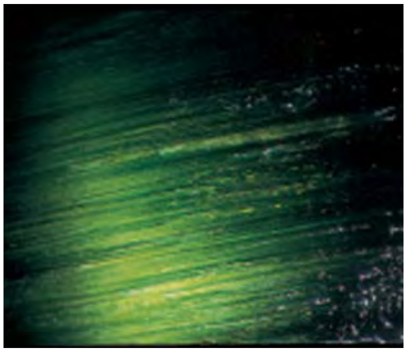
ble spectra and Chelsea filter reactions indicated the presence of chromium, and the "eyes" of both showed an intense green color, we concluded that they were cat's-eye demantoid garnets.

Gems & Gemology has reported on cat's-eye demantoid in the past (see Fall 1985 Lab Notes, p. 174; Winter 1994 Gem News, pp. 272–273). Most recently, a Gem News International item in the Spring 2004 issue (pp. 67–68) described yellowish green to dark "emerald" green demantoid garnets from Iran, some displaying chatoyancy. Two yellowish green cat's-eyes were illustrated in an accompanying photo. However, the two cabochons featured here represent the other end of the color range for cat's-eye demantoid. Except for the eye, these stones appeared virtually black in reflected light. The parallel bundles of fine fibers (most likely a form of asbestos; figure 7) that produced the chatoyancy reflected the intense green bodycolor of the material.

The two stones described here are owned by Robert Petersen of Dublin, California. Reportedly, they are from an undisclosed locality within the U.S., which makes them that much more unusual.

Elizabeth P. Quinn

Figure 7. Parallel bundles of fine fibers are responsible for the chatoyancy in the two cat's-eye demantoids in figure 6. Magnified 20×.



High R.I. GLASS Sold as Peridot

Recently, the East Coast laboratory was asked to identify a large (38.00 × 23.95 × 16.30 mm) dark yellowish green modified shield mixed cut set in a white metal ring that also contained numerous transparent near-colorless and green round brilliants (figure 8). The ring had been purchased at auction with the center stone represented as peridot. The story was that the "peridot" was purchased by the original owner as a loose stone in Africa; on returning to the U.S., the owner had it set in this custom mounting.

The first thing we noticed when viewing the ring was the extremely high dispersion of the center "gem." To the trained gemologist, this feature made it look more like sphalerite than peridot (see, e.g., Fall 1992 Gem News, p. 204). Standard gemological testing revealed a refractive index above 1.81 (over the limits [OTL] of the refractometer), which conclusively ruled out peridot. As there are several OTL gem materials with similarly high dispersion, such as cubic zirconia, strontium titanate, synthetic rutile, sphene, and sphalerite, the next step was to narrow down the field by optic character. The specimen acted in a singly refractive (SR) manner in the polariscope, and no visible doubling was seen with magnification. This meant it was either SR or amorphous, which ruled out synthetic rutile and sphene. Even though most glass used to imitate gemstones has an R.I. of around 1.40–1.60, it could not be ruled out as a possibility, since we have seen examples of manufactured glass that were OTL (see, e.g., Winter 1993 Gem News, p. 289).

Specific gravity can be a useful property by which to separate gems that are OTL, but such testing was not possible in this case because the specimen was mounted. No reaction was seen to either short- or long-wave ultraviolet radiation. However, with magnification one tiny, high-relief gas bubble was evident through the crown near the girdle. This feature ruled out sphalerite, indicating instead that the specimen was either a melt-process synthetic or a glass.

Figure 8. The large dark yellowish green modified shield cut in this ring exhibits high dispersion. Although it was purchased as a peridot, advanced testing identified it as glass.

Advanced testing was required for a final identification. Qualitative chemical analysis by EDXRF spectroscopy revealed that the specimen consisted mostly of zirconium with some titanium and silicon—not consistent with any known gem mineral, natural or synthetic. Infrared spectroscopy revealed two broad peaks associated with glass. The most conclusive information, though, came by taking a minute scraping and performing X-ray diffraction analysis. This test revealed that the specimen did not have a crystal structure and was in fact amorphous. As a result, we concluded that the item in question was a manufactured glass.

This is not the first time we have seen glass sold as peridot. In the Spring 1999 Lab Notes (p. 44), we reported on a 26.28 ct faceted oval we had identified as glass; it had been purchased at the 1998 Tucson gem show as Chinese peridot. Coincidentally, like this most recent piece, that material had an R.I. that was OTL.

Wendi M. Mayerson

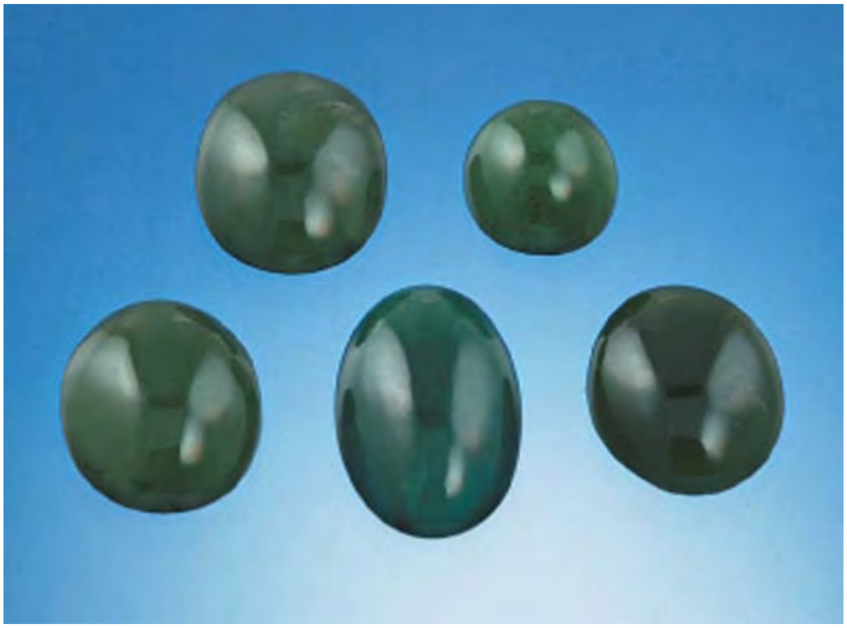


Figure 9. The 17.35 × 9.56 × 3.97 mm dyed jadeite cabochon in the center of the bottom row closely resembles the nephrite cabochons surrounding it.

Dyed JADEITE, Resembling Nephrite

In the spring of 2004, the East Coast laboratory received a 5.65 ct translucent green oval cabochon measuring 17.35 × 9.56 × 3.97 mm. The client believed the cab was nephrite and had submitted it for an identification report. Seen as the bottom-middle cabochon in figure 9, it did resemble the four surrounding nephrites taken from the laboratory research collection. Yet standard gemological testing revealed an R.I. of 1.67 on the base of the cabochon and a volumetric S.G. of 3.31, properties that pointed to jadeite, not nephrite.

Testing with a desk-model spectroscope revealed a dye band at approximately 670 nm, slightly higher than the 650 nm band standard for dye, and there was no reaction to short or long-wave UV radiation. Magnification used in conjunction with transmitted light confirmed the presence of dye (seen in figure 10) as threads of green color in fractures and between individual grains. This visual confirmation is useful even when a dye band is not present, as was the case with the bangle bracelet reported in the Summer 1997 Lab Notes (pp. 138–139). Infrared spectroscopy, a test run as standard procedure on all jadeite, showed no evidence of impregnation.

In 1984, both the East and the West Coast laboratories had the opportunity to study a dyed nephrite cabochon (Spring 1984 Lab Notes, p. 48). That 1.06 ct stone resembled fine green jadeite in color and showed dye concentrations in and around cracks. Notice the shape of the dye concentrations in that dyed nephrite sample (figure 11, left). The grain structure seen in our dyed jadeite, which allows the dye to surround the individual grains, is typical for jadeite (figure 11, right); nephrite is known to have a more fibrous texture (R. Webster, *Gems*, 5th ed., rev. by P.G. Read, Butterworth-Heinemann, London, 1994, p. 272). In fact, it has been suggested that the reason dyed nephrite is not common is because the structure of nephrite resists the dyeing process (Spring 1984 Lab Notes, p. 48).

Figure 10. In transmitted light, the dye concentrations in this 5.65 ct jadeite cabochon could be seen surrounding individual grains, as well as filling surface-reaching cracks and fractures.

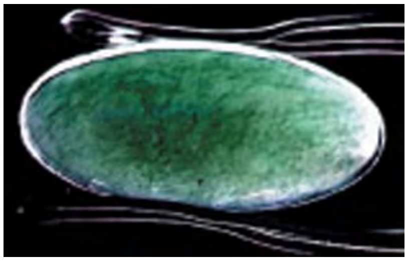
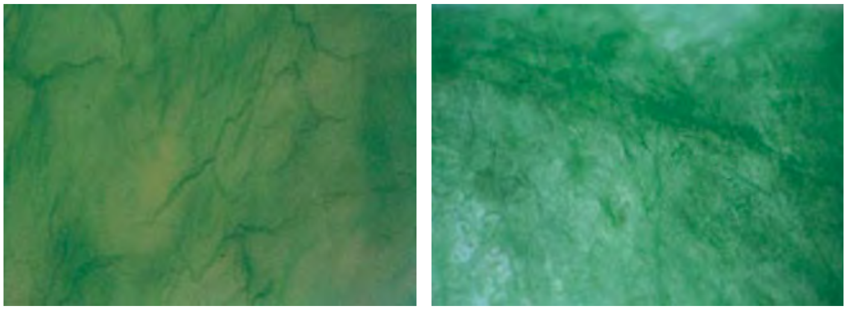


Figure 11. There is a noticeable difference in the way jadeite and nephrite accept dye, due to the differences in their grain structures. The fibrous nephrite grains are more closely interlocked and seem to restrict the absorption of dye to surface cracks and fractures (left, magnified 15×). The more rounded grains of jadeite allow dye to seep in between individual grains and surround them, as well as concentrate in surface cracks and fractures (right, magnified 20×).



Jadeite is often dyed to imitate the finest Imperial jadeite, a bright, vivid green. What makes this piece so unusual is that the color more closely resembles nephrite—typically a darker, less saturated green. It is possible, since there was no polymer impregnation, that this is an old piece in which the dye has degraded over time; it may also just be a poor dye job. It is hard to imagine why this cabochon (or any jadeite) would be dyed specifically to imitate nephrite.

Wendi M. Mayerson

Green QUARTZ with Brazil-law Twinning

Recently, the West Coast laboratory examined a 9.70 ct transparent light grayish yellowish green oval modified brilliant that was readily identified as quartz (figure 12). It displayed a noteworthy example of Brazil-law twinning, which aided us in the identification (figure 13).

Brazil-law twinning is a type of polysynthetic twinning that typically occurs in natural amethyst. Its presence is usually a very good indication that the material is of natural origin. Most synthetic quartz contains no such twinning. While some hydrothermal synthetic quartz grown on twinned natural amethyst seeds may contain Brazil-law twinning (J. I. Koivula and E. Fritsch, "The growth of Brazil-twinned synthetic quartz and the potential for synthetic amethyst twinned on the Brazil law," Fall 1989 *Gems & Gemology*, pp. 159–164), in our experience little if any of this material is available on the market.

Brazil-law twinning is observed when stones are viewed parallel to the optic axis between crossed polarizing filters. Because it may be difficult to see this twinning in some faceted amethysts due to their small size and/or the position of the optic axis, immersion of such stones in water is recommended as a viewing aid. We concluded that the otherwise clean green quartz we examined was of natural origin based on the presence of the well-defined Brazil-law twinning.

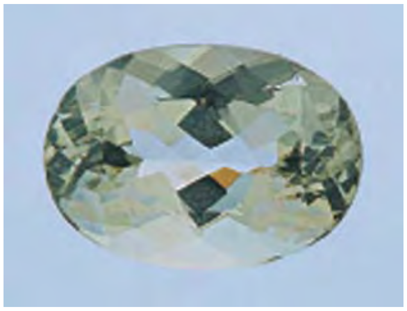


Figure 12. This 9.70 ct light grayish yellowish green modified brilliant proved to be natural quartz.

Figure 13. When the light green quartz in figure 12 was observed parallel to the optic axis between crossed polarizers, it displayed a notable example of Brazil-law twinning. Such twinning is characteristic of natural amethyst.

As with the much more common yellow variety, citrine, green quartz is typically produced by heat treating amethyst, although the green color can occur naturally, as with the green quartz found on the California-Nevada border (T. R. Paradise, "The natural formation and occurrence of green quartz," Spring 1982 *Gems & Gemology*, pp. 39–42). However, there are unsubstantiated reports that the green color of the stone described in this entry was instead produced by an irradiation technique.

Currently there is no way to separate naturally heated from heat-treated green quartz. This material is sometimes referred to as "greened amethyst" or "prasiolite" in the trade.

Elizabeth P. Quinn

SYNTHETIC SAPPHIRE with Unusual Yellowish Green Bodycolor

The light yellowish green emerald cut shown in figure 14 was submitted to the East Coast laboratory last spring for an emerald report. This service indicates whether or not clarity enhancement is present and, if it is, to what degree. Measuring 12.29 × 10.32 × 6.37 mm, the 8.85 ct specimen was eye clean—atypical for emerald, but not uncommon for green beryl. However, standard gemological testing revealed an R.I. of 1.761–1.770, a specific gravity (measured volumetrically) of 4.02, and tiny scattered high-relief gas bubbles seen with magnification and horizontal fiber-optic illumination. These properties indicated the specimen was a synthetic sapphire.

Light yellowish green is an uncommon color for sapphire, whether natural or synthetic. However, we

Figure 14. This 8.85 ct light yellowish green emerald cut submitted for an emerald report was identified as a synthetic sapphire. Its unusual color is attributed to a combination of cobalt and vanadium.

have reported on two similar synthetic sapphires, one even displaying asterism (Lab Notes: Spring 1995, pp. 57–58; Spring 1996, p. 51). As in both previous cases, the current gem did not show any iron-related bands in the desk-model spectroscope (450–470 nm). This absorption contributes to the color in natural green sapphires, which are often dark and inky in appearance. Nor, however, did we see any features around 670 nm, which were observed in the two examples described previously. When tested with EDXRF spectroscopy, both of these earlier samples were found to be colored solely by cobalt (Co^{3+}). This was also the case for some Swiss-manufactured synthetic sapphires in this color range that were examined by GIA Research and the laboratory (again, see the Spring 1995 Lab Note).

For further comparison of this specimen to the two we had reported on previously, we also submitted it to qualitative chemical analysis by EDXRF spectroscopy, which revealed vanadium (V^{3+}) as well as cobalt (Co^{3+}). This combination of elements has been found in non-phenomenal green synthetic sapphires produced in the U.S. (again, see the Spring 1995 Lab Note). To date, cobalt has not been documented as a coloring agent in natural sapphire.

Wendi M. Mayerson

SPINEL

With Interesting Etch Tubes

An 8.88 ct transparent orange-red modified rectangular mixed-cut gem, represented as spinel, was submitted to the West Coast laboratory by Zava Master Cuts of Fallbrook, California, for an identification report (figure 15). The 12.88 × 9.13 × 8.96 mm stone was reportedly from Tanzania's Umba Valley, and contained some interesting internal features.

Gemological properties were consistent with those previously recorded for natural spinel. The stone was singly refractive with an R.I. of 1.711 and a hydrostatic S.G. of 3.60. It fluoresced medium to strong red to long-wave UV radiation and extremely weak red to short-wave UV. Using a Beck prism spectroscope, we observed weak chromium lines in the red end of the visible spectrum, along with a band centered at about 560 nm.

Figure 15. This attractive 8.88 ct orange-red spinel is reportedly from the Umba Valley of Tanzania.

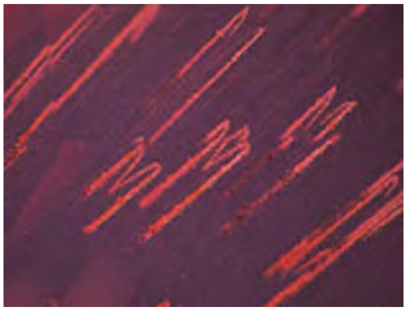


Figure 16. Laboratory staff members had never before observed the unusual "M"-shaped etch tubes seen in the spinel in figure 15. Magnified 10×.

Microscopic examination revealed stringers, a plane of fine particles, and some unusual etch tubes that we had never seen before. What was interesting was that several of these etch tubes joined to form the letter "M" (figure 16).

Etch tubes form as a result of chemical dissolution along dislocations in their host. Since such dissolution starts at the host's surface and works inward, the resulting hollow tubes must also extend to the surface unless the host went through a second growth period after the development of the etch tubes. In this spinel, the etch tubes reached the surface and were filled with an orangy yellow limonite-like material, leading us to believe that no secondary growth period occurred. The "M"—or "W"—shapes of these features suggest that they developed in dislocations between octahedral planes, although this could not be precisely determined due to the faceted form of the stone and the isometric nature of spinel.

Elizabeth P. Quinn and John I. Koivula

Natural, Identified with Photoluminescence

An 8.38 ct purple-pink oval modified brilliant was received at the West Coast laboratory for identification (figure 17). The stone was very clean, with just a few pinpoint inclusions and a small feather visible with a standard gemological microscope. Gemological properties included: R.I.—1.714, singly refractive; hydrostatic S.G.—3.59; and fluorescence—weak red to long-wave and inert to short-wave UV radiation. With a desk-model spectroscope, the stone showed Cr^{3+} lines (684 and 685.5 nm) and an Fe^{2+} line (460 nm). These properties, particularly the low R.I., fluorescence reactions, and lack of any anomalous double refraction in the polariscope, were consistent with natural spinel. Additionally, we have not encountered any synthetic spinel with this strong purple color.

However, we still felt that the near-absence of inclusions warranted a more in-depth investigation. Therefore, we performed EDXRF chemical analysis, which revealed a rather high iron content (consistent with the spectroscopic observation) but very little zinc. According to data presented in S. Muhlmeister et al. ("Flux-grown synthetic red and blue spinels from Russia," Summer 1993 *Gems & Gemology*, pp. 81–98), the flux-grown synthetic spinels they studied were consistently low in Zn and Fe, but the natural spinels they examined showed a wide range of Zn and Fe. For comparison, we conducted EDXRF analyses of nine faceted natural spinels and four flux-grown synthetic spinels (three faceted and one rough) from the GIA Museum and Research collections. All the natural samples had colors as similar as possible to the stone in question, whereas the synthetic ones were in different shades of red. All the natural spinels had high Zn, significant Fe, and varying Ga contents. The synthetic samples, however, showed little or no Zn, Fe, or Ga, which is consistent with the Muhlmeister et al. study.

Recently, photoluminescence (PL) spectroscopy has also been applied to study red and blue spinels (F. Notari and C. Grobon, "Spectrométrie de fluorescence du chrome (Cr^{3+}) dans les spinelles," *Revue de Gemmologie a.f.g.*, No. 147, 2003, pp. 24–30; V. A. Deeva and Y. B. Shelementiev, "Gemological properties of synthetic flux spinel," *Gemmological Bulletin*, No. 6, 2002, pp. 9–17). Therefore, we recorded PL spectra for the 14 samples mentioned above, using a high-resolution spectrometer with a 514 nm laser. The spectra of two of the natural and two of the synthetic samples are shown in figure 18. All peaks were due to traces of Cr^{3+}; however, the natural samples showed narrow peaks, while the synthetic spinels showed broad "humps." This is consistent with the spectra shown in Deeva and Shelementiev (2002). We agree with these authors, who suggested that the broader bands in synthetic spinels are due to the presence of irregularity (disorder) and defects in their crystal lattice. The PL spectrum of the client stone was nearly identical to the spectra of the natural spinels (again, see figure 18).

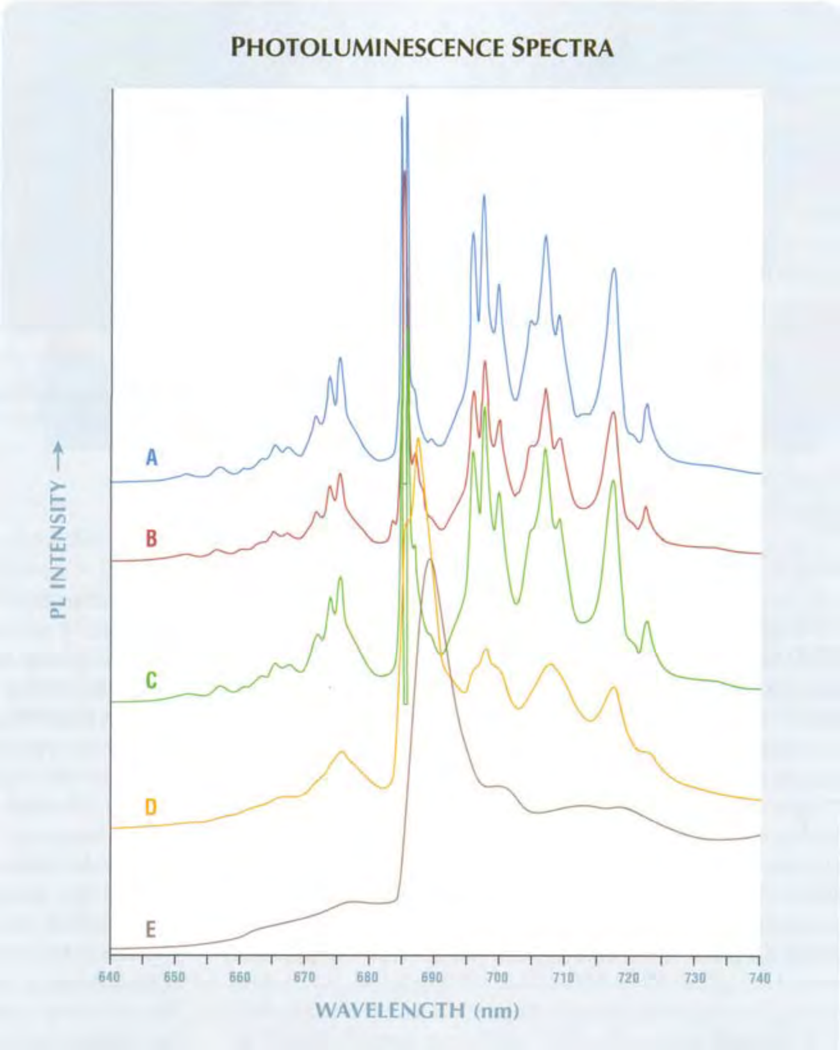


Figure 18. The PL spectra of the stone in figure 17 (A), two natural (B-C), and two flux-grown synthetic (D-E) spinels are given here. The natural spinels show much sharper and narrower peaks than do the synthetics, which have broader "humps." The sharp peaks in spectrum A clearly show the natural origin of the spinel in figure 17.

Figure 17. This 8.38 ct purple-pink spinel proved to be of natural origin based on its photoluminescence spectra.

Even more so than EDXRF, photoluminescence spectroscopy provides an easy and unambiguous separation of synthetic spinel from its natural counterpart.

Andy Hsi-Tien Shen, Christopher M. Breeding, and Dino DeGhionno

PHOTO CREDITS
Elizabeth Schrader—1, 2, 4, 8, 9, and 14; V. Cracco—3; Wuyi Wang—5; Maha Tannous—6, 12, 15, and 17; Shane F. McClure—7 and 11; Wendi M. Mayerson—10; John I. Koivula—13 and 16.