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Diamond Cut: A Foundation for Grading

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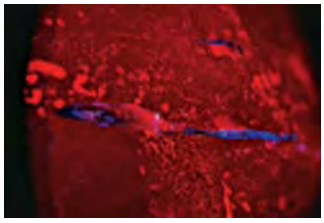
EDITORIAL



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spectroscopy found no evidence of polymer impregnation. Thus, we concluded that these beads were, in fact, of natural color and not impregnated—an impressive result for such a well-matched, highly polished set of beads this size. Alternating with yellow metal spheres pavé set with numerous transparent yellow round brilliants, these coral beads were the highlight of a stunning necklace.

Wendi M. Mayerson

DIAMOND

Four Blue Diamonds from a Historic Necklace

The Cullinan blue diamond necklace (figure 2) holds a special place in the history of African diamond mining. While its classic style, workmanship, and rare blue diamonds have made it famous, it started as a personal memento—a gift to celebrate a special event. This Edwardian gold back, silver top, festoon necklace was presented by Thomas Cullinan, then chairman of the Premier mine, to his wife Annie in 1905 to commemorate the gift of the 3,106 ct Cullinan diamond to England's King Edward VII and Cullinan's subsequent knighthood. Mr. Cullinan could not have known at the time that blue diamonds such as those in the necklace would one day become as synonymous with the Premier (recently renamed Cullinan) mine as the famous large colorless crystals it has produced. Nor would he have known that blue diamonds would remain rare and among the most highly valued of all diamonds.

The exhibition of the Cullinan blue diamond necklace at GIA's museum in Carlsbad this fall presented a welcome opportunity to examine the necklace for the first time in many years, and to do so in detail for the first time ever. For this occasion, the current owner requested that detailed gemological information accompany the exhibition of the piece so as to better inform the public about this unique necklace. For our examination,

Figure 2. The Cullinan blue diamond necklace dates back to 1905 and contains several rare type IIb blue diamonds, the largest of which is 2.60 ct. Courtesy of S. H. Silver Co., Menlo Park, California.

the four principal blue diamonds (an oval shape weighing 2.60 ct—referred to as the Cullinan blue diamond—and three Old European cut brilliants weighing 0.75 ct, 0.73 ct, and 0.42 ct) were removed from the mounting for grading (figure 3), and the necklace itself was given a thorough inspection. Three of the four blue diamonds (all except the 0.42 ct) had been previously graded by GIA, most recently in 1993. That grading took place prior to the 1995 enhancements to GIA's colored diamond color grading system. Additionally, the 0.75 ct and 0.73 ct Old European brilliants had been graded in the mounting, which did not allow a precise assessment. Thus, this was an important opportunity to review the grading of these diamonds.

The 2.60 ct oval-shaped center stone was described as Fancy Intense blue. The three Old European brilliants were each color graded Fancy grayish blue. The range of color in which blue diamonds occur is relatively compressed in saturation, and varies more widely in tone. Therefore, appearance differences are often differences in lightness to darkness rather than the strength or purity of the color. The four blue diamonds are relatively similar in tone, which explains their selection for the necklace. It is the stronger saturation of the 2.60 ct oval that accounts for its Fancy Intense grade.

Other gemological properties were consistent with those of typical type IIb natural-color blue diamonds (see J. M. King et al., "Characterizing natural-color type IIb blue diamonds," Winter 1998 *Gems & Gemology*, pp. 246–268). None of the diamonds showed a noticeable reaction to long- or short-wave ultraviolet radiation, and all of them were electrically conductive. Electrical conductivity is measured by placing the stone on a metal base plate and touching a probe carrying an electrical current to various surfaces of the

Figure 3. The four main blue diamonds are shown here removed from the necklace. The Fancy Intense blue oval at top weighs 2.60 ct, while the three Fancy grayish blue Old European brilliants weigh, from left to right, 0.75 ct, 0.42 ct, and 0.73 ct.

diamond. The conductivity value can vary with direction, so a number of measurements are made and the highest value is recorded. As noted in previous studies (again, see King et al., 1998), the highest electrical conductivity value can vary widely within and between color grades. We found this to be the case with these diamonds, as each showed a range of values. Interestingly, the Fancy Intense blue oval—the most strongly colored—displayed the lowest value.

It is common for type IIb blue diamonds to phosphoresce after exposure to short-wave UV radiation, and this characteristic was noted for all four stones. Although the best-known phosphorescent reaction in blue diamonds is that of the famous Hope diamond, the Hope's long-lasting strong red phosphorescence is actually quite rare. It is much more common for phosphorescence to be very weak to weak blue or yellow and of short duration; this more common reaction was exhibited by the diamonds from the necklace.

Microscopic examination revealed characteristics consistent with other type IIb blues. Such diamonds frequently have an uneven color distribution, which was observed here. It is also typical for them to have relatively few solid inclusions, with fractures and indented naturals being more common. This was also consistent with our findings. As would be expected, the blue diamonds, as well as other diamonds in the necklace, exhibited minor chips and abrasions consistent with the necklace's nearly 100-year history (figure 4).

Figure 4. Minor chips and abrasions such as those seen here on the 0.42 ct Old European brilliant are often encountered on diamonds that have been worn over a long period of time.

Examination of these historic stones also gave us an important opportunity to study spectroscopic features of known natural IIb diamonds. Infrared spectroscopy showed absorptions in all four stones at 2801 and 2454 cm^{-1}, which are typical features of type IIb diamonds. Photoluminescence spectra collected using an argon laser (at 488 nm excitation) revealed emission features characteristic of natural diamonds. A relatively strong 3H emission (503.5 nm) was detected in all four stones.

Luminescence imaging is a useful way to study diamond growth, and was performed using the De Beers DiamondView. As shown in figure 5, blue luminescence and networks of polygonized dislocations are evident. Similar dislocation features were observed in all four stones. This type of dislocation network is a specific feature of natural diamond, and has never been observed in synthetic diamond.

John M. King, TMM, and Wuyi Wang

Figure 5. This luminescence image of the 2.60 ct oval-shaped diamond was collected using the De Beers DiamondView. A blue luminescence and networks of polygonized dislocations are evident; such dislocation networks are characteristic of natural diamond.

Irradiated Blue Diamond Crystal

Irradiation with or without annealing is a common technique used to enhance the color of diamonds, and those suspected of being treated in this manner are routinely submitted to the laboratory for origin-of-color testing. Most such stones are treated after faceting, and depending on the type of treatment, diagnostic color distribution features are sometimes seen. Among the few laboratory-irradiated rough diamonds we have examined was a 2.95 ct well-formed bluish green octahedron (Winter 1989 Lab Notes, pp. 238–239).

Recently, a large crystal that resembled the sample in the 1989 Lab Note was submitted to the East Coast laboratory for origin-of-color determination. The experienced client who brought the stone to our attention was suspicious of its origin even though it was represented as coming directly from the mine in central Africa.

The 11.60 ct crystal (figure 6), which measured 13.11 × 12.85 × 9.09 mm, exhibited typical octahedral crystal morphology and showed obvious resorption features on its surface. It also showed a distinct greenish blue coloration. In contrast to similarly colored natural diamonds, no green or brown radiation stains were observed with magnification. However, a slight color concentration was evident at the edges of the crystal faces (again, see figure 6). We observed a strong blue fluorescence to long-wave UV radiation and a weak green-yellow reaction to short-wave UV.

Infrared spectroscopy revealed features typical of a type Ia diamond with very high nitrogen content and a weak absorption due to hydrogen impurities. In rare cases, a high concentration of structurally bonded hydrogen in diamond could produce blue coloration, but that definitely was not the case for this crystal. A weak H1a absorption was present (at 1450 cm^{-1}), but there were no H1b, H1c, or H2 absorptions. In the UV-visible spectrum collected when the diamond was cooled by liquid nitrogen (figure 7), strong N3 (415 nm), moderate N2 (478 nm), weak H3 (503 nm), and weak 595 nm absorptions were detected; a strong and broad GR1 (741 nm) absorption also was apparent.

Figure 6. The strong blue coloration in this 11.60 ct diamond octahedron proved to be the result of laboratory irradiation.

These gemological and spectroscopic features led to the conclusion that this crystal was artificially irradiated without subsequent annealing. Considering the large size of the crystal, it is possible that the radiation-related color does not penetrate evenly throughout, as is suggested by the concentration of color along the edges.

Wuyi Wang and TMM

Irradiated Type IIb Diamond

Type IIb diamonds are often blue, due to small amounts of boron impurities. Depending on the occurrence of other defects (e.g., plastic deformation), some type IIb diamonds exhibit a gray or, more rarely, a brown color (see, e.g., King et al., 1998, cited in earlier entry). Blue also can be produced in an otherwise colorless diamond by exposure to radiation (either naturally or in a laboratory) to create a vacancy defect. Although it is technically possible to enhance the blue color of a type IIb diamond by irradiation, mixing of two different color-causing mechanisms in the same diamond may not necessarily produce an attractive color. Brown natural

Figure 7. A strong and broad GR1 absorption (741 nm), together with a weak absorption at 595 nm, indicated that the 11.60 ct greenish blue diamond was irradiated in a laboratory. The pre-existence of relatively strong Cape absorptions (e.g., N3 and N2) resulted in the green modifier.

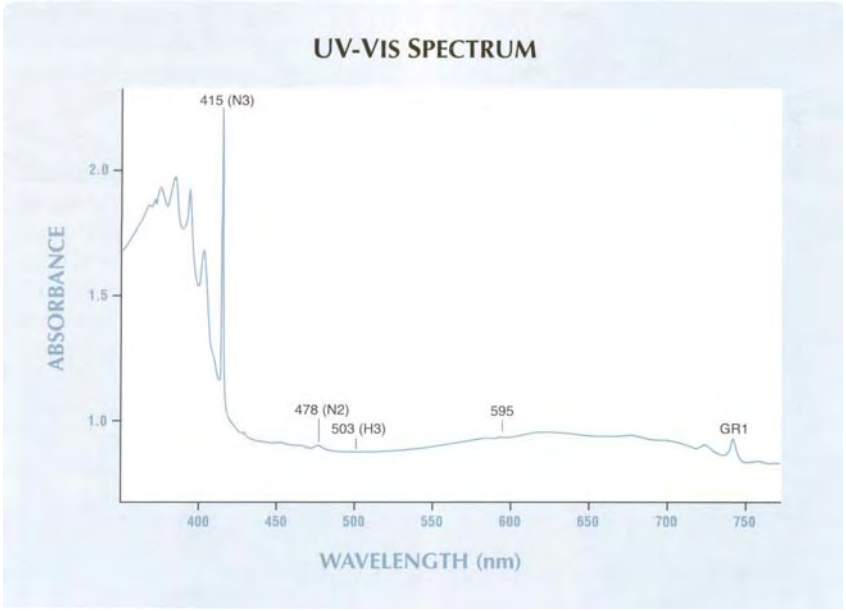

Figure 8. This 2.00 ct Fancy Dark green-gray type IIb diamond was found to have been laboratory irradiated.

radiation stains were reported on an unusual type IIb blue diamond (Fall 1991 Lab Note, pp. 174–175), but the radiation did not appear to have had any effect on the color of this faceted stone. An artificially irradiated type IIb diamond recently submitted to the East Coast laboratory gave us an extremely rare opportunity to examine a sample of this nature.

The 2.00 ct oval brilliant cut (10.52 × 7.14 × 4.21 mm) in figure 8 was color graded Fancy Dark green-gray. Although this hue was not outside the range of hues we have seen in natural-color type IIb diamonds, the cause of the color was not immediately obvious. No green or brown natural radiation stains were observed on the surface with magnification and dark-field illumination. Nor did the diamond have any notable internal characteristics such as solid inclusions or fractures, or any distinct colored graining. We did not see fluorescence to either long- or short-wave UV radiation, but very weak yellow phosphorescence was detected after exposure to short-wave UV. Infrared absorption spectroscopy only showed features typical of a type IIb diamond (e.g., strong and clear absorptions at 2801 and 2454 cm^{-1} due to substitutional boron impurities). However, when the diamond was examined more carefully with low-power binocular magnification and diffused light, a distinct blue color concentration was noted near the culet (figure 9). This type of color zoning is typical for diamonds that have been artificially irradiated with a low-energy source, as is usually done today with an electron beam.

Absorption spectroscopy collected at liquid nitrogen temperature in the ultraviolet-visible range (figure 10) showed a strong GR1 band (vacancy, 741 nm) and several other lines of the GR series (GR2 through GR8). A clear TR12 absorption at 469.9 nm also was detected. It is very rare for a natural-color type IIb diamond to show any detectable GR1 or TR12 absorption with UV-Vis absorption spectroscopy. In addition, in the photoluminescence spectrum seen with a laser Raman microspectrometer, the intensity of the 3H defect with a zero-phonon line at 503.5 nm (another typical radiation-related defect in diamond) was significantly stronger than

Figure 9. When examined with a microscope and diffused light, the diamond in figure 8 revealed a strong concentration of blue near the culet, which proved that it had been artificially irradiated. Field of view is 6.0 mm high.

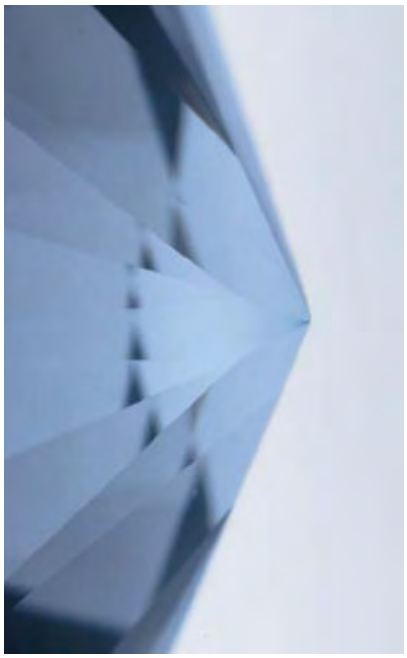

Figure 10. This UV-Vis absorption spectrum of the green-gray diamond shows a strong GR1 band and some additional lines from the GR series. A clear TR12 band also was detected. A gradual increase in absorption at higher wavelengths is attributed to the presence of boron impurities.

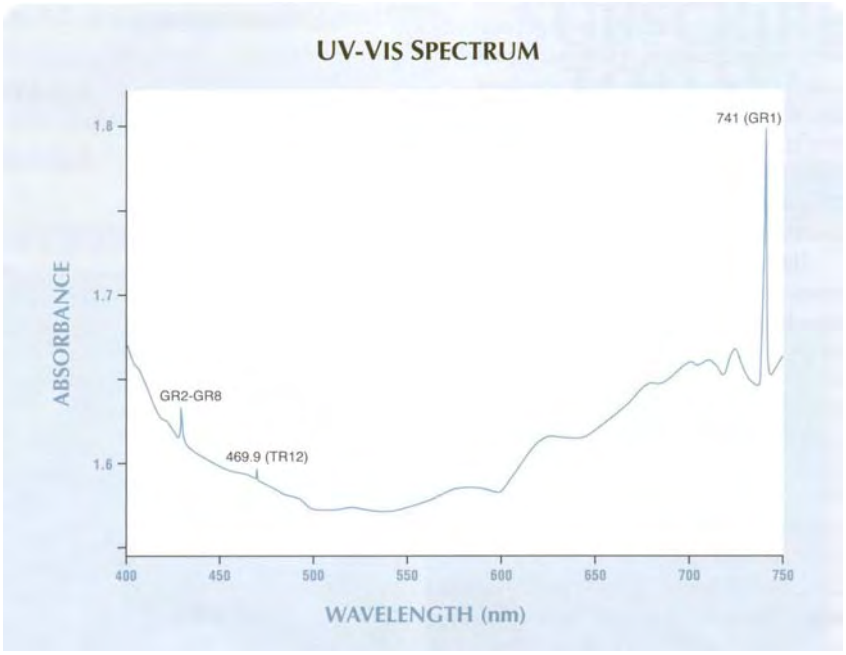

Figure 11. The color appearance of the 12+ ct Very Light blue type IaB oval modified brilliant in the center is due to scattering of light and not to any of the typical causes of natural blue color. The 6+ ct pear-shaped diamond on the left is colorless (D-color); the 5.5+ ct type IIb on the right is Fancy Light blue.

that in any natural-color type IIb diamonds we have examined. All these observations led to the conclusion that this type IIb diamond had been treated by irradiation in a laboratory.

Little is known about the interaction between vacancies and boron in diamond and the possible impact on color. The color of this specific sample is not very attractive. A possible reason is that prior to irradiation the stone may have had a strong brown component. This also would explain the green coloration after treatment.

Wuyi Wang, TMM, and Thomas Gelb

Unusual Cause of Blue Color in a Diamond

It is unusual for the laboratory to encounter natural blue diamonds with a cause of color other than boron impurities, natural irradiation, or the presence of hydrogen (see, e.g., E. Fritsch and K. Scarratt, "Natural-color nonconductive gray-to-blue diamonds," Spring 1992 *Gems & Gemology*, pp. 35–42; and King et al., 1998, cited above). Thus, it was quite a surprise when the East Coast lab recently tested an oval diamond over 12 ct (figure 11, center) with a blue color typical of that produced by boron but none of the other properties one would expect for such diamonds.

When color graded, the oval was classified as Very Light blue. On testing for electrical conductivity, the diamond was found to be nonconductive. We observed a moderate blue reaction to both long- and short-wave UV radiation. Infrared spectroscopy proved that the diamond was type IaB and did not show any elevated levels of hydrogen. Spectroscopic analysis further ruled out any possibility that this stone was irradiated in a laboratory. However, microscopic examination revealed clouds of pinpoints and internal whitish graining.

In this case, we believe the color was caused by a scattering of light in the diamond from the clouds of pinpoint inclusions. This effect is similar to the one that causes cigarette smoke to appear blue, a phenomenon often referred to as the Tyndall effect. Named after its discoverer, 19th-century British physicist John Tyndall, this effect is caused by reflection and/or scattering of light by very small particles in suspension in a transparent medium. It is often seen from the dust in the air when sunlight enters a room through a window or comes down through holes in clouds. Most diamonds that have dense clouds and also show scattering have a predominantly white or gray appearance (e.g., figure 12). The difference in color is probably related to the size of the particles and the density of the cloud.

Figure 12. More typically, the scattering of light from micro inclusions produces a predominantly white (as shown in this 7.00 ct marquise) or gray color in diamond.

We have documented diamonds with these properties from a few different geographic locations, including India and Australia. This unusual stone indicates that micro-inclusions in diamond can generate colors other than black, gray, and white. The nature of the micro-inclusions (chemistry, particle size, density, and distribution) and the size of the stone, along with the light source and its distribution of output, are all factors in determining the final color appearance of the diamond.

John M. King, Wuyi Wang, TMM

NEPHRITE that Mimics Serpentine

Because of their similar appearances, some nephrite and serpentine can be impossible to distinguish by visual observation alone. Although the two mineral species usually can be readily separated on the basis of their refractive index and specific gravity values, in some cases even these physical properties can be misleading. The West Coast laboratory recently received a 142.27 ct translucent mottled green-gray carving of a water buffalo that exhibited both an artificial water-soluble reddish stain outlining details of the carving, and a light brownish yellow coating that partially concealed the underlying host material (figure 13).

Microscopic examination revealed that the host was a fine-grained aggregate. When tested in an inconspicuous area, the coating dented and scratched easily with a metal probe, similar to the response of a wax.