NOTES
· AND ·
NEW TECHNIQUES

AN INVESTIGATION OF A SUITE OF BLACK DIAMOND JEWELRY

By Robert C. Kammerling, Robert E. Kane, John I. Koivula, and Shane F. McClure

This article reports on the gemological properties of six large black diamonds set in a suite of jewelry. The color of the diamonds was determined to be caused by numerous black inclusions lining cleavages and fractures. Such stones are difficult to cut and polish, and require great care in setting. They can be separated from artificially irradiated dark green black-appearing diamonds and from other black and black-appearing materials on the basis of their distinctive visual and gemological features.

Reports in the gemological literature have described diamonds in a great variety of colors and have ascribed the causes of these colors to a number of mechanisms. According to the comprehensive review by Fritsch and Rossman (1988), these include structural defects of unknown origin (which produce purple, pink to red, and brown colors in diamond); band transitions caused by the presence of boron (which are responsible for blue); a general radiation (GR1) center (neutral carbon vacancy) plus defects that absorb in the red (which cause green); and aggregated or isolated nitrogen impurities (resulting in yellow).

However, relatively little has been written about black diamonds and even less about the cause of their color. Some of the information that is available is contradictory or incomplete. An early reference ("Black Diamonds," 1934, p. 86) reported that black diamonds are opaque, with a structure "like fine-grained steel." They "are not used as gems, but solely for industrial purposes." Orlov (1977, p. 113) described black diamonds as resembling hematite, having no visible inclusions and being deeply colored throughout. He speculated that the color "may be due to partial changes in the crystal structure and the formation of finely dispersed graphite particles, invisible even at very high magnifications." Subsequently, however, Bruton (1978, p. 390) described black diamonds as being "usually translucent to very strong light" and often having gray spots. He attributed the black color to "their very large number of very small or sub-microscopic black inclusions which absorb nearly all the light falling on the stone." Later (1986, pp. 110–111), Bruton expanded on the controversy: "Prominent diamantaires have long declared that there are no black diamonds—that they exist only in detective stories. The origin of this belief may be that some so-called black diamonds are actually dark brown with so many specks of dark mineral inclusions that they only appear black." In some cases, artificial irradiation

ABOUT THE AUTHORS

Mr. Kammerling is director of technical development, and Mr. Koivula is chief gemologist, at the Gemological Institute of America, Santa Monica, California. Mr. Kane is supervisor of gem identification, and Mr. McClure is senior staff gemologist, in the GIA Gem Trade Laboratory, Santa Monica.

The authors wish to thank Jean-Pierre Kuntz of Marina del Rey, California, for providing the opportunity to examine and photograph the suite of black diamond jewelry shown in figure 1.

Gems & Gemology, *Vol. 26, No. 4, pp. 282–287*

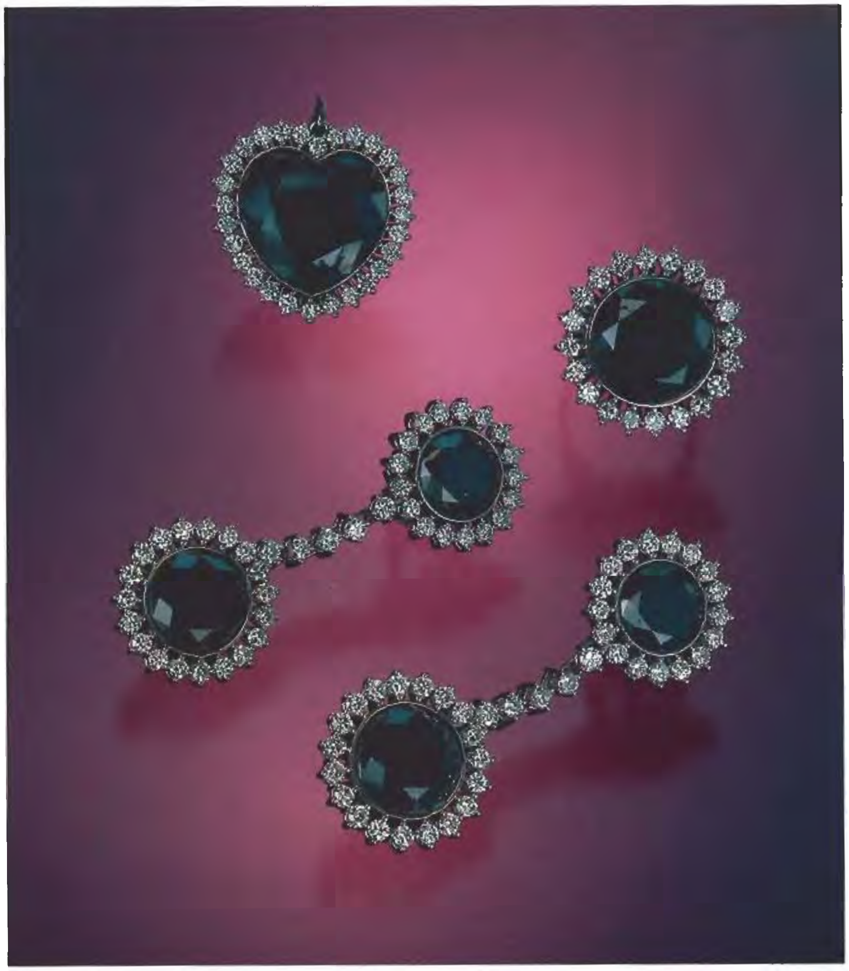


Figure 1. The six black diamonds in this impressive suite were studied for this report. The largest stone measured approximately 19.20 mm × 20.70 mm × 9.60 mm. Jewelry courtesy of Jean-Pierre Kuntz; photo by Shane F. McClure.

may produce a green color that is so dark that the diamond appears to be black (Liddicoat, 1989).

Some notable black diamonds are known, but the mechanism(s) responsible for their color has not been studied in detail. These include the Black Star of Africa, at 202 ct reportedly the largest of this color (Bruton, 1986); and the Black Orloff, a 67.50-ct cushion-shaped stone that has been described as having a "gunmetal" color (Bruton, 1986; Balfour, 1987).

Recently, the authors had the opportunity to examine a suite of jewelry that featured six brilliant-cut black diamonds (figure 1): a pendant with a heart-shaped black diamond measuring approximately 19.20 × 20.70 × 9.60 mm; a ring with a round center stone measuring approximately 16.05–16.20 × 10.02 mm; and a pair of clip-back drop earrings, each containing two round black diamonds ranging from 11.0–11.2 × 7.85 mm to 12.7–12.8 × 9.6 mm. All of these stones were subjected to standard gemological tests and examined with the microscope. The results of these tests are provided below, and conclusions are drawn with regard to the cause of color in these six stones and to the features that can be used to separate them both from artificially irradiated black-appearing diamonds and from other black gem materials with which they might be confused.

GEMOLOGICAL PROPERTIES

Visual Appearance. Several interesting observations were made with the unaided eye using overhead illumination (both incandescent and fluorescent). The body color as observed in oblique incident light could best be described as black. The luster of all six stones, as expected for diamond, was adamantine. The authors agreed that both the dark body color and (lack of) transparency contributed to the high luster, which gave the stones an almost metallic appearance. As would be expected for diamond, the facet junctions were extremely sharp, unlike what would be seen on a gem material with a very dark body color and high luster but lower hardness, such as "Alaskan black diamonds," a misnomer sometimes used for faceted hematite. Careful examination revealed that

Figure 2. Even with the unaided eye, numerous breaks can be seen reaching the surface of the black diamonds, as illustrated here by one of the round brilliants. Photo by John I. Koivula; oblique illumination.

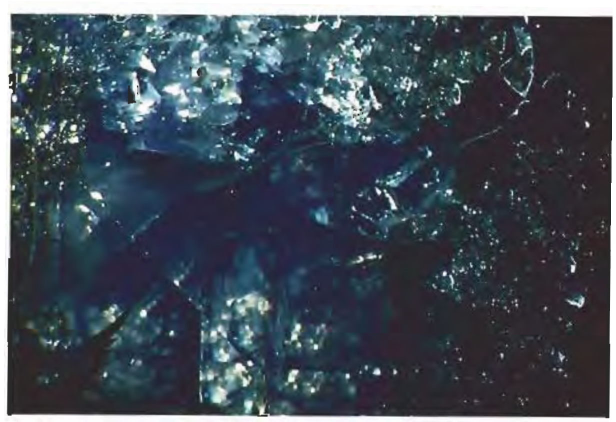
Figure 3. Artificially irradiated black-appearing diamonds typically reveal a dark green coloration through thin, relatively transparent edges when examined with intense illumination. This treated diamond, however, appeared green throughout most of the stone, even under the table as shown here. Photomicrograph by Robert E. Kane; magnified 10×.

all six stones were heavily variegated, consisting of a few transparent areas surrounded primarily by opaque zones that are caused by dense concentrations of black inclusions. Also evident to the unaided eye were small cavities and irregular interconnecting fissures on the surfaces of these stones (figure 2).

Transmission of Light. It is the authors' experience that the only conclusive method of determining if the color of a black diamond results from artificial irradiation is to pass light through a thin edge, such as at the girdle or culet. Artificially irradiated "black" diamonds exhibit a very dark green color (figure 3) at the thin edges and in the relatively transparent areas when examined using a 150-watt tungsten-halogen fiber-optic illuminator or when placed over the intense tungsten-halogen base light on a GIA GEM spectroscope unit (Liddicoat, 1989).

A fiber-optic illuminator placed perpendicular to the table under each of the mounted black diamonds revealed the following: The diamond in the ring was almost completely opaque, with only a very few, minute areas allowing the passage of white light; the lower stone in one of the earrings was also almost totally opaque, with even fewer transparent areas than the stone in the ring; the other three black diamonds in the earrings all showed several small areas that were transparent and appeared essentially colorless; the heart-shaped stone in the pendant showed numerous areas (some large) that transmitted light and ranged from light gray to colorless. At certain positions the fiber-optic light pipe caused a blue luminescence (as is seen in "Jager diamonds," an old trade term for colorless diamond with a strong blue fluorescence) in the transparent areas of the heart-shaped diamond (figure 4) and in the upper diamond of one of the earrings.

Figure 4. The transparent areas of the heart-shaped black diamond luminesced blue to an intense fiber-optic light source. Photomicrograph by Robert E. Kane; magnified 15×.



Microscopic Features. As with virtually all of the natural black diamonds the authors have collectively examined, the polish on these six stones was poor. The facets were pitted and covered with prominent polishing and drag lines, which would appear to be due to the abundance of cleavages, fractures, and inclusions that break the surfaces of the stones (figure 5). It is generally known in the trade that black diamonds are very hard to polish and can damage polishing lap.

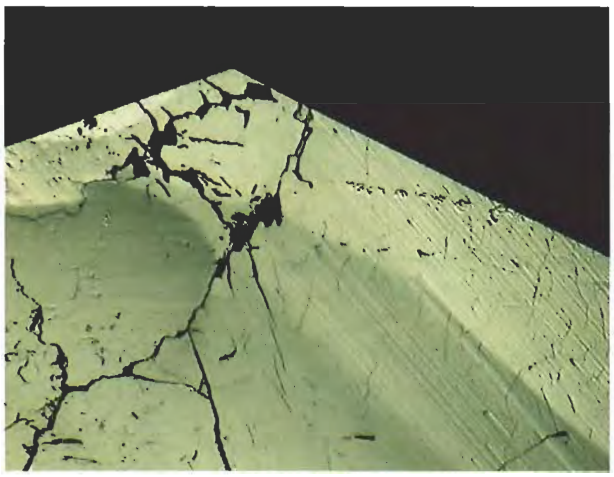


Figure 5. The numerous pits and polishing and drag lines seen on all the black diamonds studied for this report are evident on this stone. Photomicrograph by Robert E. Kane; coaxial illumination, magnified 15×.

Examination of near-surface areas and thin edges revealed that the opacity of the stones was due to numerous minute black inclusions that lined the extensive system of cleavages and fractures (figure 6). In one area on the heart-shaped stone that was covered with these opaque black inclusions, a minute part of a small cleavage plane was exposed on the surface. Careful application of a needle probe to this small section revealed that these inclusions had the platy texture and easy cleavage characteristic of graphite, in addition to the typical black color. It is known that cleavage and fracture systems in diamonds can become lined with graphite through the process of graphitization, in which the surface layer of diamond in the breaks is converted to graphite (Harris, 1968; Harris and Vance, 1972). Some sulfides, such as pyrrhotite and pentlandite, may look similar to graphite when viewed with transmitted or darkfield illumination, and may be found in cleavages and fractures immediately surrounding silicate and sulfide inclusions. However, they have an entirely different appearance (i.e., brassy yellow compared to the characteristic gray of graphite) when oblique illumination is used. We know of no published report where oxides or sulfides that resemble graphite have been seen to line the faces of extensive surface-reaching cleavage and fracture systems of the type observed in these "black" diamonds. Therefore, we concluded that the inclusions in these diamonds were graphite. Because the stones were so heavily cleaved and fractured, we decided that the potential for damage was too great to attempt to obtain a scraping for X-ray diffraction analysis. Unfortunately, the client could not leave the suite in the laboratory for the time needed to perform chemical analysis on this material.

Absorption Spectra. The visible-light absorption spectra (400 to 700 nm) of the six black diamonds were examined using a hand-held type of Beck prism spectroscope, first at room temperature and then cooled with an aerosol refrigerant to approximately −65°F/−54°C. Because the diamonds were essentially opaque, the external reflection method of spectroscope lighting was used. At either room or low temperature, we observed no

Figure 6. Numerous minute black inclusions lining cleavages and fractures were responsible for the almost opaque nature of the black diamonds. Photomicrograph by Robert E. Kane; oblique illumination, magnified 20×.

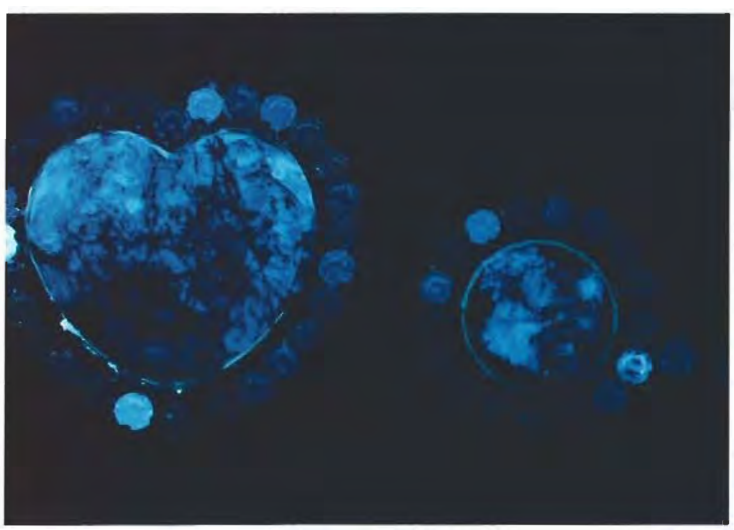
distinct lines or bands in any of the six black diamonds.

It should be noted that treated green black-appearing diamonds may on very rare occasions reveal the treatment-associated 595-nm line in the hand-held spectroscope.

Ultraviolet Fluorescence. Some of the black diamonds displayed a very unusual reaction to long- and short-wave ultraviolet radiation. The heart-shaped stone in the pendant and the top stone in one of the earrings (the same stone that showed a blue luminescence with transmitted light) exhibited a strong blue fluorescence to long-wave U.V. radiation that formed very distinct patches and veins, intermixed with inert areas (figure 7). The sections that fluoresced seemed to correlate to the more transparent areas of the stones. These same sections fluoresced a moderate chalky greenish yellow to short-wave U.V. radiation. Although still very mottled, the short-wave fluorescence was even more extensive than the long-wave fluorescence: There were very few inert areas.

The other black stone in the same earring also fluoresced to long-wave U.V. radiation, but the reaction was quite different from that described above: a very weak, chalky greenish yellow over most of the stone, again with some mottling. The large stone in the ring and both stones in the other earring were inert to both long- and short-wave U.V. radiation.

Figure 7. The heart-shaped black diamond and the upper black diamond in one of the earrings fluoresced an uneven, strong blue in distinct patches and veins, intermixed with inert areas, to long-wave U.V. radiation. Photo by Shane F. McClure.



When we examined the stones with magnification, we saw that all had been glued into their mountings. This was evident from the numerous gas bubbles present in the glue. The glue was also marked by the white fluorescent line it produced around portions of the girdle when the pieces were exposed to both long- and short-wave ultraviolet radiation. The long-wave reaction, however, was the stronger of the two. The authors hypothesize that the diamonds were glued into their mountings because of concern that any pressure from setting might cause these highly cleaved and fractured stones to break.

Streak. All six of the black diamonds cut easily into the streak plate without leaving any residue.

Thermal Conductivity. All six black diamonds registered well within the "Diamond" range on a GIA GEM Instruments pocket diamond tester.

Refractive Index. As is the case with all diamonds, the refractive indices of all six study stones were over the limits of the conventional refractometer (1.80 or 1.81).

SEPARATION FROM POSSIBLE SIMULANTS

There are some black or black-appearing gem materials that, because of their relatively high luster, might be visually confused with black diamonds. Table 1 summarizes the distinguishing properties of black diamonds and these other materials.

CONCLUSION

The six black diamonds examined for this report all contained extensive cleavage/fracture systems that were lined with black inclusions that are believed to be graphite. The presence of these inclusions is undoubtedly responsible for the black color exhibited by these stones. The fact that the areas of transparency in these stones were colorless and the absence of a 595-nm line in the spectroscope served to separate them from arti-

TABLE 1. Comparison of natural black diamonds to gem materials with which they may be confused.[a]

Material	R.I.	S.G.	Mohs hardness	Luster	Additional features
Black diamond	2.417	3.52	10	Adamantine	With magnification, numerous black inclusions can be seen lining cleavages and fractures; nonincluded areas are transparent and range from light gray to colorless
Irradiated "black" diamond	2.417	3.52	10	Adamantine	Dark green color in transmitted light; may rarely show a 595-nm absorption line in spectroscope
Hematite	Approx. 3.0	5.08–5.20	5.5–6.5	Metallic	Reddish brown streak, splintery fracture
Imitation hematite	Over limits of conventional refractometer; no measured data available	4.00–7.00	2.5–6.0	Metallic	Dark brown to black streak, granular fracture, magnetic
Melanite (titanian andradite garnet)	1.885	3.84	6.5–7.0	Subadamantine to vitreous	Conchoidal to uneven fracture, white to gray streak
Psilomelane with chalcedony	1.535–1.539	3.0–3.1	6.5–7.0	Metallic to submetallic	May be banded; conchoidal fracture, white to gray streak
Black cassiterite	2.006–2.097	6.99	6–7	Adamantine to submetallic or vitreous	White, grayish, or brown streak, subconchoidal to uneven fracture
YIG (yttrium-iron garnet)	No measured data available	Approx. 6	No measured data available	Vitreous to submetallic	Strongly attracted to magnet, does not exhibit electrical conductivity
Uraninite (pitchblende in massive form)	No measured data available	7.5–10.0 (single crystals) 5.2–9.0 (pitchblende)	5–6	Submetallic, also resinous to greasy	Causes radiation burns if worn, will generate autoradiograph; fracture is conchoidal to uneven, streak is black, brownish black, gray, or brownish green

[a]*This information is based on the six stones examined for this article. The properties of the other gem materials are as reported in Liddicoat (1989).*

ficially irradiated black-appearing diamonds, which are in reality a very dark green. They can be separated from other black or black-appearing materials on the basis of their distinctive gemological properties.

REFERENCES

Balfour I. (1987) *Famous Diamonds.* William Collins Sons Co., Glasgow, Scotland.

Black diamonds (1934). *Gemmologist,* Vol. 4, No. 39, p. 86.

Bruton E. (1978) *Diamonds.* Chilton Book Co., Radnor, PA.

Bruton E. (1986) *Legendary Gems or Gems that Made History.* Chilton Book Co., Radnor, PA.

Fritsch E., Rossman G.R. (1988) An update on color in gems. Part 3: Colors caused by band gaps and physical phenomena. *Gems & Gemology,* Vol. 24, No. 2, pp. 81–102.

Harris J.W. (1968) The recognition of diamond inclusions. Part 2: Epigenetic mineral inclusions. *Industrial Diamond Review,* Vol. 28, No. 335, pp. 458–461.

Harris J.W., Vance E.R. (1972) Induced graphitisation around crystalline inclusions in diamond. *Contributions to Mineralogy and Petrology,* Vol. 35, pp. 227–234.

Liddicoat R.T. (1989) *Handbook of Gem Identification,* 12th ed., 2nd rev. printing. Gemological Institute of America, Santa Monica, CA.

Orlov Y.L. (1977) *The Mineralogy of the Diamond.* John Wiley & Sons, New York.