Gems & Gemology

VOLUME XXVI

WINTER 1990

The quarterly journal of the Gemological Institute of America

WINTER 1990
Volume 26 No. 4

Gems & Gemology

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ABOUT THE COVER: The Dresden Green is one of the few green diamonds that is known to be of natural color. At approximately 41 ct, it is also one of the largest, and, to some, the finest, natural-color green diamonds in existence. Two senior staff members of the GIA Gem Trade Laboratory traveled to Dresden, Germany, to study in depth this remarkable stone; they were aided in this research by the director of the Green Vaults, the collection to which the Dresden Green belongs. The illustration reproduced here is based on a reconstruction suggested by Herbert Tillander. It is derived from written descriptions of the badge of the Order of the Golden Fleece, reportedly manufactured in 1746, in which both the Saxon White and Dresden Green were believed to be set. Rendering by Judy Evans, Krementz Gemstones; © Robert E. Kane.

Typesetting for Gems & Gemology *is by Scientific Composition, Los Angeles, CA. Color separations are by Effective Graphics, Compton, CA. Printing is by Waverly Press, Easton, MD.*

ISSN 0016-626X

Gems & Gemology

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Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in the Spring 1990 issue of the journal, or contact the editor for a copy. Letters on articles published in *Gems & Gemology* and other relevant matters are also welcome.

Gems & Gemology is published quarterly by the Gemological Institute of America, a nonprofit educational organization for the jewelry industry, 1660 Stewart St., Santa Monica, CA 90404.

Postmaster: Return undeliverable copies of *Gems & Gemology* to 1660 Stewart St., Santa Monica, CA 90404.

The Country of Origin Question

There was a time when the source of diamonds was considered important by some dealers. If it were possible to establish that a diamond came from Golconda in India, for example, it was considered to be superior. Actually, if the diamond had fine color and was highly transparent, it met the standards thought to be characteristic of the very finest product from Golconda. Over the years, impartial laboratory grading has rendered opinions on diamond source, though interesting, unnecessary.

Such a situation is not true with rubies and sapphires. It would appear that if a ruby originated in Burma, it has a mystical property that makes it worth appreciably more than an identical ruby from another source. The same situation applies to sapphires from Kashmir. Yet, if two stones are identical in appearance, with no hidden faults, it is difficult to understand why one should have greater value than the other.

In many cases, an experienced gemologist can be relatively certain that a ruby came from Burma, or from Thailand, or from Sri Lanka. But there are other situations in which the decision is little more than an educated guess. There are stories afloat in the jewelry industry of two stones cut from the same rough being declared from Burma in one instance and from a different source in the other. There are also cases of different origins being issued on the same stone by different laboratories. In virtually all of these cases, the decision is being made based on opinion rather than established criteria. The problem that arises when such decisions are based on opinion, even when that opinion relies on extensive experience, is that they tend to reflect on the credibility of gem testing laboratories in general.

It is my personal belief that the sourcing of colored stones misleads the public and imposes an artificial price differential. Why should someone pay more for an inferior ruby because it came from Burma? Gemstone purchases are made for the beauty of the stone—not for some artificial differentiation imposed by the trade or a laboratory.

One of the interesting features of the historic Dresden Green diamond, which is described in detail in this issue, is that it is believed to come from the Golconda mines of India. While this information is useful in establishing the provenance of this stone, it does not affect its intrinsic value economically or scientifically. The article outlining the diagnostic features of Kashmir sapphires not only gives guidelines for determining locality of origin, but also indicates how difficult, and even precarious, efforts to determine the source of a stone can be at the present time, even for the most experienced gemologist.

There is no question that diamond sales have been improved markedly by impartial grading. I feel that sales of colored stones, likewise, could be improved materially by impartial laboratory grading of the elements of quality of such stones.

Richard T. Liddicoat
Editor-in-Chief

THE LEGENDARY DRESDEN GREEN DIAMOND

By Robert E. Kane, Shane F. McClure, and Joachim Menzhausen

The approximately 41-ct Dresden Green diamond is the largest, and perhaps the finest, green diamond known to have a color of natural origin. A diamond so rich in history is well worth studying for that reason alone, but the Dresden Green offers the unique opportunity of adding valuable data to the quest for means to distinguish natural from laboratory-irradiated green diamonds. In November of 1988, two senior GIA staff members visited the Green Vaults with this goal in mind. The Dresden Green diamond proved to be not only of extraordinary quality but also a very rare type IIa—one of the purest forms of diamond. In addition, the spectral characteristics of this stone were found to overlap those of known treated diamonds. The history, locality origin, and properties of the Dresden Green diamond are discussed in detail in this article.

ABOUT THE AUTHORS

Mr. Kane is supervisor of identification, and Mr. McClure is senior staff gemologist, at the GIA Gem Trade Laboratory, Inc., Santa Monica, California. Dr. Menzhausen is director of the Grünes Gewölbe (Green Vaults), Dresden, Germany.

Please see end of article for acknowledgments.

Gems & Gemology, *Vol. 26, No. 4, pp. 248–266*

Many gemologists dream of being able to examine some of the truly famous gemstones of the world. Unfortunately, few such dreams are realized, since these gems are rarely made available. This was the case for many years with the fabled Dresden Green diamond (figure 1).

Yet just such an opportunity came to pass in late November 1988, when the three authors met in the ancient city of Dresden (figure 2), in what was then East Germany, for the purpose of examining the Dresden Green in the Green Vaults.

Noted jeweler and diamond historian Herbert Tillander was instrumental in making these arrangements. Mr. Tillander is a grandson of the famous Alexander Tillander who founded A. Tillander Jewelers, a well-known firm in St. Petersburg around the turn of the century. The Imperial family of Russia was among their clients. At a conference they had both attended in 1985, Mr. Tillander explained to Mr. Kane that during his research he had had the opportunity to examine many of the diamonds in the Green Vaults. He subsequently made the necessary introductions and inquiries that enabled GIA to negotiate the first complete gemological examination of the Dresden Green diamond. The administrators of the Green Vaults gave their consent to the project in January 1986. As one might expect, the details of such a trip were many and complicated. It was ultimately agreed that the examination should take place November 19–25, 1988, when the museum would be closed for cleaning and the diamond could be removed from its display case. An invitation was subsequently extended to George Bosshart, of the Swiss Foundation for the Research of Gemstones (SSEF), to examine the stone at the same time.

The importance of examining this diamond goes beyond its size and history, to the need to distinguish natural from laboratory-irradiated green diamonds, which is a key concern of GIA and a number of others in the

Figure 1. For more than 200 years, the approximately 41-ct Dresden Green diamond has resided in this hat ornament made by Prague jeweler Diessbach in 1768. The flowery bottom portion was originally fashioned by Geneva jeweler André Jacques Pallard in 1746 as a section of a badge of the Order of the Golden Fleece. Photo by Shane F. McClure.

jewelry industry. One of the stumbling blocks of research on this subject is the fact that very few diamonds available for examination possess a green body color that can be proved to be of natural origin. The history of the Dresden Green is documented from 1741 to the present. Its recorded color descriptions over 250 years parallel its present appearance (*Inventory Book,* 1733; Gruner, 1862; Streeter, 1882; Erbstein and Erbstein, 1884; Bauer, 1896; Bauer, 1904; Sponsel, 1915; Menzhausen, 1968), which precludes the possibility that the diamond might have been irradiated during its brief tenure in the USSR after World War II. In the authors' opinion, the consistency of these color descriptions with the current appearance of the stone provides overwhelming evidence that this

Figure 2. Today, the Green Vaults are part of a museum complex in the heart of Dresden. The Elbe River is in the foreground. Photo by Shane F. McClure and Robert E. Kane.

diamond is naturally green. It is also the largest natural green diamond known. In the more than 30 years of GIA Gem Trade Laboratory reports available, there is no record of a natural-color green diamond this large.

This article presents a brief history of the Green Vaults, a detailed chronology of the legendary green diamond, a discussion of the probable locality origin of this stone, and a complete gemological description of the Dresden Green.

Figure 3. The graceful vaulted ceilings complimented the Jewelry Room of the Green Vaults before they were damaged during World War II. Photo © The Worshipful Company of Goldsmiths, London.

A BRIEF HISTORY OF THE GREEN VAULTS

In 1721, Friedrich Augustus I, elector of Saxony (1694–1733) and king of Poland (1697–1733) – better known as Augustus the Strong – gave orders that a certain room of about 90 m^2 on the somewhat elevated ground floor of the Dresden Palace should have an opening made in its northern wall to make it accessible from the adjoining hall. This "room" – actually three chambers – was his original treasury.

The three original chambers were designated the "Silver Room," the "Jewellery Room," and the "Hall of Preciosities." Historically in this region, royal and religious treasuries alike had been closed repositories, well guarded and secured (Menzhausen, 1968). By opening these rooms to more general access, Augustus the Strong announced his intention to have his treasury represent a new kind of collection: a museum.

The walls had originally been painted green, a fact discovered recently when portions added in the 18th century were taken down for restoration. There is also reference by Augustus the Strong in 1727 to rooms with vaulted ceilings in this general area that were used to house his collection. The descriptive name *Green Vaults* (*Grünes Gewölbe*) had very probably been used colloquially by the inhabitants of the palace ever since this part of the building was completed in 1554; the name appears for the first time in a document written in 1572. Today, *Green Vaults* is the name given to the rooms that house the collections in what is now known as the Albertinum, the museum that occupies the structure that used to be the Dresden Palace. The Green Vaults still contain artifacts and works of art from the original collection of Augustus the Strong (Menzhausen, 1968).

In 1942, during the upheaval of World War II, the collections of the Green Vaults were packed into crates and removed to nearby Königstein Fortress, where they had been deposited twice before, during the Seven Years' War (1756–1763) and the "Wars of Liberation" (1813). With the end of World War II, in 1945, former French prisoners of war held at Königstein took command of the fortress. They protected the collection until a detachment from the Soviet army that was specially commissioned to safeguard works of art arrived to take it to Moscow (Menzhausen, 1968).

Although most of the original Dresden Palace was destroyed during the war, along with the entire center of Dresden, two of the original three rooms of the Green Vaults remained almost intact. There was considerable damage, however, to the Jewellery Room (figure 3). In addition, the special library of the collection was destroyed by fire, including all the card indexes and records, as well as several files concerning the history of the Green Vaults. Hundreds of descriptive reports were also lost, together with the drawings made by the 18th-century court jewelers. Only the inventory books were saved, thanks to the care and energy of Dr. Erna von Watzdorf, one of the scholars then working in the Historical Museum, who had them taken to a repository outside of Dresden. They now form the basis for all new work on the Green Vaults. The collection of the Green Vaults was returned to the German people by the Soviet government in 1958 (Menzhausen, 1968). The collection is now on display in the contemporary surroundings of the Albertinum (figure 4).

HISTORY OF THE DRESDEN GREEN DIAMOND

The Dresden Green diamond has had a fascinating and complex history. In researching this history, we used a variety of sources, including archives in Dresden, London, Idar-Oberstein, and the United States. The known chronology of the Dresden

Figure 4. The collections of the Green Vaults are now housed in a contemporary museum, the Albertinum, built on the site of the original Dresden Palace. The Jewellery Room is at the far end of this photo. Photo by Shane F. McClure.

Chronological History of the Dresden Green Diamond.*

During or prior to 1726	The large green diamond is brought (presumably to London) from the Golconda district of India by Marcus Moses.
1726	The green diamond (possibly in the rough) is offered for sale out of London in 1726 to Friedrich Augustus I ("Augustus the Strong"), elector of Saxony and king of Poland. The asking price is £30,000
1741	The green diamond is sold to Friedrich Augustus II at the Great Annual Easter Fair at Leipzig by a Jewish merchant named Delles. The price has been quoted alternately as 60,000, 200,000, or 400,000 thaler.
1742	Court Jeweler Johann Friedrich Dinglinger is commissioned by Friedrich Augustus II to fashion a badge of the Order of the Golden Fleece to hold the Dresden Green.
1746	Dinglinger's Golden Fleece is broken up and another is created by Genoan master goldsmith André Jacques Pallard. Also set in this Fleece is the approximately 49-ct Saxon white diamond.
1753	The British Museum in London receives a model of the Dresden Green diamond that was probably made when the stone was cut.
1756-63	The green diamond and the contents of the Green Vaults are moved to Königstein Fortress for safekeeping during the Seven Years War.
1768	After Saxony's defeat in the Seven Years War, Pallard's Fleece is dismantled by a jeweler named Diessbach from Prague. The section holding the Dresden Green is kept intact and is made part of the hat ornament in which it curently resides. The section holding the Saxon white also remains intact and is made part of a shoulder knot that also exists today.
1813?	During the Wars of Liberation, the green diamond and the contents of the Green Vaults are again safely stored in the old Königstein Fortress.
1925	Professor Rösch and Dr. Krümbhaar, of Germany, photograph and examine the green diamond in great detail with an optical goniometer.
1942	During World War II, the entire collection of the Green Vaults is again stored in the vaults of the Königstein Fortress.
1945	At the close of World War II, a Russian organization called the Soviet Trophies Commission removes the collection, including the Dresden Green diamond, from Königstein and takes the items to Russia.
1958	The contents of the Green Vaults are returned to Dresden.
1959	A major exhibition at the Albertinum in Dresden features items from the Green Vaults and other collections. The Dresden Green diamond is placed on public display for the first time since 1942.
1974	The Green Vaults are reopened and a representative selection of the jewelry collection is placed on display.
1988	The first complete gemological examination of the Dresden Green diamond.

*See text for corresponding references.

Green diamond is summarized in the accompanying box and discussed below.

The first reference to the presence of the green diamond in Dresden is in inventory book no. 16 of the Green Vaults (figure 5). The entry for the Dresden Green reports that in 1741 a merchant named Delles sold it to the son of Augustus the Strong, Friedrich Augustus II, elector of Saxony and (as Augustus III) king of Poland (1733–1763).

Little is known about the diamond before 1741. It was mentioned in a 1726 letter from Baron

[page 89] Second Drawer Lit: B

Sixth Shelf Folio: 202

A Large Diamond Set

No. 50. An order of the Golden Fleece consists of an extraordinarily beautiful green oval shaped diamond surrounded by small diamonds. The flames on both sides are partly set with small diamonds, partly enameled with red.

The hook is fashioned as a scroll and set with many small diamonds. In the middle is a medium sized rectangular diamond.

The green diamond was supplied in 1741 by the Jew Delles and has a weight of 160 green.* The Golden Fleece was made by the Court Jeweler Dinglinger and delivered in 1742 to the Green Vault.

Note

The golden Lambskin hanging below, with the three diamonds transferred to it, belong to the Golden Fleece with the cat's eyes as recorded. See certificate dated July 31, 1743.

No. 50. This fleece was sent in about 1745 via Prague to Vienna for redesigning. The large green diamond was used again in the new Order of the Golden Fleece and recorded as No. 55 in this diamond set. The flames and scroll were stored in the stock of diamonds; numbers 42 and 43. The setting of the small diamonds around the green diamond, however, remained in the hands of his Majesty.

This certification is signed by the official guardian on January 1748

Bleichmann

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*From the English word "grain"; 160 grains equals approximately 40 Lipish carats.

Figure 5. The hat ornament containing the Dresden Green diamond is seen here displayed on the original inventory book no. 16 of the Green Vaults. The book is open to entry No. 50, in which the acquisition of the green diamond is recorded. A translation of this entry is given below. It is interesting to note that the cover of the book is green (see inset). Photos by Shane F. McClure.

Gautier, "assessor" at the "Geheimes Rath's Collegium" in Dresden, to Le Coq, then Polish ambassador to London. The letter spoke of the green diamond being offered to Augustus the Strong by a merchant from London for the sum of 30,000 pounds sterling (Boutan, 1886).

The only other reference to the existence of the green diamond before 1941 that the authors were able to locate was encountered in a book by respected mineralogist C. J. Spencer (1971). Spencer makes reference to a model of the Dresden Green diamond that was part of the massive collection of Sir Hans Sloane, which was acquired by the British Museum of Natural History in 1753. On checking with the museum, we discovered that they did indeed have such a model (figure 6). In fact, they have two. The registry index cards (registry no. 85438 A and B) for these models state that one of them is probably from Sloane. An entry that appears to be from Sloane's own catalog of his collection is quoted on the registry card: "A modell of the green diamond brought from the diamond mines in Golconda by Marcus Moses valued at 20000 ls." This remarkable record, of which we could find no previous report in the literature, both establishes a firm link between the green diamond and India, and names the man who first brought the rough to the West. We could find no further mention of Marcus Moses in the course of our research. Because it is unlikely that a private collector could have acquired a model of the Dresden Green after the stone was in the hands of Saxon royalty, the logical source of the model is the cutter of the diamond, sometime before 1741.

Figure 6. This glass model of the Dresden Green diamond was acquired by the British Museum of Natural History in 1753. Courtesy of the British Museum; photo by Shane F. McClure.

Friedrich Augustus II purchased the green diamond at the Great Annual Easter Fair at Leipzig (Boutan, 1886). The merchant, Delles, has been alternately described as Jewish (Green Vaults inventory book no. 16), Armenian (Boutan, 1886), Dutch (Copeland, 1974), and English (Watzdorf, 1962). The purchase price of the Dresden Green is also a matter of controversy in the literature. The most frequently quoted figure is 200,000 thaler (Streeter, 1882; Erbstein and Erbstein, 1884; *Führer*, 1918; Watzdorf, 1962; Holzhausen, 1966; Menzhausen, 1968; Balfour, 1987), while other references list 60,000 thaler (Cattelle, 1911; Bauer, 1932). The most interesting reference we uncovered quotes still another price. It is mentioned in a collection of letters of Frederick the Great, king of Prussia (1712–1786), that was compiled by Max Hein (1914). The quote states that "For the siege of Brünn the King of Poland was asked for heavy artillery. He refused due to the scarcity of money; he had just spent 400,000 thaler for a large green diamond."

In 1742, Friedrich Augustus II ordered Court Jeweler Johann Friedrich Dinglinger to set the green diamond in a badge of the Order of the Golden Fleece. This order was founded in 1429 by Phillip the Good to encourage and reward virtue and faith among men of high lineage (Tillander, 1988). The original Golden Fleece only survived four years. For reasons unknown, Dinglinger's badge was broken up in 1746. Friedrich Augustus II then commissioned Geneva goldsmith André Jacques Pallard (who was then living in Vienna) to fashion another Golden Fleece featuring the Dresden Green together with the largest diamond in the Green Vaults collection, the Saxon White (which has alternately been described as weighing 48.50 ct [Menzhausen, 1968] and 49.71 ct [Gaal, 1977]). These two stones reportedly remained in this setting for more than 20 years (Menzhausen, 1968). The rendering of this piece shown in figure 7 is based on a reconstruction suggested by Tillander (1988).

From 1756 to 1763, the contents of the Green Vaults were stored at the Königstein Fortress to protect them against the ravages of the Seven Years' War. Several years after the close of this war (in which Saxony was defeated), Pallard's Fleece was also dismantled. In 1768, a jeweler named

Diessbach from Austrian Prague was commissioned to dismantle the badge and use two of the main sections to fashion a shoulder knot and a hat ornament, both of which exist today (Menzhausen, 1968).

The Dresden Green now resides in Diessbach's hat ornament (figure 1). The bottom portion of the ornament that contains the green diamond is actually an intact section of the Golden Fleece made by Pallard (Menzhausen, 1968). From the back (figure 8), one can still see a loop on the bottom of the piece that once connected it to the flames of the Golden Fleece. Above this section Diessbach added a ribbon-like design set with rows of small old-mine-cut diamonds that sweeps up from the sides and culminates in a bow. The bow is set with somewhat large antique-brilliant-cut diamonds. In addition, two large antique-cut brilliants were added, one in the center of the bow and another directly below it in the middle of the ribbons. On the back of the bow are two large loops that allowed the hat ornament to be attached by a ribbon or hat band.

The green diamond remained in the Green Vaults for the next several decades, until the early 19th century, when the Wars of Liberation forced the contents of the Green Vaults to once again be moved to Königstein Fortress.

In 1925, Prof. S. Rösch (a German mineralogist) and Dr. W. Krümbhaar (former director of the Dusseldorf Laboratory for Diamond Research) were allowed to examine the Dresden Green in great detail with an optical goniometer. This enabled them to measure exact facet angles within the limits of the bezel that still held the diamond (Rösch and Krümbhaar, 1926; Rösch, 1957).

In 1942, the treasures of the Green Vaults were once again moved to Königstein Fortress for safekeeping. At the close of World War II, a Russian organization called the Soviet Trophies Commission took the contents of the Green Vaults to Moscow; they were returned to Dresden in 1958.

The Dresden Green and its hat ornament are now on display in the Green Vaults as part of a jewelry set referred to as the "Brilliant Garnitur" (figure 9).

THE COUNTRY OF ORIGIN DEBATE: INDIA OR BRAZIL?

Tillander (1988) states that "without doubt the rough diamond [from which the famed 41-ct Dresden Green was cut] is of Indian origin even though

Figure 7. This rendering of a badge of the Order of the Golden Fleece reportedly manufactured by Pallard in 1746 is a theoretical reconstruction based on a suggestion by Tillander (1988). The top section holding the approximately 49-ct Saxon White diamond and the center section holding the Dresden Green diamond still exist today in a shoulder knot and a hat ornament, respectively. The flames and fleece on the bottom of the piece are based on written descriptions and existing examples of Pallard's work. Rendering by Judy Evans, Krementz Gemstones; © Robert E. Kane.

Figure 8. The back side of the Dresden Green hat ornament clearly shows, on the bottom of the piece, the loop that is a remnant of the Golden Fleece manufactured in 1746. Photo by Shane F. McClure.

in a few publications Brazil has been suggested." The latter suggestion probably results from reports in the literature of a colorless diamond from Brazil of similar shape (but larger, 76 ct) owned by a Mr. E. Dresden (see, e.g., Reis, 1959). This stone was also referred to as the English Dresden (Streeter, 1882).

Tillander's statement receives further support from the registry card to the Sloane Collection model of the diamond that was discussed above. The description that accompanied the model stated that the original stone was of Golconda (India) origin.

THE DRESDEN GREEN: PHYSICAL APPEARANCE

We began our examination of the Dresden Green with a thorough evaluation of its physical appearance and characteristics. These included the shape and cut, estimated carat weight, proportions, finish, clarity, and color (see table 1).

Shape and Cut. The Dresden Green diamond is a modified pear-shaped brilliant cut. It has the general facet shape, small table, and large culet that are commonly associated with the old-mine and old-European styles of cutting. The attractive overall shape of this stone has been referred to as a "pendeloque" (Boutan, 1886; Balfour, 1987).

Although the Dresden Green is securely set in a gold bezel with eight prongs, we used a screw micrometer in conjunction with a gemological microscope to obtain what we believe are accurate measurements of the stone: 29.75 mm long × 19.88 mm wide × 10.29 mm deep.

Carat Weight. Because the famous green diamond could not be removed from the bezel-prong mounting without risk of damage to the historic metalwork, we could not obtain an accurate weight with

Figure 9. Today, the hat ornament that holds the Dresden Green is displayed as part of this set of jewelry known as the "Brilliant Garnitur." The hat ornament had been removed for our examination at the time this photo was taken; a disturbance in the open area of velvet above the sword indicates where it was mounted. This set of jewelry also contains the Saxon White diamond (approximately 49 ct), set in the shoulder knot on the left, and the Dresden Yellow diamond (38 ct), one of the unmounted yellow diamonds at the bottom center. Photo by Shane F. McClure.

TABLE 1. Gemological description of the Dresden Green diamond.

SHAPE AND CUT	MODIFIED PEAR-SHAPED BRILLIANT[a]
Measurements	29.75 × 19.88 × 10.29 MM
Weight	41 CARATS[b]
PROPORTIONS	
Depth	51.8%
Table	51%
Girdle	EXTREMELY THIN TO VERY THIN[c]
Culet	SLIGHTLY LARGE
FINISH	
Polish	VERY GOOD
Symmetry	GOOD
CLARITY	VS_1 (VERY SLIGHTLY INCLUDED)[d]
COLOR[e]	
Hue	GREEN
Tone	MEDIUM (5)
Saturation	SLIGHTLY GRAYISH (1.5)
Fluorescence	None[f]

[a] *Facet shape and size are consistent with the antique style of cutting commonly associated with old-mine and old-European cuts.*
[b] *As reported by J. Menzhausen (1986).*
[c] *Nearly the entire area of the girdle is covered with nicks and chips, with a very few bruted areas.*
[d] *The nature and location of the inclusions and surface blemishes that could be seen (given the presence of the bezel) suggest that if this diamond were properly recut it could possibly receive an internally flawless or even a flawless grade. We are not, however, suggesting that such an important historical diamond ever be recut.*
[e] *In accordance with GIA Colored Stone Grading System nomenclature.*
[f] *When exposed to a GIA Gem Instruments 4-watt combination short-wave (254.6 nm)/long-wave (366 nm) ultraviolet radiation lamp.*

a modern electronic balance. However, we were able to establish an estimated weight. On the basis of extensive archival research, we concluded that the last time the diamond was weighed was before it was set in its present "bezel" mounting in 1742. The original 1741 handwritten entry in the no. 16 inventory book of the Green Vaults (again, see figure 5) states that the green diamond "has a weight of 160 green [sic]." This is in reference to the English word "grain." Based on numerous calculations made by Streeter (1882), there are four grains in an antique carat. This would equate to a weight of 40 antique carats for the Dresden Green. The carat as a unit of measure was not standardized until the metric carat (200 mg) was accepted in the beginning of the 20th century. Before then, its value depended on the city or country in which it was being used. In Leipzig, where the Dresden was purchased, one carat was equal to 205 mg (Lenzen, 1970). Thus we arrive at the generally accepted weight of 41 metric carats for the Dresden Green (Menzhausen, 1968, 1986). Prof. Rösch and Dr. Krümbhaar (1926) arrived at approximately the same weight on the basis of the calculations they made during their 1925 examination of the stone.

Proportions. As discussed above, in 1925 Rösch and Krümbhaar used an optical goniometer to measure the angles of inclination of all the completely accessible facets outside the bezel mounting (Rösch, 1957; see table 2). Tillander (1988) also studied the cutting and proportions of this diamond. Table 3 shows the present authors' analyses of the Dresden Green's proportions.

The depth percentage of a pear shape is its depth (table to culet) expressed as a percentage of its maximum width (perpendicular to its length) at the girdle. This value is calculated by simply dividing the actual depth by the width. The depth percentage of the Dresden Green diamond is 51.8%.

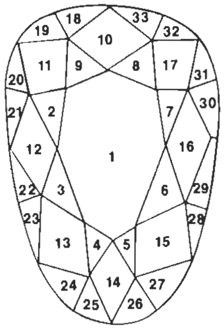
The accepted method of expressing the table percentage of fancy-cut diamonds is first to measure the width at the center of the table, point to point, in millimeters. This measurement for the Dresden Green was 10.15 mm. This value is then divided by the largest width (at the girdle), which was 19.88 mm. The table percentage for the Dresden Green diamond was calculated to be 51%.

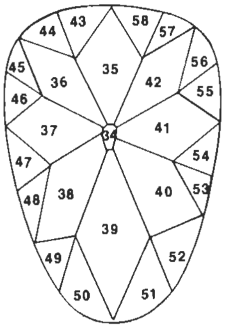
Because of its unique bezel-prong setting, about 20% of the girdle was completely obscured from view. The areas that were visible ranged from extremely thin to very thin, and were marked by

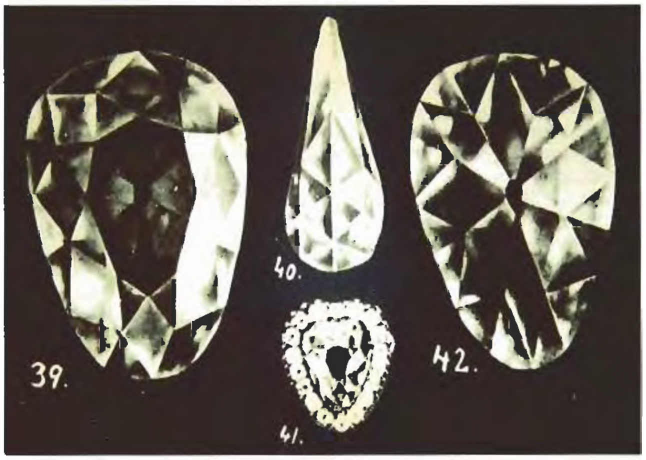
TABLE 2. Data and illustrations from Professor Rösch and Dr. Krümbhaar's 1925 detailed examinations of the Dresden Green diamond, including precise facet angle measurements obtained using an optical goniometer (Rösch and Krümbhaar, 1926; Rösch, 1957).

Facet name[a]	Surface number	Angle of inclination	Azimuth angle
Table	1	0	—
Star facets	4–5	22.3	38.2
	3–6	30.8	72.0
	2–7	30.1	100.9
	9–8	27.5	157.0
Bezel facets	14	26.9	0.0
	13–15	37.3	62.7
	12–16	42.6	86.9
	11–17	37.6	130.0
	10	38.0	180.0
Upper girdle facets	25–26	40.1	33.2
	24–27	39.9	57.7
	23–28	48.2	74.1
	22–29	48.5	81.7
	21–30	47.5	93.2
	20–31	45.5	118.0
	19–32	44.2	150.0
	18–33	44.6	171.2
Culet	34	0	—
Pavilion main facets	39	21.4	0.0
	38–40	29.6	61.3
	37–41	32.1	84.4
	36–42	26.2	123.8
	35	24.3	180.0
Lower girdle facet numbers 43–58	Professor Rösch was unable to obtain goniometrical measurements on the lower girdle facets, because the girdle was obscured by the bezel mounting. He did, however, state "that their angle is around 40 degrees" (Rösch, 1957).		

[a]The English translation of most of the facet names has been converted to modern terms.







This 1925 photo taken at the Green Vaults by Rösch and Krümbhaar shows crown and pavilion views of the Dresden Green, along with a 17-ct drilled briolette-cut colorless diamond and a light blue diamond set in a ring. Courtesy of the Rudolf Dröschel Archive, Idar-Oberstein.

numerous nicks, abrasions, and small chips. The girdle was slightly wavy.

The culet, an elongated heptagon, measured 3.25 mm × 1.65 mm. In GIA diamond-grading terms, the culet of the Dresden Green would be called slightly large.

Finish. We were very impressed with the quality of the finish. It seemed remarkable that a diamond cut prior to 1741 would have a polish of sufficient quality to deserve a "very good" grade by today's rigid diamond-grading standards. The symmetry was "good," displaying only very minor pointing and alignment faults, a slightly wavy girdle, and several extra facets on the pavilion at the girdle.

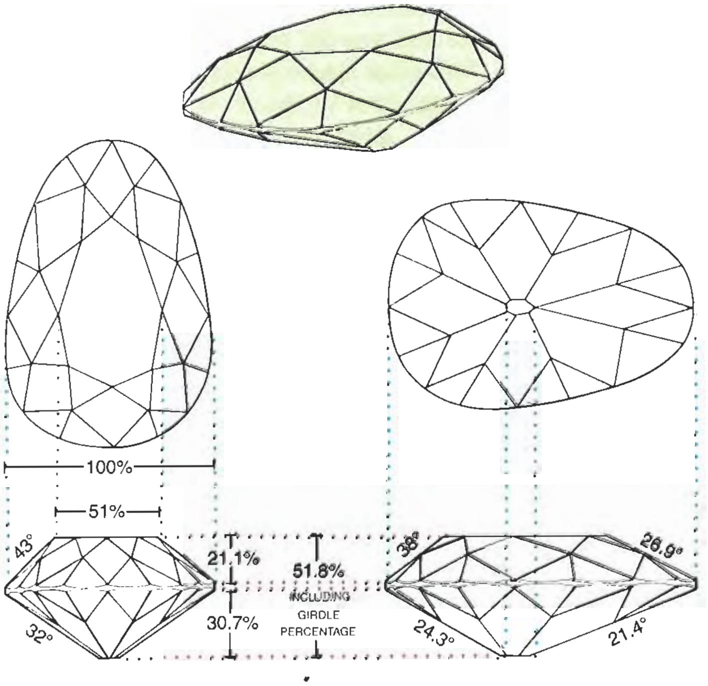
Clarity. One is immediately impressed by the exceptional transparency of the Dresden Green. In spite of the considerable thickness of the diamond, objects viewed through it could be seen very clearly. While the superior polish on the stone certainly contributes to this, the diamond itself has an apparent transparency that is, in the experience of the authors, very rare. It is reminiscent of that observed in colorless diamonds from the ancient Golconda mining district of India, which are also frequently large (see Krashes, 1988, for illustrations and descriptions of famous Golconda diamonds once sold by Harry Winston). Diamonds from the Golconda district are legendary throughout the diamond trade for their exceptional transparency, which is rarely equaled in diamonds from other localities (Bauer, 1896; Bauer, 1904; Gaal, 1977; R. Crowningshield, pers. comm., 1990). Although the assessment of transparency is unavoidably subjective, the remarkable transparency of a "Golconda-type" diamond is not soon forgotten.

TABLE 3. Proportions of the Dresden Green diamond.

Parameter	Measurement (mm)	Percentage[a]
Length	29.75	—
Width	19.88	100
Total depth	10.29	—
Depth percentage	—	51.8
Table[b]	10.15	51.1
Crown height		
Average[c]	4.2	21.1
End	5.0	25.2
Tip	4.0	20.1
Center, right	3.7	18.6
Center, left	4.1	20.6
Girdle (concealed by bezel)	—	—
Pavilion depth[c]	6.1	30.7

Length to width ratio—1.5:1
Crown angle[d]—43°
Pavilion angle[d]—32°

[a] All percentages are expressed in relation to the width of the stone (width = 100%).
[b] Width.
[c] Estimated averages.
[d] Refers to average of surface angles of center bezel facets and center pavilion main facets, respectively, in relation to the girdle plane, as reported by Rösch (1957).



We determined the clarity of the green diamond to be VS_1. As the plotting diagram in figure 10 shows, all of the chips and small feathers are near the girdle and all are fairly shallow. The only completely internal inclusion is a tiny opaque brown crystal (approximately 0.1 mm × 0.05 mm) that is plotted under a bezel facet. We estimated the crystal to be located approximately 0.15 mm from the nearest surface of the pavilion. Even with high magnification (near 120×), we could not identify a clear crystal habit for this inclusion. It appeared to be an aggregate composed of minute, slender, pointed crystals.

Over the course of two-and-a-half centuries, the Dresden Green diamond has suffered only very slight abrasion damage on some of the facet junctions, primarily around the edge of the table. A few minute abrasions are present on other crown facet junctions, as well as on the junctions in the vicinity of the culet. Even the most prominent of these abrasions are not easily visible with the unaided eye. There is also one small scratch on the table, as shown on the diagram in figure 10.

Even with the viewing limitations imposed by the bezel mounting, we feel that it would be possible to recut the Dresden Green diamond to improve its clarity, perhaps even to "flawless," without a significant weight loss. While we certainly do not suggest that this should ever be done to such a historic diamond, it is a measure of the superior quality of this stone.

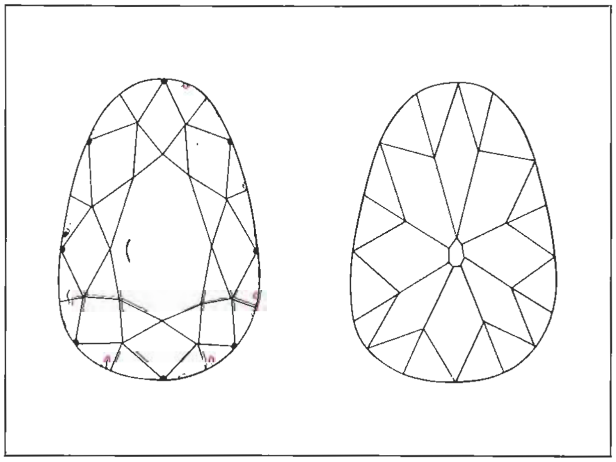


Figure 10. In this plotting diagram of the Dresden Green diamond, the prongs are shown in black; chips, a feather, and a small crystal are plotted in red; the scratch and the radiation stains are plotted in green; and the cavity is plotted in red and green. Artwork by Peter Johnston.

Color. The color of the Dresden Green diamond is its most intriguing feature and was the principal focus of this investigation. This color has been described in the literature by many fanciful terms, with "apple green" perhaps the one most commonly used (Streeter, 1882; Bauer, 1896; Webster, 1947; Smith, 1950; Twining, 1960; Balfour, 1987). Using GIA Colored Stone Grading nomenclature, we visually estimated the color of the diamond to be a medium slightly grayish green. Insofar as the mounting permitted, we determined that the current GIA Gem Trade Laboratory system would grade this historic stone as "Fancy Green."

The ingenuity of the cutter of this stone becomes apparent when one realizes that the Dresden Green shows much more color face up than it exhibits face down. The cutter apparently understood that different proportions are necessary to maximize the face-up color of fancy-color diamonds. He cut the green diamond with a ratio of crown height to pavilion depth that was contrary to what was common practice at that time. London jeweler David Jefferies, in his 1750 treatise on the methods of manufacturing diamonds, stated that the proper proportions were approximately 33% for the crown and 66% for the pavilion. The Dresden Green, however, was fashioned with approximately 41% for the crown and 59% for the pavilion. Tillander (1988) states that during the early 1700s, cutting of this quality almost certainly was done in London.

GEMOLOGICAL PROPERTIES

A thorough investigation was carried out on the Dresden Green diamond to document as many gemological characteristics as possible and to search for any evidence that might prove useful in distinguishing natural and laboratory-irradiated green diamonds. Some of these observations concur with those reported by Bosshart (1989); others reflect our research conducted during and subsequent to the examination.

Color Distribution. Examination of the diamond in darkfield and diffused transmitted illumination revealed no evidence of color zoning. The body color was evenly distributed throughout the gem.

Graining. When the stone was examined with magnification and darkfield illumination, internal planar graining was evident in three different directions (figure 11). The appearance of the colorless, parallel striations was consistent with that often referred to by gemologists as "phantom" graining (Kane, 1982). These growth features, or graining, appeared to be of a triangular octahedral stratified structure. However, as discussed below, this diamond is a type IIa, and Orlov (1977) states that "type II diamonds do not show octahedral-plane stratification."

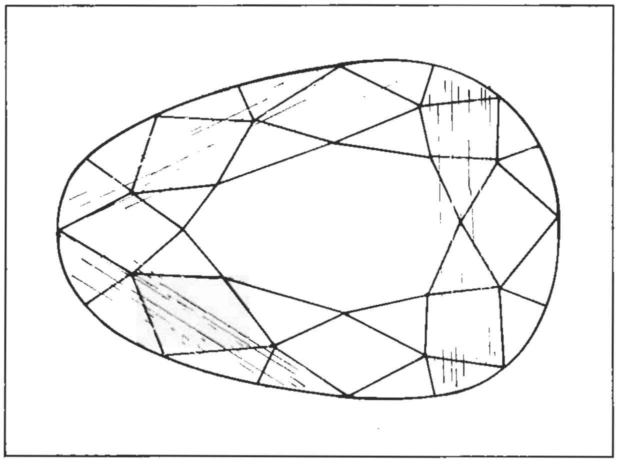


Figure 11. The unusual triangular pattern of graining seen in the Dresden Green indicates that it is a "three-point" diamond. Artwork by Peter Johnston.

The distinctly triangular pattern formed by these three directions of graining is not often seen in faceted diamonds. It suggests that the Dresden Green is a "three point" diamond; that is, the table has been oriented parallel to the direction of a possible octahedral face (for more information, see Watermeyer, 1982).

Strain. Polarized microscopy with the stone held table to culet revealed strong, tightly woven, "cross-hatched" birefringence patterns that are sometimes referred to as "tatami," after the Japanese straw mat of the same name (Orlov, 1977). Both these "tatami" patterns and the linear strain patterns that were also present appeared gray to black. Turning the stone in various directions revealed strong linear and loose cross-hatch strain of a somewhat higher order, with dull, moderately saturated colors of yellow and blue.

Some of the areas of linear strain visible with crossed Polaroids seemed to correlate directly to the colorless graining seen in darkfield illumination through the crown.

Reaction to Ultraviolet Radiation. With a standard GIA GEM short-wave/long-wave ultraviolet lamp used in conjunction with a GIA GEM ultraviolet viewing cabinet in ideal conditions of darkness, we observed no fluorescence in the Dresden Green diamond to either long- or short-wave ultraviolet radiation.

We then used a more powerful long-wave ultraviolet radiation unit (VEB Quarzlampen Markkleeberg UA150.1, 220 volt, 140 watt, 365 nm). With this extremely strong source, we observed a weak dull green fluorescence. There was no phosphorescence.

Transmission Luminescence. Because some diamonds exhibit a phenomenon known to gemologists as transmission luminescence, we examined the Dresden Green for this characteristic. The diamond was placed, both table down and table up, over the strong light source emanating from the small opening of the nearly closed iris diaphragm over the transmitted light portal of the microscope. The stone showed no transmission luminescence at all, not even the very weak, whitish scattering of light seen in many fancy-color diamonds.

Evidence of Radiation Damage. One of the first things we looked for when examining the Dresden Green with the microscope was the presence of green or brown "radiation stains" (as they are referred to in the gemological literature), which indicate radiation damage to the stone. We fully expected to find some and were not disappointed. Three areas displayed small dark green stains: two at the girdle edge on one side of the diamond and one on an upper girdle facet (figure 12) The last was unusual because the stains were coating the walls of a small, narrow cavity that reached the surface by means of a thin fissure (figure 13). This suggests that the diamond was exposed to a radioactive solution that was able to penetrate the cavity through the minute fissure. It is possible that other stains could have been present on the small portion of the girdle obscured by the remaining bezel.

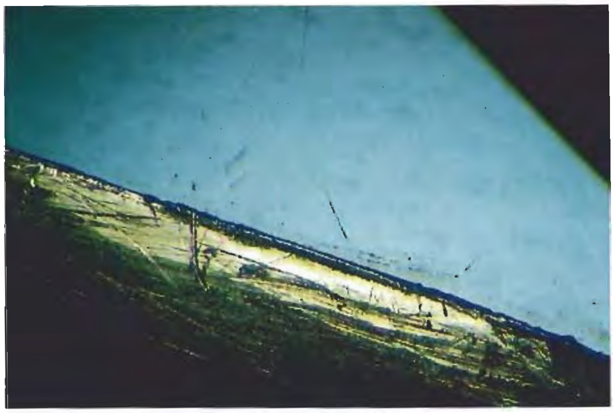
While these stains provide evidence that the Dresden Green originated from a green-skinned piece of rough, they are much too small to account for any of the face-up color of the stone. The Dresden Green diamond is a "body color" green diamond; that is, the color is uniform throughout.

Diamonds with green "skins" or scattered green patches (radiation stains) are common. They are found in varying concentrations in many diamond deposits (Orlov, 1977; Vance et al., 1973). When such diamonds are cut, they generally produce near-colorless stones.

Faceted diamonds with a natural green body color, like the Dresden, are extremely rare. Unlike transparent green surface coats, green body color can be produced by only a few types of ionizing radiations. Alpha and beta particles penetrate diamond to a very shallow depth, on the order of hundredths of a millimeter and a millimeter, respectively (Ashbaugh, 1988), which virtually excludes them from causing the color in the Dresden diamond, although they typically cause the green "skins" or radiation stains. The penetration of ionizing radiation forces carbon atoms out

Figure 12. At first glance, this appears to be a normal radiation "stain" (evidence of radiation damage) on the surface of an upper girdle facet of the Dresden Green diamond. Photomicrograph by Robert E. Kane; magnified 25×.

Figure 13. Upon closer inspection in reflected light, it can be seen that the radiation stain is actually inside a cavity that has only a very narrow opening at the surface. Photomicrograph by Robert E. Kane; magnified 25×.



of their positions in the crystal lattice, leaving behind what are known as vacancies. These vacancies produce what is referred to as a GR1 color center, which displays a sharp absorption band at 741 nm and absorbs light in the red portion of the spectrum, thereby contributing to the green color in a diamond.

The same process occurs with gamma rays and neutrons, but penetration depths are much greater than for alpha and beta particles. As the documented history of the Dresden Green predates the nuclear industry by almost two centuries, natural-occurring radiation sources are responsible for the color. Nuclides and daughters (decay products) of uranium-238, thorium-232, and potassium-40 are the probable materials, as these produce alpha, beta, and gamma rays. Of these, gamma rays seem the most likely candidate, but there is another possibility. Uraninite, a concentrated uranium-bearing oxide, sometimes undergoes natural spontaneous nuclear fission, which releases neutrons, so that neutrons as well as gamma rays may have damaged the Dresden Green to give the diamond a green body color (G. MacKenzie, pers. comm., 1990).

Nuclear laboratory radiation sources are much more intense than natural sources, and therefore produce in a matter of hours, or even minutes, a coloration in diamond that may require hundreds of millions of years in nature (C. Ashbaugh, pers. comm., 1990). Nuclear reactors generate both gamma rays and fast neutrons.

Small green-to-brown radiation stains (damage) on the surface of diamonds used to be considered a strong indication (but not proof) of natural color (Fryer et al., 1981; Crowningshield, 1985, 1986), since such stains had not been reported to have been produced artificially (Fritsch et al., 1988; Kammerling et al., 1990; Shigley and Fritsch, 1990). However, the possibility now exists that near-colorless and light green or yellow diamonds with these stains may be irradiated to induce or intensify (to light, medium, or dark) a green color. In fact, Kammerling et al. (1990) examined several faceted diamonds with brown radiation stains both before and after irradiation treatment. Even though the originally pale green and near-colorless stones turned dark green with irradiation, there was no change in the appearance of the radiation stains.

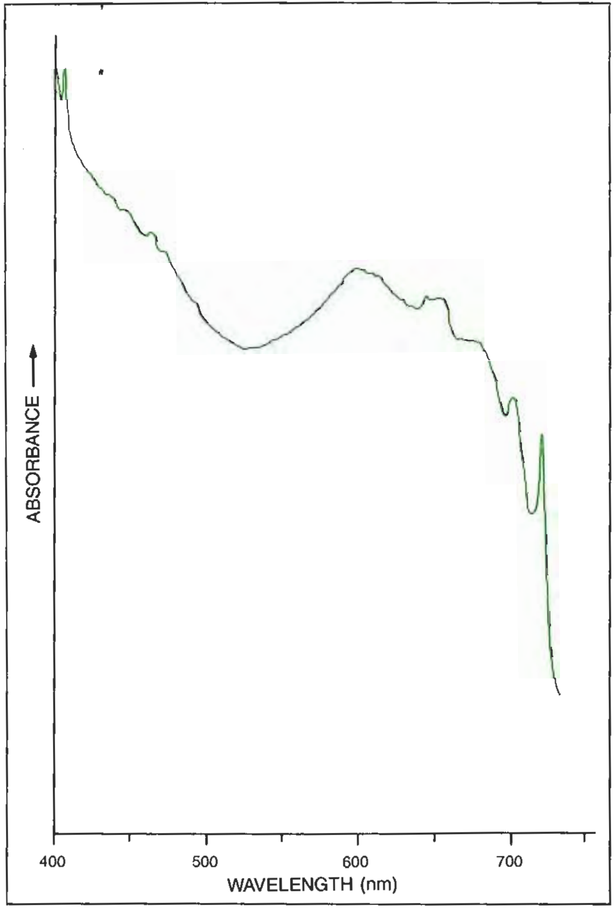
Spectra Visible with a Hand-held Type of Spectroscope. We initially examined the visible-light absorption spectrum (400 to 700 nm) of the Dresden Green diamond using the GIA GEM Maxilab unit with a Beck prism spectroscope. Close inspection at room temperature revealed no distinct absorption features; only a very weak, broad absorption was visible around 500 nm.

U.V.–VIS Spectra. The U.V.–visible absorption spectrum of the Dresden Green was recorded on a Pye Unicam SP8-100 UV/VIS spectrophotometer, which was supplied and operated by George Bosshart of the SSEF. This examination, performed at close to liquid nitrogen temperature, revealed a well-developed GR (General Radiation) absorption system as well as very weak lines at 495 nm and 594 nm, the TR12 line (470 nm), R11 and R10 lines (310.8 nm and 393.5 nm, respectively) and a steep absorption edge beginning at approximately 225 nm (as illustrated in Bosshart, 1989, p. 358). It is interesting to note that the spectrum of the Dresden Green shares many similarities with a dark green diamond that was identified as being artificially irradiated (see figure 14). The presence of a color-zoned culet identified this diamond as being treated (Fritsch and Shigley, 1989).

The steep absorption at 225 nm, the fundamental absorption edge, is observable in type II diamonds, which have fewer crystal defects than their type I counterparts (Clark et al., 1956). The GR series, ranging from GR1 through GR8, is found in all diamonds that have been subjected to radiation damage, with the GR1 at 741 nm being by far the strongest (Collins, 1982). The TR12 line (TR standing for Type II Radiation) is the strongest in a series of lines that are referred to as TR12 through TR17 (470.1, 468.8 [TR12A], 464.3, 446.5, 444.7, 440.2, and 438.0, respectively). Davies et al. (1981) reported that these lines have only been found in type II diamonds that have been irradiated. The R11 (310.8 nm) and R10 (393.5 nm) lines are also produced by radiation damage. The R11 is reported to be found only in type IIa diamonds (Davies, 1977); the R10 is also known as ND1 and can be created in all types of diamonds. It is not usually visible in type Ia diamonds because it is masked by a secondary absorption edge typical of that type (Walker, 1979).

For many years, the presence of a 594-nm line was believed to prove laboratory irradiation in a faceted diamond (see, e.g., Liddicoat, 1989). The line is associated with the annealing of irradiated diamonds (Dugdale, 1953; Crowningshield, 1957; Collins, 1982; Guo et al., 1986; Fritsch et al., 1988), so it is normally visible in annealed colors (e.g., yellow, brown, orange, pink). It is also occasionally seen in laboratory-treated diamonds that are still green (Kane, 1988; Fritsch et al., 1988). While the 594-nm line has been reported in a number of uncut natural-color diamonds (Cottrant and Calas, 1981; Guo et al., 1986; Shigley and Fritsch, 1990), it has rarely been reported in faceted diamonds that could be proved to be natural. By virtue of its documented 250-year history, the Dresden Green now stands as an undisputable example of such a diamond.

Figure 14. This visible absorption spectrum of a type II green diamond that was identified as being treated by means of characteristic color zoning at the culet, shows many features that are present in the spectrum of the Dresden Green. Courtesy of the GIA Research Department.



Infrared Spectra. To determine which of the well-recognized diamond types the Dresden Green belongs to, infrared spectroscopy was used. For a discussion and excellent review of these types (Ia, Ib, IIa, IIb, or a mixture) see, for example, Robertson et al. (1934), Custers (1952), Davies (1977), Clark et al. (1979), Collins (1982), Davies (1984), and Shigley et al. (1986). Very simply stated, type I diamonds have a fairly substantial (up to 3000 ppm, or 0.3%) nitrogen content (Shigley et al., 1986). Type Ia diamonds have aggregated nitrogen atoms, while the nitrogen atoms in type Ib diamonds are isolated or "singly substitutional." Type II diamonds have an extremely low nitrogen content, if any (undetectable or barely detectable using IR spectroscopy); type IIb diamonds contain boron, while type IIa stones do not contain boron in detectable quantities. A diamond can be readily characterized as to type by the way it absorbs or transmits infrared radiation between about 900 and 1400 wavenumbers (cm^{-1}; see figure 15).

The infrared spectrum of the Dresden Green diamond (figure 16) was recorded at room temperature on a Carl Zeiss/Jena Specord 75IR infrared spectrophotometer by Dr. K. Herzog and Mrs. R. Lunkwitz of the Technical University of Dresden. The green diamond was mounted in the sample chamber with the infrared beam perpendicular to the table, so that it entered at the table and exited at the culet. The large culet and the depth (10.29 mm) of the green diamond allowed for easy set-up and an excellent optical path. As shown in figure 15, the spectrum is typical of a type IIa diamond, that is, largely free of nitrogen features in the 1400 to 900 wavenumber region.

Type IIa diamonds (of any clarity and color, or absence thereof) are very rare in nature (Field, 1979). Natural diamonds that are of type IIa and have a dominant green color, whether irradiated naturally or in a laboratory, are exceedingly rare. In an ongoing GIA Research project that formally began in 1986, more than 1300 colored diamonds (which were either submitted to the GIA Gem Trade Laboratory for official reports or loaned to GIA for scientific study) have been carefully documented to date. Of these, approximately 300 were predominantly green (some with secondary hues of gray, brown, yellow, blue, etc.), with varying tones and saturation (J. Shigley, pers. comm., 1990). Of these 300 "green" diamonds, only 18 were classified as type IIa, with the remainder being type Ia; none was in the Ib or IIb categories.

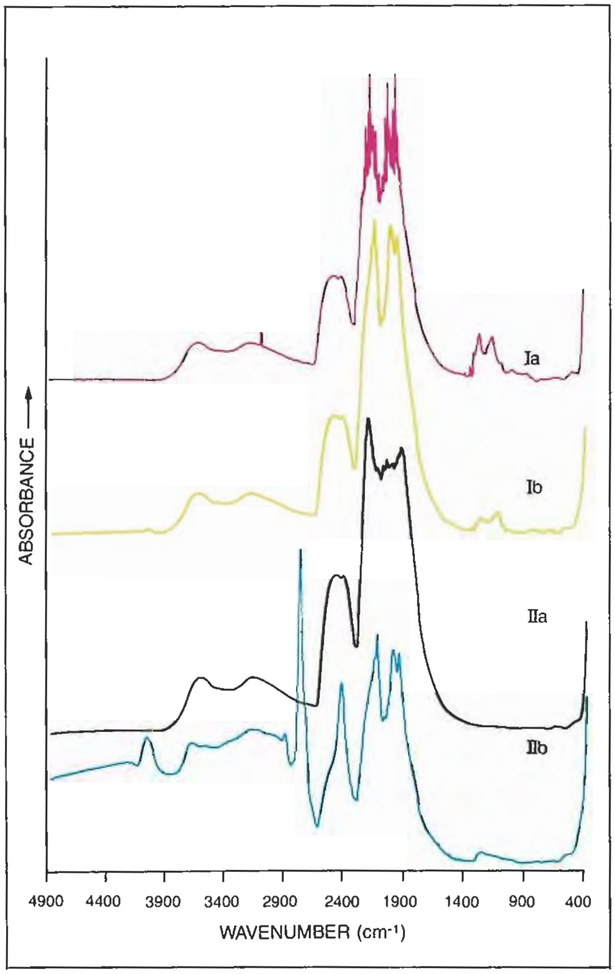


Figure 15. These infrared absorption spectra were recorded with the GIA Research Department's Nicolet 60XS FTIR spectrometer for each of the four basic types of diamond. Each type can be readily characterized by the way it absorbs or transmits radiation between about 900 and 1400 wavenumbers (cm^{-1}).

Therefore, not only is the famed Dresden Green the largest known natural green diamond, but it is also a very rare type IIa. This was an unexpected discovery, since type Ia diamonds represent as much as 95% of natural gem diamonds (Collins, 1982).

CONCLUSION

Natural green body-color diamonds are extremely rare in nature, and there are few documented examples. The Dresden Green falls into this category. The vast majority of natural-color green diamonds are only green on the surface of the rough, with the color produced by surface stains and coatings. These stones are usually no longer green when they are cut. The cause of the green surface coloration has been attributed to the diamond being in close proximity to an alpha-particle-emitting source for a very long period of time.

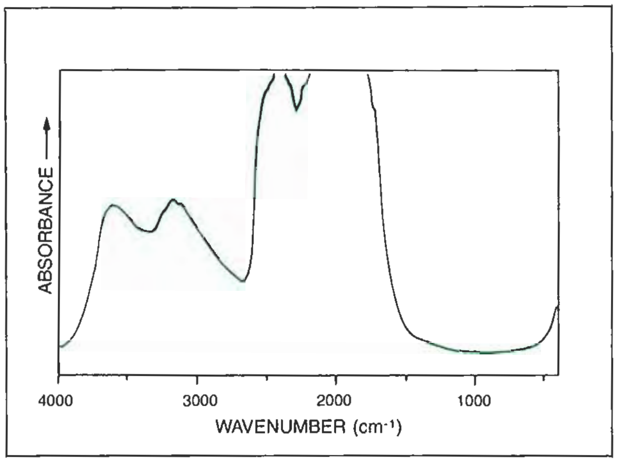


Figure 16. The infrared spectrum of the Dresden Green diamond. Note the similarity of the area between 900 and 1400 wavenumbers with that illustrated in figure 15 for type IIa diamonds. This spectrum was originally recorded in transmittance; here, it is shown converted to absorbance. Spectrum recorded by Dr. K. Herzog and Mrs. R. Lunkwitz of the Technical University of Dresden.

Laboratory-irradiated green diamonds have become increasingly common in the trade. Green color in diamonds has been produced by radium salts since 1904, by cyclotron treatment since 1942, and more recently by high-energy electrons, neutrons, and (less commonly) by gamma rays. Whereas radium and americium salts and cyclotron treatment leave readily identifiable clues (radioactivity and what is commonly referred to as the "umbrella" effect, respectively; see Kammerling et al., 1990), treatment by the more modern methods is extremely difficult to detect in most green diamonds.

Alan Collins stated in 1982 that it would be of considerable help to the understanding of naturally occurring color centers if absorption spectra could be obtained for a natural body-color green diamond. This unique opportunity to examine the Dresden Green provided such information. The documentation of this famous diamond is now complete, with the exception of the precise weight, which may never be known. Our investigation uncovered evidence to support the opinion that the stone was mined in India and cut in London. It was also shown to be a rare type IIa diamond. Most important, perhaps, is the fact that the spectral characteristics of this stone overlap those of known treated green diamonds, which indicates that we must continue the search for reliable tests to separate natural from treated green diamonds. It is ironic that a stone with a history that spans more than two and a half centuries should play such a pivotal role in confirming the need for this research.

Acknowledgments: The authors thank Dona Dirlam, Rosemary Tozer, and the others at the Richard T. Liddicoat Library and Information Center of GIA for their help in archival research; Holly Baxter, Dr. Barbara Bopp, Dr. John Hummel, and Caio Maia for translations; Dick Agnew and Bob Van den Heuvel for the design and construction of specialized equipment for the investigation; Dr. Peter Tandy and Dr. A. M. Clark of the British Museum of Natural History, for information and loan of the model; David Beasley of Goldsmith's Hall, London, for black-and-white reproductions; Herbert Tillander for supplying historical information and making the necessary introductions to gain access to the Green Vaults; George Bosshart of the SSEF for supplying the information on the UV–VIS spectra; Dr. Werner Quellmalz, Dr. Mathe, Mrs. Christine Engemann-Wendt, Dr. U. Arnold, Dr. Klaus Herzog, Mrs. Renate Lunkwitz, Prof. Dr. Walther E. Steger, Dr. Copal, Dr. Tallheim, Dr. Schneider, Mr. Wunsche, and all the other people in Dresden who assisted during the visit; Dr. Karl Schmetzer, Eric Bruton, Michael O'Donoghue, Ian Balfour, Rudolf Dröschel, and Mr. and Mrs. Jerusalem for their help with literary research; Dr. George Rossman, Chuck Ashbaugh, Dr. Jeff Harris, Bob Crowningshield, and Dr. James Shigley for their useful comments and observations; the GIA Research Department for making available their diamond literature database; GIA executives William E. Boyajian, Richard T. Liddicoat, Courtney A. Walker, Thomas C. Yonelunas, and C. W. Fryer for their support of the Dresden Expedition; and Mary Smith for her expertise and patience in word processing the many drafts of the manuscript.

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DIAGNOSTIC FEATURES AND HEAT TREATMENT OF KASHMIR SAPPHIRES

By Rolf Schwieger

The locality origin of natural-color blue sapphires from Kashmir can, in many cases, be positively identified. However, the field of origin determination is a very complex one—especially with the now-common practice of heat treatment. Today, only by combining different gemological tests with years of practical experience, can a conclusive determination of the origin of a sapphire be made. For all practical purposes, examination of inclusions in conjunction with optical spectrophotometry remain the most important tests.

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Acknowledgments: The author thanks the following people for their help throughout this project: Ronny Totah, Eric Horovitz, Theodore Horovitz, Michael Kazanjian, Dr. Henry Hänni, Karl Vogler, Laxman Rawat, Jean and Albert Boghossian, Eli Namdar, Emmanuel Guillaume, Mourad Hatik, John Block, Bernard Berger, Renata von Paczinsky, and Valerie Vlasaty.

Gems & Gemology, *Vol. 26, No. 4, pp. 267–280*

Among fine blue sapphires, it is generally recognized that those from Kashmir (figure 1) are most highly prized. As a result, in certain segments of the gem market, a major concern is to establish the provenance of any particular blue sapphire.

Recent record-setting prices paid at auction for some of these exceptional stones have further raised public awareness of Kashmir sapphires and reinforced the desire on the part of many gemologists to be able to identify the provenance of such stones. For example, in October 1989, at Sotheby's New York, a Kashmir sapphire and diamond necklace by Van Cleef & Arpels sold for US$3,520,000, at the time a world record for any necklace sold at auction (figure 2). In May of 1990, at Christie's Geneva, another Kashmir sapphire and diamond necklace by Van Cleef & Arpels sold for US$1,100,000.

Because the mine origin of a stone is so rarely documented by reliable witnesses, gemologists have been forced to seek other methods of locality determination. For some time now, research involving highly sophisticated methods and instrumentation has been carried out on Kashmir sapphires (e.g., Hänni, 1990). Most practicing gemologists, however, cannot routinely gain access to a spectrophotometer or a means of chemical analysis such as the scanning electron microscope with energy-dispersive system (SEM-EDS) or energy-dispersive X-ray fluorescence (EDXRF). For them, the microscope remains the most important source of information.

Thus, based on a review of the literature and the author's personal examination of several hundred known Kashmir sapphires, this article will concentrate on inclusions and other microscopic features of Kashmir sapphires that can be helpful in making a locality determination. Other methods of identification are also discussed, especially the potentially critical role of spectrophotometry. The article concludes with the results of experimentation in—and the identification of—heat treatment of sapphires from Kashmir.

Figure 1. Fine Kashmir sapphires are among the most sought-after of gemstones. Yet determination of the locality of origin of any gemstone is difficult, and of Kashmir sapphires is particularly complex. On the basis of a variety of factors, which are the focus of this article, the author and others determined that the large stone in this magnificent sapphire and diamond bracelet by Cartier is from the famous Kashmir mines. At 65 ct, it is one of the largest known faceted Kashmir sapphires in the world. Photo by Michael Oldford.

HISTORY

A landslide that took place around 1881 in a small glacial cirque above the village of Sumjam, on the southwest slopes of the Zanskar range in the Himalaya Mountains, exposed gem-quality blue corundum crystals embedded in altered pegmatites (Atkinson and Kothavala, 1983). In 1884, in his book *Precious Stones and Gems*, Edwin W. Streeter became one of the first to mention the Kashmir mines. He tells the story of how the maharajah of Kashmir heard of the discovery and took immediate possession of the site by sending his own guards to the original mine, situated at a height of 4,500 m (14,800 ft.), near the level of perpetual snow. In the first years of exploitation, some superb sapphires were found there, as well as in placer deposits on the valley floor. In 1904, Bauer (p. 289) reported that "some [of the rough sapphires from Kashmir] are of considerable size, weighing 100 or even 300 carats." More recent finds, however, have been less spectacular; today, most of the stones on the market are small, and only rarely does one see faceted gem-quality stones over 20 ct (figure 3). By 1926, new mines had been opened within 200 m of the original deposit. However, mining operations have always been extremely

Figure 2. This Van Cleef & Arpels necklace of predominantly Kashmir sapphires (ranging from 10.96 to 36.00 ct) and diamonds was auctioned in 1989 by Sotheby's in New York for US$3,520,000. Photo by Michael Oldford; courtesy of Sotheby's.

difficult and limited by the weather to no more than three months per year. Mining has long been complicated, too, by political instability in the area. Two wars have already been fought between India and Pakistan for control of the Kashmir region since the discovery of sapphires there and, as this article is being written, the area is yet again in dispute.

Further information, and a detailed chronology of the Kashmir deposits, can be found in Atkinson and Kothavala (1983). Due largely to the difficult mining conditions, the low yield of gem-quality material, and, recently, the political upheaval in the area, no mining has occurred within the last 10 years. A new mining operation was planned for the summer of 1990, but it was not undertaken because of the political situation.

REVIEW OF DIAGNOSTIC FEATURES

Since blue sapphire shows little variability from locality to locality in its essential physical and optical properties, most of the basic characteristics of Kashmir sapphires are also found in sapphires from other regions. As a result, researchers have been forced to look for subtle distinguishing features for locality determination, a search that has been complicated by the shortage of Kashmir sapphires of reliably documented provenance—a shortage due partly to the relatively brief history of their mining (only slightly over 100 years) and partly to the lack of reliable witnesses who can attest to the origin of any particular stone. Nevertheless, some research work is available for assessment.

Perhaps the most obvious features of the gem-quality Kashmir sapphires are their intense blue color and their turbid, or "velvety," appearance (Streeter, 1884; Smith, 1912; Bauer, 1932; Halford-Watkins, 1935); unlike sapphires from most other localities, the blue color of Kashmir sapphires tends to improve under incandescent light. These features undoubtedly led to the rapid rise of sapphires from Kashmir to their legendary status. However, the variable presence of these characteristics in Kashmir sapphires, as well as their appearance—though rarely—in sapphires from other localities, makes them less than reliable as determinants of locality.

Most of the studies on diagnostic features of Kashmir sapphires have focused on microscopic characteristics (Gübelin, 1948, 1953; Phukan, 1966; Schubnel, 1972; Gübelin, 1973, 1985; Gübelin and Koivula, 1986; Hänni, 1990). Perhaps the most obvious microscopic feature is a sharp, well-defined color zonation that occurs in virtually all Kashmir sapphires (Phukan, 1966; Atkinson and Kothavala, 1983; Gübelin, 1985; Gübelin and Koivula, 1986; Hänni, 1990). In fact, as early as 1904, Bauer noted that even within low-quality and milky gray material, some of the "single crystals often show a difference of color in different portions; thus the center of a crystal may be of fine blue color, and the two ends colorless." Usually, the zonation consists of alternating blue and near-white, or "milky," layers that contribute to the reduced transparency ("velvetiness") of the stones. Although color zonation has been observed in sapphires from other localities (e.g., Pailin and Sri Lanka), the zoning seen in sapphires from Kashmir is usually distinctive. The milky layers are thought to contain microscopic and submicroscopic particles that may be exsolutions of rutile (see Halford-Watkins, 1935; Gübelin and Koivula, 1986; Hänni, 1990), but these inclusions have not yet been positively identified because they are so small.

Also contributing to the Tyndall effect of light scattering throughout these stones are clouds, lines, and strings of slightly larger but still very fine, dust-like inclusions, probably exsolutions of rutile (Gübelin and Koivula, 1986; Hänni, 1990), but positive identification of these inclusions, too, remains to be made. However, the cumulative Tyndall scattering effect produced by these features can be considered as indicative of Kashmir origin (Gübelin and Koivula, 1986, p. 342). "Flags" or healed fissures are commonly mentioned in connection with Kashmir sapphires (Phukan, 1966; Schubnel, 1972; Gübelin and Koivula, 1986; Hänni, 1990), while twin lamellae have been seen, if rarely (Hänni, 1990).

Solid inclusions that have been reported in Kashmir sapphires include zircon (euhedral, with or without fracture halos, and sometimes described as "corroded"), tourmaline (rarely euhedral), and pargasite (prismatic or as long, fine needles) crystals (Phukan, 1966; Schubnel, 1972; Gübelin and Koivula, 1986; Hänni, 1990). Zircon has also been observed in blue sapphires from other localities, including Australia, Burma, Montana, Sri Lanka, Pailin (Cambodia), and Tanzania (Schubnel, 1972; Gübelin, 1973; Gübelin and Koivula, 1986). However, tourmaline and pargasite are considered diagnostic of Kashmir origin, and have not been seen in blue sapphires from other localities (Schubnel, 1972; Gübelin, 1973; Gübelin and Koivula, 1986; Hänni, 1990).

Strongly corroded colorless crystals have been identified as plagioclase, and in one case a colorless crystal with stress fissures was determined to be allanite (Hänni, 1990). The allanite crystal was identified using energy-dispersive analysis on an SEM, and this type of analysis also led Hänni to identify cubic black crystals as uraninite. However, plagioclase has been observed in sapphires from Pailin and Thailand, and uraninite has been seen in sapphires from Sri Lanka (Gübelin and Koivula, 1986), so their presence cannot be considered diagnostic of Kashmir origin. On the other hand, it appears that allanite, like tourmaline and pargasite, has as yet been seen only in sapphires from Kashmir and can thus be regarded, when present, as proof of locality. Unfortunately, these crystalline inclusions only rarely occur in Kashmir sapphires.

Figure 3. Most of the Kashmir sapphires seen in the gem market today are fairly small, but a few larger stones can still be found. The unusually fine stones in this collection range from 3 to over 30 ct. Photo by Michael Oldford.

Trace-element analysis by nondestructive energy-dispersive X-ray fluorescence (EDXRF) spectrometry (Stern and Hänni, 1982) has also been explored by Karl Vogler with considerable success as a method that contributes to identifying the provenance of sapphires. Graphs that relate the ratios Fe:Cr and Ti:Ga appear to provide the best solution (K. Vogler, pers. comm., 1990). His research indicates that sapphires from Kashmir can be distinguished by EDXRF from those of Pailin (Cambodia), Thailand, Australia, and Nigeria and, in some cases, from those of Burma (now Myanmar). Sri Lankan sapphires are more difficult to separate, as they have iron and chromium contents similar to those of Kashmirs, although gallium can occasionally be a useful indicator. However, further research is needed before conclusions can be drawn about the reliability of this method for these important distinctions.

Optical spectrophotometry has been used primarily to study the causes of color in blue sapphires (Schmetzer and Bank, 1981), but, as with rubies (Bosshart, 1982; Schmetzer, 1985), it has also been suggested that this method can provide means to determine the locality origin for Kashmir sapphires (Hänni, 1990).

MATERIALS AND METHODS

Over a 10-year period, the author has had the opportunity to examine more than 500 gem-quality sapphires reportedly from Kashmir (i.e., with at least one certificate of origin from a major gem laboratory*), from which a file of over 3,000 photomicrographs was developed. In addition, during a visit to Kashmir in September 1989, the author obtained six non-gem-quality Kashmir sapphire crystals (figure 4) from the old stock of Jammu & Kashmir Minerals (the state-owned company that controls the Kashmir mines). Similar non-gem-quality Kashmir sapphire rough from old stocks of other Indian dealers was also examined for this study.

Photomicrography was performed with a Leitz Orthoplan mineralogic microscope, using oblique illumination as provided by a powerful (200-watt) Schott fiber-optic light. Optical spectra were ob-

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**Editor's Note: Although GIA recognizes the value of studies to determine locality of origin of a gem material, the GIA Gem Trade Laboratory, Inc., has a long-standing policy of not indicating locality of origin on any identification report it issues.*

Figure 4. These six non-gem-quality samples, two of which were obtained by the author in Kashmir from the old stock of Jammu & Kashmir Minerals, were among the faceted and rough samples examined for this study. They range from 2 to 6 ct. Photo by Michael Oldford.

tained with a Beckman DU-70 spectrophotometer and a microbeam condenser. Where possible, chemical analyses of inclusions were performed on a scanning electron microscope with an energy-dispersive system (Philips SEM 515 with a Tracor EDS). Heat treatment was performed in Bangkok on a 29-ct faceted commercial-quality specimen.

OBSERVATIONS

Microscopic Features. The characteristic sharp-bordered blue (sometimes with colorless layers) and whitish (milky) color zoning of Kashmir sapphires was readily apparent in most of the specimens examined for this study (figure 5). This zoning was present in almost all of the stones, but in some cases it was difficult to see. In some of the stones, even at relatively low (40 ×) magnification, extremely fine features could be seen in the milky layers (figure 6).

Using a strong fiber-optic light source in conjunction with magnification, the author also observed the clouds and lines of somewhat larger but still very fine, dust-like inclusions (figure 7) that are commonly present in Kashmir sapphires and also contribute to the "velvety" appearance of reduced transparency. These inclusions often resemble snowflakes (figure 8). Sometimes they take the form of fine, short needles (figure 9). As stated

Figure 5. Most of the specimens examined showed the sharp blue and milky or whitish zoning that appears to be characteristic of sapphires from Kashmir. Photomicrograph © Rolf Schwieger; magnified 25 × .

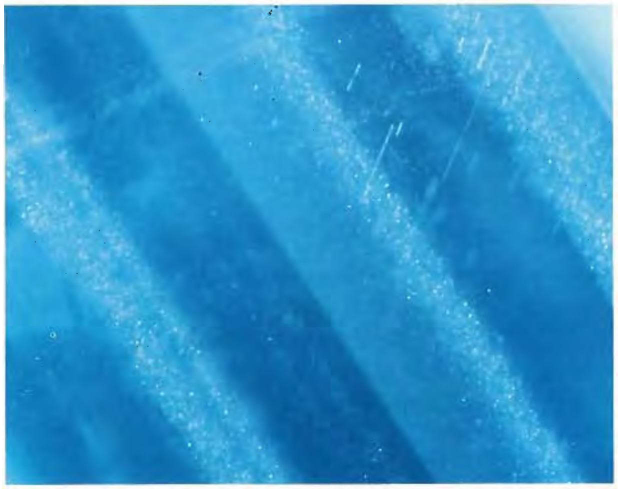


Figure 6. Even at 40× magnification, with the strong illumination provided by a powerful fiber-optic light source, the tiny particles that contribute to the haziness of the milky layers can be seen in some Kashmir sapphires. Photomicrograph © Rolf Schwieger.

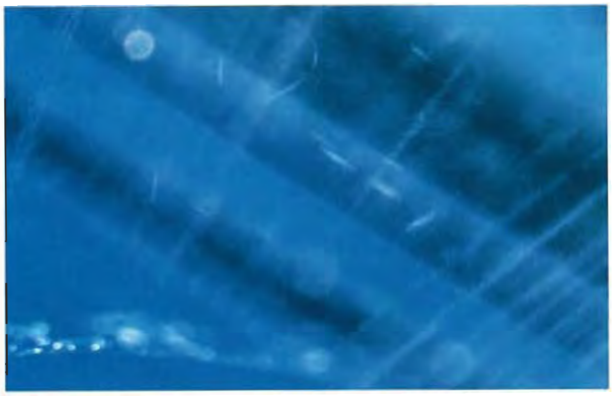


Figure 7. Clouds and lines of fine, dust-like inclusions (exsolutions of rutile?) were commonly present throughout the Kashmir sapphires examined. Photomicrograph © Rolf Schwieger; magnified 40×.

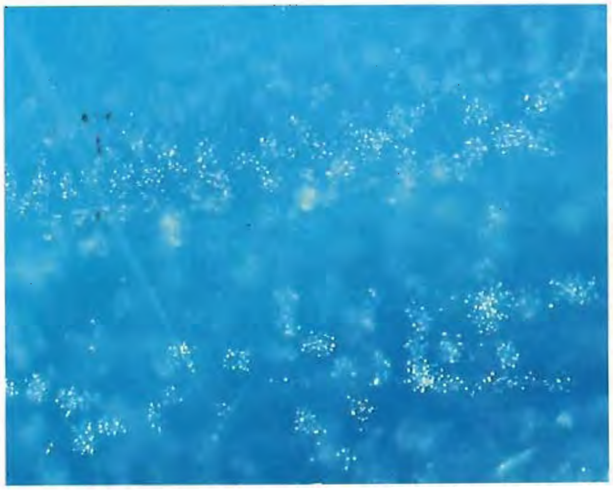


Figure 8. The clusters of dust-like inclusions often resemble snowflakes. This type of formation has not been seen in sapphires from other localities. Photomicrograph © Rolf Schwieger; magnified 40×.

earlier, the exact nature of these inclusions (like those in the milky layers) has not yet been determined. However, their orientation — intersecting at 60° angles and aligned with the hexagonal symmetry of the host corundum (again, see figure 9) — strongly suggests that they are exsolutions of rutile. The "snowflake" formations have not been seen in sapphire from other localities.

The form and distribution of these particles suggests a geologic growth condition for Kashmir sapphires in which the variations in pressure and temperature did not allow complete formation of typical rutile needles, such as those commonly found in Sri Lankan and Burmese sapphires (figure 10; K. Vogler, pers. comm., 1990; H. Hänni, pers. comm., 1990).

Figure 9. In some instances, the dust-like particles appear to be fine, short needles. They intersect at 60° angles and are aligned with the hexagonal symmetry of the sapphire. This orientation suggests that they are probably exsolutions of rutile. Photomicrograph © Rolf Schwieger; magnified 25×.

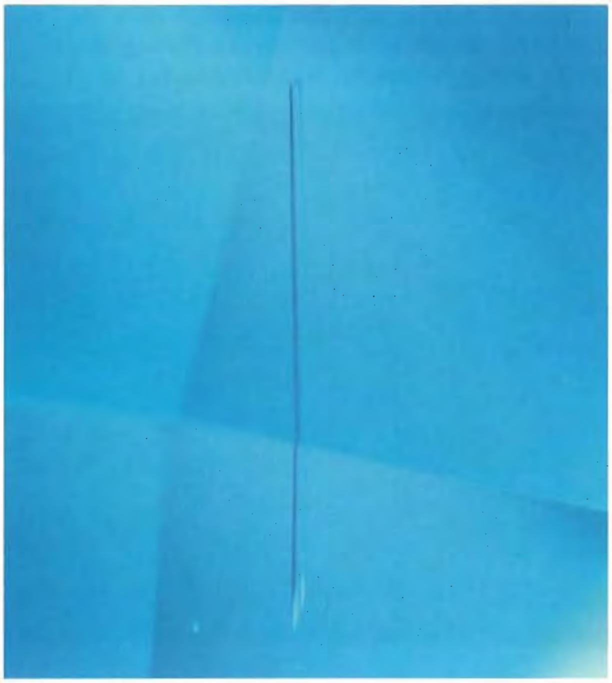
Figure 10. The appearance of the dust-like inclusions observed in Kashmir sapphires is very different from the well-formed rutile needles commonly seen in unheated sapphires from Sri Lanka (as shown here) and Burma. Photomicrograph © Rolf Schwieger; magnified 25×.

Although crystal inclusions in Kashmir sapphires appear to be rare when normal magnification is used, high magnification (50× or more) revealed mineral inclusions in about 60%–70% of the specimens examined. In as many as half of these instances, magnification of 100× or more was required to determine the morphology of the inclusions. Positive mineralogic identification of such inclusions usually depends on their exposure at the polished surface of a cut gem. However, since these stones are too valuable to be sacrificed to scientific investigation, this could not be done in most instances. Further research using a Raman laserprobe, which allows analysis of subsurface inclusions (Fritsch and Rossman, 1990), is needed. Schubnel (1977) was the first to identify (by SEM-EDS) pargasite as an inclusion in Kashmir sapphire, and his findings have since been confirmed by Hänni (1990) and this study (also using SEM-EDS). These needle-like inclusions (figure 11) sometimes cut across an entire stone, and were seen in about 10% of the specimens.

About 5% of the study stones were found to contain long, prismatic, colorless crystals such as those shown in figure 12. Although they could not be conclusively identified by the methods available, their morphology suggests that they are also pargasite. In the author's experience, this type of inclusion has not been seen in sapphires from other localities.

Tourmaline as an associated mineral of Kashmir sapphires has been described by several researchers (e.g., Bauer, 1904; Smith, 1912; Halford-Watkins, 1935; Brown, 1956; Atkinson and Kothavala, 1983; Gübelin and Koivula, 1986; Hänni,

Figure 11. Long, thin, needle-like crystals of pargasite were observed in about 10% of the stones examined for this study. Pargasite has not been reported in sapphires from other localities. Photomicrograph © Rolf Schwieger; magnified 40×.



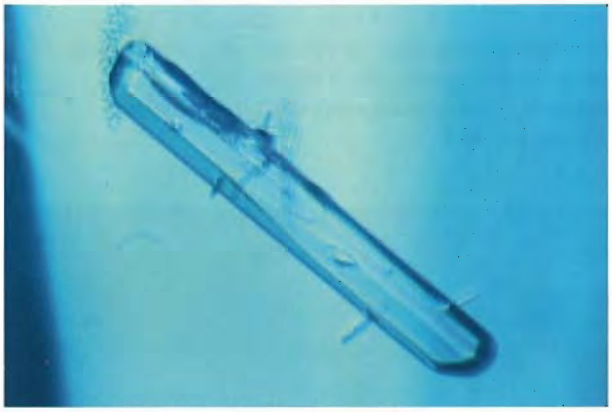


Figure 12. This type of long, prismatic, colorless crystal was also observed in a number of the sample Kashmir sapphires. While these crystals could not be identified with available methods, their morphology suggests that they, too, are pargasite. Photomicrograph © Rolf Schwieger; magnified 100×.

Figure 13. Although tourmaline commonly occurs in association with sapphires from Kashmir, it was only rarely observed as an inclusion in the sample stones (as shown here). However, tourmaline has not been reported in sapphires from other localities. Photomicrograph © Rolf Schwieger; magnified 40×.

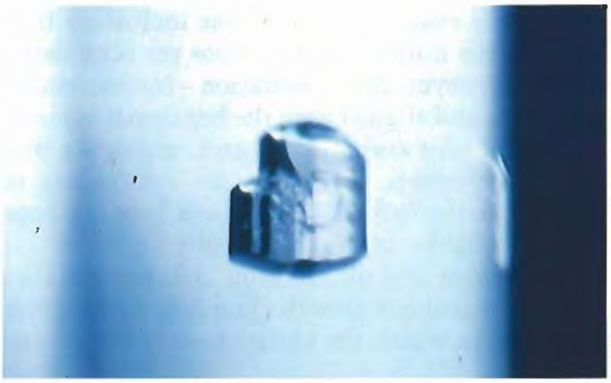


Figure 14. The Kashmir samples examined commonly contained small, slightly corroded crystals with indentations that match earlier descriptions of zircon. The smaller, black, cube-like crystals shown here on a zircon-like crystal in a Kashmir sapphire appear to be uraninite. Photomicrograph © Rolf Schwieger; magnified 200×.

Figure 15. More than half of the Kashmir sapphires studied were found to contain strongly corroded crystals of what appear to be plagioclase. Photomicrograph © Rolf Schwieger; magnified 63×.

1990), and can be found quite often as brown, greenish brown, or green crystals attached to Kashmir sapphire rough. Nevertheless, tourmaline is an infrequent inclusion in Kashmir sapphires (observed in only 5% of the study samples) and is rarely euhedral when it does occur (figure 13).

Commonly observed in the Kashmir samples examined were slightly corroded small crystals with indentations (figure 14) that match previous descriptions for zircon. Although, as noted above, zircon has been seen in sapphires from other localities, this particular form seems to be indicative of Kashmir sapphires.

Strongly corroded colorless crystals (figure 15) were, like zircon, observed in approximately 50% of the sample stones; these were similar to those identified by Hänni as plagioclase. In this form, they also appear to be indicative of Kashmir sapphire. Even more common (seen in 60% of the test samples) were cubes of opaque black prismatic crystals with tails (figure 16) or tension halos that match the reports of Phukan (1966); Hänni identified similar crystals as uraninite (see also figure 14). Allanite was seen in only 1%–2% of the samples in this study (figure 17).

Figure 16. Very common in the samples studied were cubes of opaque black crystals, often with tails (as here) or tension halos, that have been identified as uraninite. Photomicrograph © Rolf Schwieger; magnified 200×.

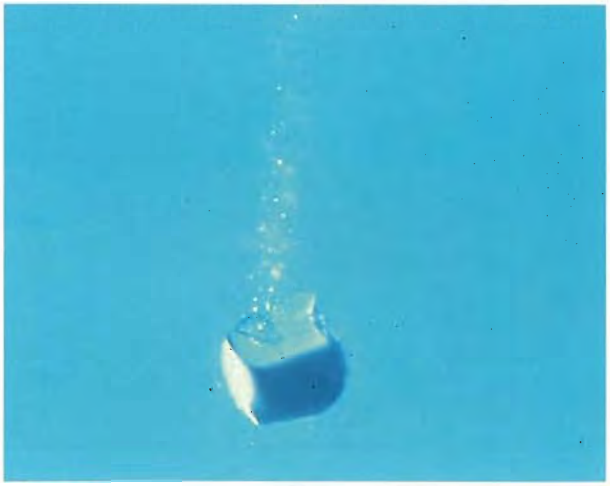


Figure 17. This group of euhedral crystals observed in a very few of the Kashmir sapphires studied matches the description given for allanite, which has not been identified in sapphires from other localities. Photomicrograph © Rolf Schwieger; magnified 40×.

Figure 18. Fingerprint-like secondary healing planes were common in the Kashmir stones examined, but have also been found in sapphires from other localities. Photomicrograph © Rolf Schwieger; magnified 40×.

"Feathers," or fingerprint-like secondary healing planes (figure 18), were also common in the Kashmir samples examined. Similar inclusions are found in sapphires from a variety of localities (see, e.g., Gübelin and Koivula, 1986).

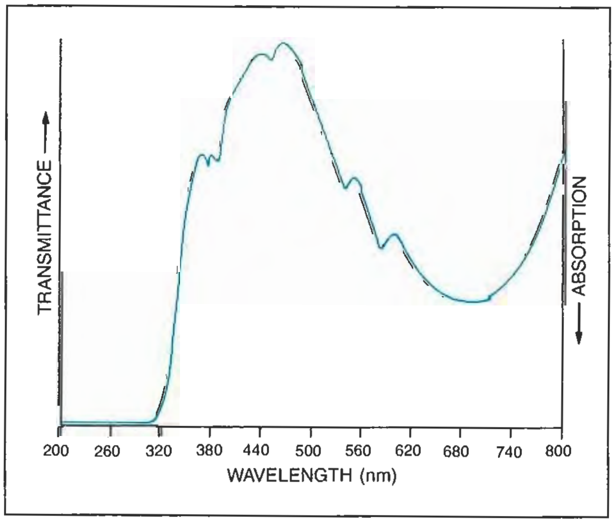
On the basis of this study and of prior reports in the literature, the following inclusions appear to be characteristic of, and most useful for origin determination of, Kashmir sapphires:

1. Color zoning as described
2. Clouds or lines of "snowflake" formations composed of dust-like particles, probably exsolutions of rutile
3. Pargasite
4. Tourmaline
5. Allanite
6. Zircons with indentations
7. Strongly corroded plagioclase

Although the color zoning may be confused with that seen in sapphires from Pailin and some heat-treated Sri Lankan sapphires, the four types of inclusions that follow on this list (in particular, the dust-like particles in a "snowflake" formation) have not been seen in sapphires from any other locality by this author or by others, as reported in the literature. The last two are, in these particular forms, at least indicative of Kashmir origin (euhedral plagioclase has been observed in sapphires from Pailin and Australia [Schubnel, 1977; Gübelin and Koivula, 1986]). At least one of these features was seen in each of the six pieces of sapphire rough obtained by the author in Kashmir. However, because of the possibility of overlap with other localities and the absence of diagnostic mineral inclusions in some stones, it is usually the combination of inclusions with optical spectra that allows the safest determination of Kashmir origin.

Spectrophotometry. From among the Kashmir sapphires studied, as well as from sapphires known to come from Cambodia (Pailin), Thailand, Vietnam, Nigeria, Australia, Burma, Sri Lanka, Montana, Brazil, and China, more than 400 optical spectra were obtained in the range 200 to 800 nm. With regard to unheated sapphires, clear differences can be noted between those of basaltic origins (Pailin, Thailand, Vietnam, Nigeria, Australia, Brazil, and China) and those of nonbasaltic origins (Kashmir, Burma, Sri Lanka, and Montana). The absorption maximum of nonbasaltic sapphires in the range of 550–800 nm is generally centered at 580 nm for the ordinary ray (o) and at 690 nm for the extraordin-

Figure 19. In most instances, the spectra of unheated Kashmir sapphires (here, the 29-ct stone that was later used in the heat-treatment experiment) appear to be distinctly different from those of their unheated counterparts from other localities. Spectral analyses of the rough sapphires obtained in Kashmir showed the same key features as this faceted stone. Transmittance spectrum, extraordinary ray.



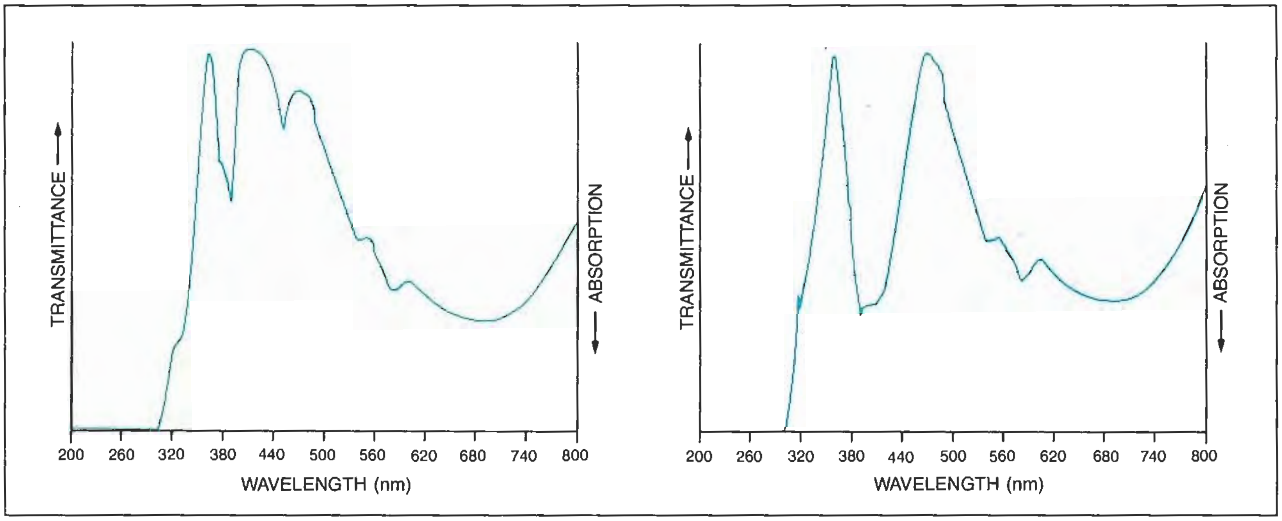


Figure 20. The spectrum shown in figure 19 for an unheated Kashmir stone is very different from those shown here for an unheated Burma sapphire (left) and Sri Lanka sapphire (right). Transmittance spectra, extraordinary ray.

ary ray (e) — caused by Fe^{2+}/Ti^{4+} pairs. In contrast, the presence of Fe^{2+}/Fe^{3+} pairs in sapphires of basaltic origin centers the absorption maximum at 800 nm.

The strength of the 450-nm system (374, 388, 450 nm) depends on the concentration of Fe^{3+}. The 450 absorption in a Kashmir sapphire is usually weak and the relative strengths of the absorption maxima at 374 and 388 are distinctive compared to those of Sri Lankan or Burmese origin. Moreover, the spectra of Kashmir sapphires (figure 19) usually reveal other features that are notably different from those of sapphires from Burma and Sri Lanka (figure 20). The absorption edge for Kashmir sapphires lies at approximately 320–340 nm, while unheated Burma and Sri Lanka sapphires usually show a "lump" at 328 nm, passing into the general absorption at about 300 nm. The absorption spectrum for a heated sapphire from any of these localities (see, e.g., figure 21) is distinctly different from that of an unheated Kashmir sapphire. This is especially important in view of the fact that some *heated* Sri Lankan sapphires superficially look like *unheated* Kashmir sapphires.

In some cases, differences are more subtle, and it is recommended that interpretation be made by an experienced specialist with files of standard comparison spectra. It is also the opinion of the author that the use of mathematically obtained parameters (Schmetzer, 1985, 1986) is not always reliable. In more than 95% of unheated Kashmir sapphires (when tested by an experienced spectroscopist), the spectra will be reliable indicators of origin. Nevertheless, in general, spectra should be used in conjunction with microscopic examination to determine conclusively the origin of a sapphire.

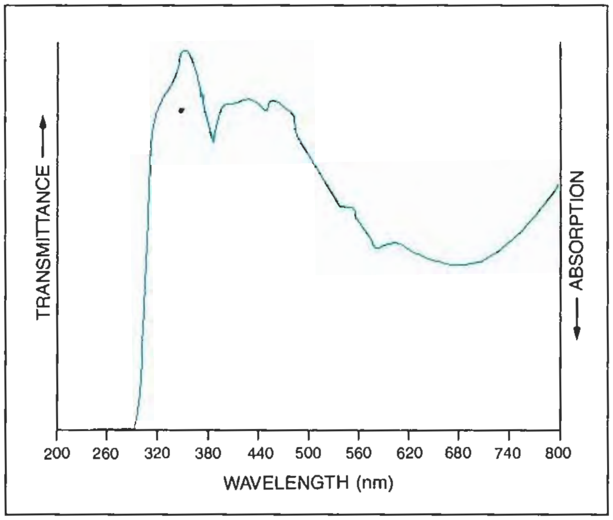


Figure 21. The author's research found that the spectrum of a heat-treated sapphire from any of the major localities (here, that of a sapphire from Sri Lanka) is significantly different from that of an unheated Kashmir sapphire. Transmittance spectrum, extraordinary ray.

HEAT TREATMENT OF KASHMIR SAPPHIRES

Heat treatment is one of the major concerns of the colored stone market, and its determination is often a serious technical problem. Although noth-

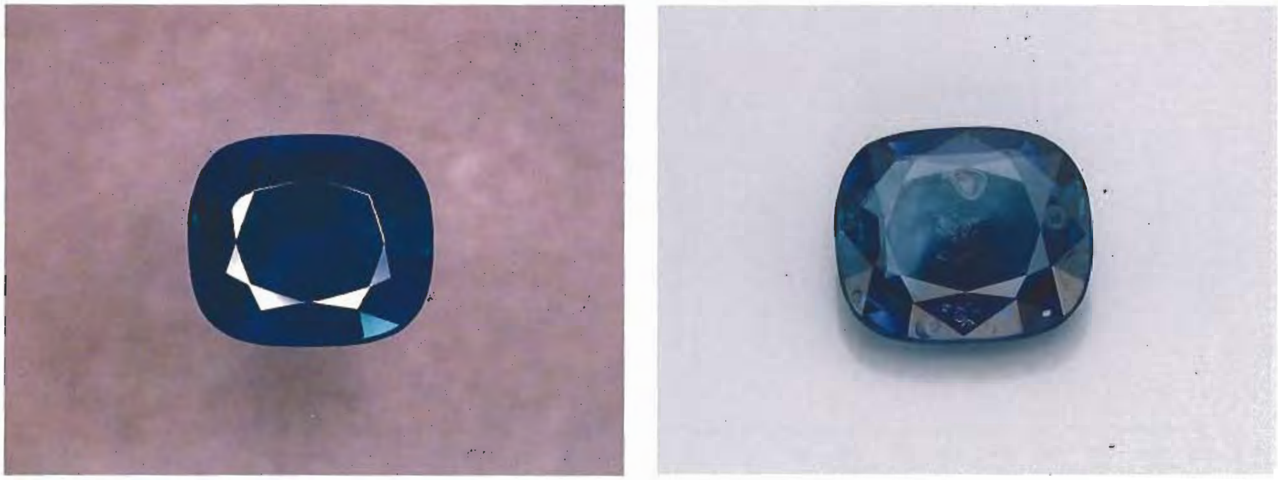


Figure 22. Before heat treatment (left), the 29-ct Kashmir sapphire was predominantly dark blue with various degrees of transparency. After treatment (right), the stone showed better transparency but also large colorless areas. Note as well the partial melting of the surface on this heat-treated stone. Photos by SSEF (left) and Michael Oldford (right).

ing has been previously reported in the literature about heat treatment of sapphires from Kashmir, it seems that, given the rarity of Kashmir stones and the unavailability of fine new material from this source, the heat treatment of existing stocks of lesser quality material is a very real probability.

The 29-ct faceted stone (with SSEF, Gübelin, and AGL certificates that state that the sapphire is of Kashmir origin) submitted for heat treatment was originally of zoned blue color ranging from mostly very dark blue to areas of light blue and with various degrees of transparency (figure 22, left). It was placed in an alumina crucible and subjected to heat treatment, with an increase in temperature of 5°C per minute until 1700°C was reached and maintained for five hours. The specimen was not coated prior to heating. The resulting stone was zoned a somewhat lighter blue with large colorless areas, and there was a general improvement in transparency (figure 22, right); partial melting of the surface was readily apparent. Repolishing, of course, would remove the telltale surface features, with a loss of no more than 3%–4% of its original weight. To remove the colorless areas, however, would require a weight loss of as much as 40%. In general, heat treatment of this stone did not result in overall improvement in appearance.

Microscopy revealed that heat treatment did produce some changes in the internal features of the stone. Color zoning was still visible, as were some of the "snowflake" formations of dust-like particles. It appears, however, that some of these dust-like inclusions were dissolved during the treatment process; we do not know whether treatment at higher temperatures and/or for a longer time would not have changed these inclusions even more. Some of the crystal inclusions were altered significantly (figure 23), which not only provided clear evidence of heat treatment but also limited their usefulness as indicators of locality origin. On the basis of this one sample, I would speculate that microscopic features (especially crystal inclusions) are usually less origin diagnostic in a heat-treated stone than in one that has not been so treated.

The spectrum of the sapphire also exhibited marked differences in absorption before (again, see figure 19) and after (figure 24) treatment, especially in the region of 360 nm. The relative strengths of absorption maxima at 374 and 388 nm (part of the 450 system) changed markedly. A shift of the absorption edge – with a weak "shoulder" at 328 nm – to a shorter wavelength below 300 nm was also apparent. Note, too, that the spectrum of the Kashmir sapphire after treatment is almost identical to that of a heat-treated Sri Lankan sapphire (again, see figure 21). Thus, spectral analysis is not useful in separating heated Kashmir sapphires from heated sapphires from Sri Lanka, which have the greatest commercial importance among treated sapphires. The fact that as many as 95% of all sapphires currently on the market may have been heat treated (see, e.g., Kammerling et al., 1990) makes this test all the more meaningful for determining not only the locality origin of, but also the absence of heat treatment in, a Kashmir sapphire.

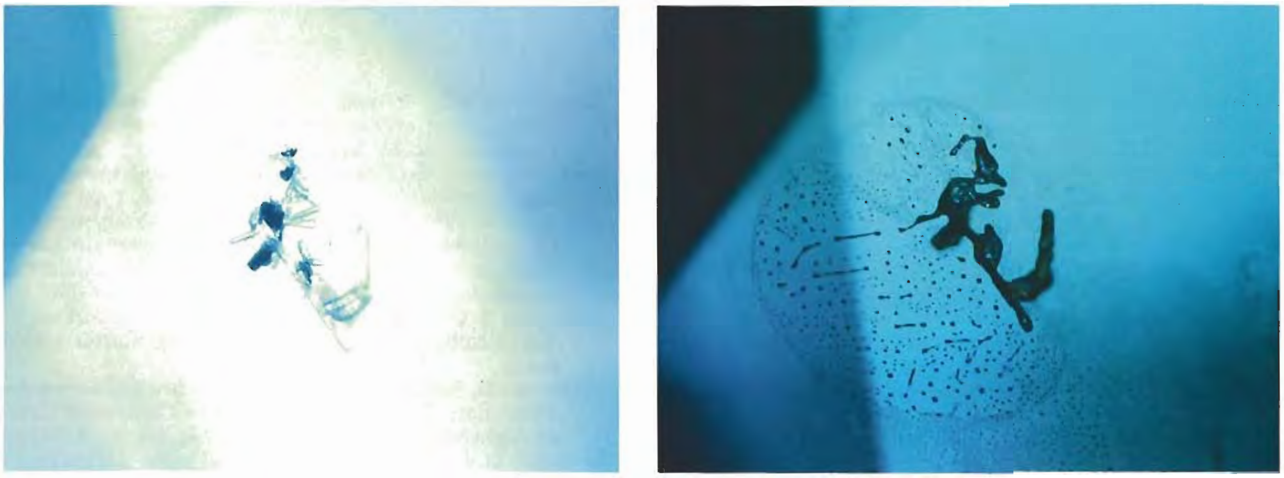


Figure 23. Heat treatment significantly altered the appearance of this group of crystals (zircon and uraninite?). They are shown here before (left) and after (right) the stone was treated. Photomicrographs © Rolf Schwieger; magnified 40×.

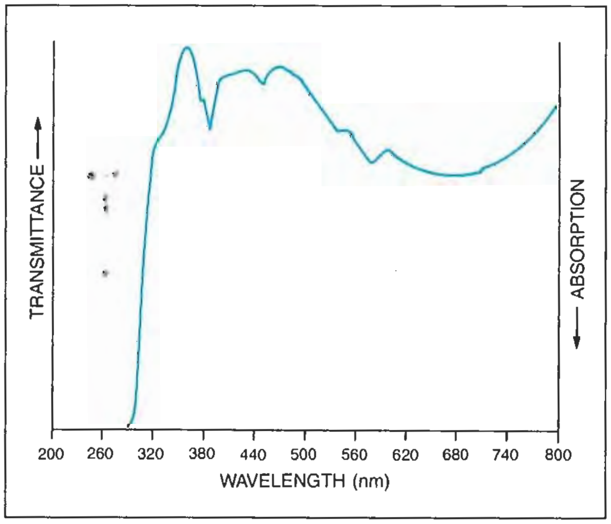


Figure 24. The spectrum of this 29-ct heat-treated Kashmir sapphire is significantly different from that of the unheated stone (see figure 19) and almost identical to those of heat-treated Sri Lankan sapphires (see, e.g., figure 21). Transmittance spectrum, extraordinary ray.

CONCLUSION

The locality origin of natural blue sapphires from Kashmir can, in many cases, be positively identified through a combination of microscopic examination and optical spectrophotometry. The characteristic features that can be seen with a microscope (using strong fiber-optic illumination) are: (1) distinctive color zoning; (2) clouds and/or lines of dust-like particles in a "snowflake" formation; (3) pargasite crystals; (4) tourmaline crystals; (5) allanite crystals; (6) zircon crystals with indentations; and (7) strongly corroded plagioclase crystals. The crystalline inclusions are relatively rare, but the first two features are quite common. Color zoning similar to that seen in Kashmir sapphires has been observed in some sapphires from Pailin and some heat-treated sapphires from Sri Lanka. While dust-like particles have been seen in sapphires from other localities, they have not been observed to occur in the "snowflake" formations that are exclusive to Kashmir stones.

Optical spectrophotometry not only differentiates basaltic from nonbasaltic sapphires, but it also provides the means to distinguish among sapphires from different nonbasaltic localities, when studied by an experienced analyst equipped with comparison spectra. This is especially useful to distinguish natural-color Kashmir stones from similar-appearing treated-color Sri Lankan sapphires.

It is likely that some Kashmir sapphires have been subjected to heat treatment. It appears, however, that the damage to crystalline inclusions and the marked differences in optical spectra caused by exposure to high temperature make it extremely difficult to establish conclusively the locality origin of a heat-treated Kashmir sapphire.

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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

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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.

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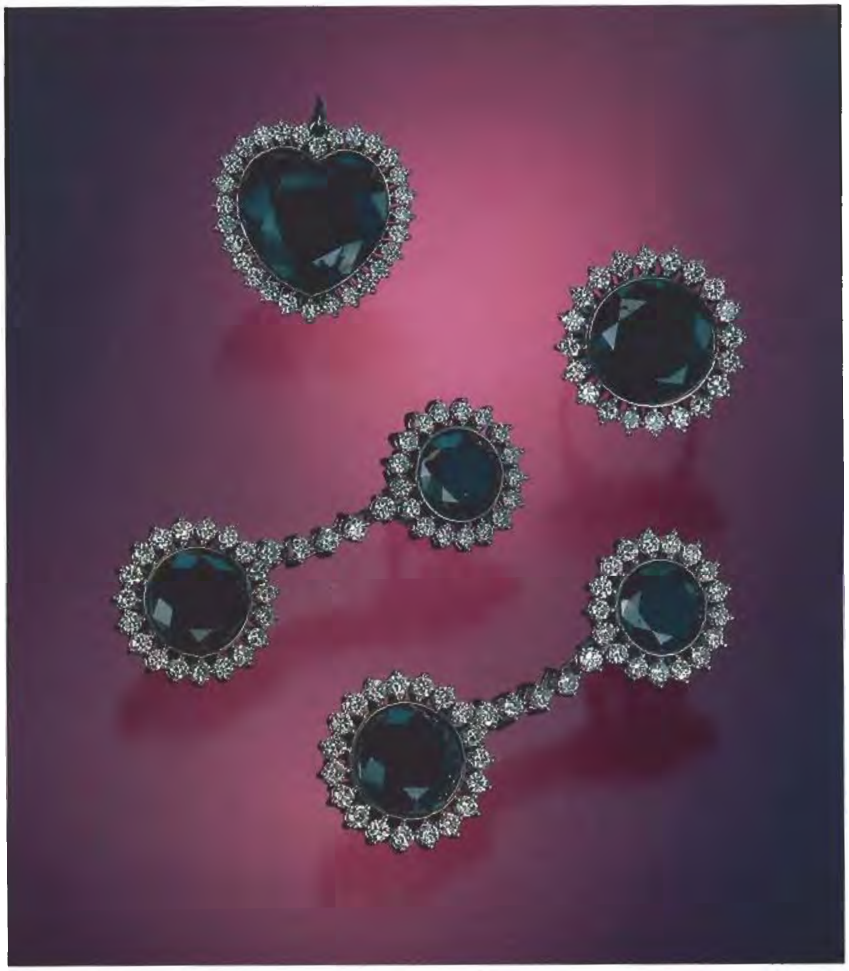


Figure 1. The six black diamonds in this impressive suite were studied for this report. The largest stone measured approximately 19.20 mm × 20.70 mm × 9.60 mm. Jewelry courtesy of Jean-Pierre Kuntz; photo by Shane F. McClure.

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.

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 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×.

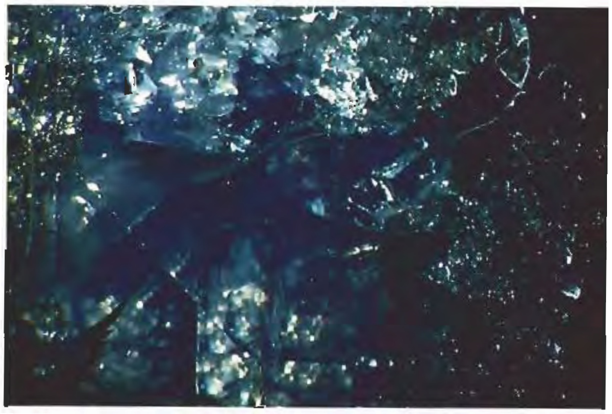


Figure 4. The transparent areas of the heart-shaped black diamond luminesced blue to an intense fiber-optic light source. Photomicrograph by Robert E. Kane; magnified 15×.

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.

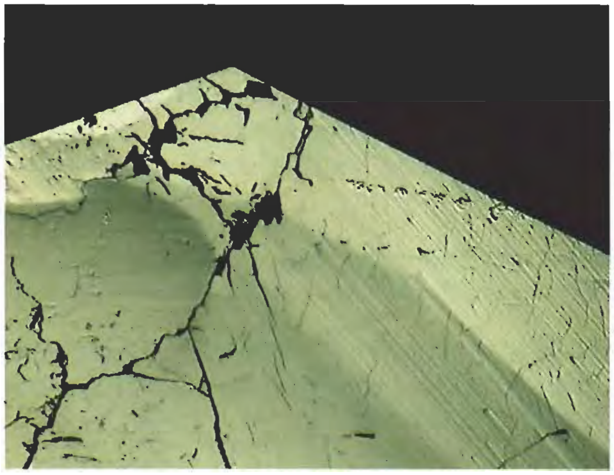


Figure 5. The numerous pits and polishing and drag lines seen on all the black diamonds studied for this report are evident on this stone. Photomicrograph by Robert E. Kane; coaxial illumination, magnified 15×.

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×.

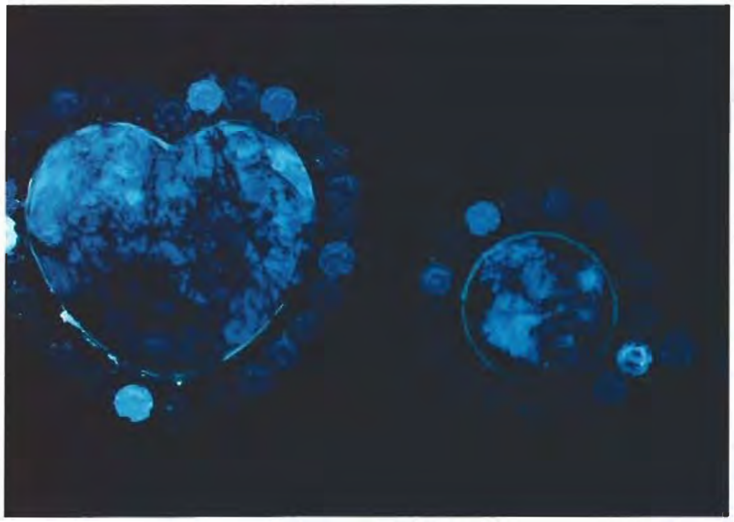
distinct lines or bands in any of the six black diamonds.

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.

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"EMERALDOLITE": A NEW SYNTHETIC EMERALD OVERGROWTH ON NATURAL BERYL

By Dominique Robert, Emmanuel Fritsch, and John I. Koivula

This article describes a new manufactured gem material marketed under the trade name "Emeraldolite," which is an epitaxial growth of flux synthetic emerald on opaque white beryl. The material has a distinctive visual appearance, and is commonly used for jewelry in its "rough" form. The gemological properties of "Emeraldolite" are very similar to those normally shown by flux-grown synthetic emeralds.

"Emeraldolite" is a new manufactured gem material that consists of a substrate of common opaque white natural beryl with an epitaxial deposit of flux-grown synthetic emerald (figure 1). Although it is not presently being produced in commercial quantities, the capacity exists for a large-scale operation. It has been used in jewelry in its "natural" form, but is also fashioned *en cabochon*. Unlike most synthetic emeralds, it is usually not faceted because of its opacity.

This article provides a general description of the procedure used to produce this new manmade gem material, and reports on its gemological properties and chemistry.

METHOD OF SYNTHESIS

"Emeraldolite" is manufactured by one of the authors (D.R.) in France. A flux process (a chemical reaction in anhydrous solvents) is used to produce the synthetic emerald overgrowth on a natural beryl seed; fluoroberyllate compounds play an important role (see Robert, 1987).

The resulting product is reminiscent of the Lechleitner overgrowth of hydrothermal emerald on prefaceted colorless beryl (see, e.g., Schmetzer et al., 1981). Both are based on the same principle: the synthesis of an epitaxial overgrowth on less expensive beryl, rather than the (more costly and more time-consuming) synthesis of an entire stone. The two products vary greatly in appearance, however, with the Lechleitner material usually translucent to transparent, while virtually all of the "Emeraldolite" produced to date has been opaque.

Figure 1. This 76.42-ct "Emeraldolite" specimen consists of a flux-grown synthetic emerald overgrowth on natural white beryl. Photo by Robert Weldon.

The flux process that produces the synthetic emerald overgrowth for "Emeraldolite" is also significantly different from that used to grow synthetic emeralds such as the Lennix product (see Graziani et al., 1987). In the Lennix process, Al_2O_3 and SiO_2 are dissolved from the crucible itself, and the flux is a typical mixture of lithium molybdate and a boron salt. By contrast, the synthetic emerald layer in "Emeraldolite" is grown using a chemical—not a physical—reaction involving fluorine as a transport agent. This allows for faster growth than the Lennix process. Further information on the procedure use to grow "Emeraldolite" must remain proprietary.

CURRENT PRODUCTION

Because "Emeraldolite" only requires the growth of a thin (0.3–1 mm) layer of synthetic emerald, it is relatively inexpensive to manufacture (see "Synthetic emeralds . . . ," 1988). With only a small furnace, 15,000–20,000 ct of material can be produced annually. The process could be adapted to accommodate larger production in a variety of shapes and styles. Presently, production is variable, with ongoing experimentation into the most attractive product for jewelry use. It has been found, for example, that the overgrowth is unpleasantly asymmetrical on all isometric shapes, such as spheres, because of preferred growth along the optic axis.

DESCRIPTION OF THE MATERIAL

A view from the base of the "Emeraldolite" sample in figure 1 shows a thin layer of transparent dark green, flux-grown synthetic emerald covering a milky-white natural beryl crystal (figure 2). The substrate, which plays the role of seed crystal, can be of any size or shape. The linear dimension of the beryl core used is not a critical parameter (pieces over 10 cm have been successfully processed); rather, the total surface area is key because it determines the amount of feed material necessary to obtain a smooth, homogeneous coverage.

The dark color of the overgrowth is very even, and is reproducible from run to run. The synthetic emerald layer has a step-like appearance caused by the juxtaposition of numerous tiny (1–5 mm in longest dimension) crystal faces that are all oriented in the same crystallographic direction. This crystallographic orientation also contributes to the homogeneity of color.

Figure 2. A different view of the specimen in figure 1 shows the thin flux synthetic emerald overgrowth. The color contrast between the white seed and the overgrowth is obvious. The numerous parallel crystal faces demonstrate the epitaxial character of the overgrowth. Photo by Robert Weldon.

Before deposition of the overgrowth, the substrate can be preformed in a particular shape (cabochon, for example) to fit in standard mountings. The "Emeraldolite" can then be polished (with greater ease than if the overgrowth were random, because there is only one crystallographic orientation) or incorporated as grown into pieces of jewelry (figure 3). Even polished, though, the surface is irregular, so visual appearance will easily separate "Emeraldolite" from natural emerald and even other synthetic emeralds.

GEMOLOGICAL PROPERTIES

To characterize "Emeraldolite" gemologically, we studied a total of 10 samples: one large (37.94 × 24.31 × 18.13 mm; 76.42 ct), very dark, irregular crystalline mass (figure 1); five smaller (20 mm in maximum dimension) rough pieces; one 20-mm piece polished as a flat tablet; and three "rough" pieces that had been mounted in jewelry (again, see figure 3). The results of our examination are summarized below. In general, the gemological properties of the "Emeraldolite" overgrowth are consistent with those of other flux-grown synthetic emeralds (Koivula and Keller, 1985).

ABOUT THE AUTHORS

Mr. Robert is a consulting engineer and professor at the St. Etienne School of Mines, St. Etienne, France. He has done extensive research in crystal growth, and currently manufactures both "Emeraldolite" and "Oulongolite." Dr. Fritsch is research scientist, and Mr. Koivula is chief gemologist, at the Gemological Institute of America, Santa Monica, California.

Acknowledgments: The authors are grateful to Robert Weldon of GIA for taking photographs of the material studied, and to Dr. James Shigley of GIA for his constructive comments.

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Figure 3. These three pieces of "Emeraldolite" jewelry represent a typical style in which this new gem material is employed. The central piece measures 5.5 × 3.5 cm. Photo by Robert Weldon.

Refractive Index. Because the essentially rough surface is covered with tiny crystal faces, we used the spot method (on a Duplex II refractometer with a white light source) on four different areas of the large crystal and one spot on each of the other pieces. All yielded an R.I. of 1.56, which is typical of flux synthetic emerald (Liddicoat, 1989; p. 101). Because of the limitations imposed by the irregular surface condition of the "Emeraldolite," no birefringence could be determined.

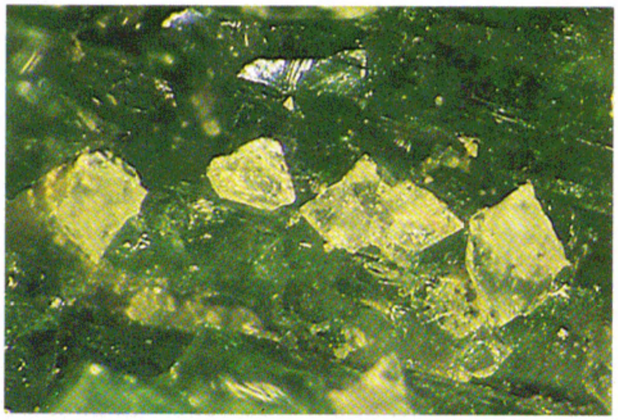
Specific Gravity. We could not determine an accurate specific gravity on any of the study specimens because the irregular surfaces trapped excessive amounts of air that could not be completely dislodged. Moreover, the specific gravity of an entire piece of "Emeraldolite" would vary depending on the specific gravity of the core. We did, however, test a 0.05-ct fragment of the synthetic overgrowth, using a mixture of methylene iodide and benzyl benzoate calibrated at 2.67. The sample floated very slowly to the surface of the liquid, on the basis of which we estimated the S.G. to be 2.66, which is typical of flux-grown synthetic emerald (Liddicoat, 1989; p. 101).

Ultraviolet Fluorescence. When examined in darkroom conditions with both long- and short-wave ultraviolet radiation, the synthetic emerald overgrowth and the white core material were inert, with no visible phosphorescence. This contrasts with the weak red fluorescence typical of most flux-grown synthetic emeralds. Although the iron content of the material is relatively low (0.28–0.34 wt.% FeO; see "Chemical Analysis" below), other synthetic emeralds containing similar amounts of iron do fluoresce red (Koivula and Keller, 1985; Graziani et al., 1987). Quenching by vanadium is possible, but unlikely. Instead, the absence of fluorescence may be due to "self-quenching," which occurs when nearby ions of the same type (here, Cr^{3+} ions) interact because of their high concentration, and the energy absorbed is given off in a form other than visible luminescence (Waychunas, 1988).

The surfaces of several specimens are speckled with numerous tiny, white, translucent, octahedral crystals (figure 4) and crusts of what appears to be "lithium feldspar"—the type of crystals obtained by Hautefeuille and Perrey when they first synthesized emerald by a flux method in 1888 (Nassau, 1976). These spots fluoresce a weak, chalky, brownish yellow to long-wave U.V. radiation, and a strong, chalky, slightly brownish yellow to short-wave U.V.

Visible-Light Spectroscopy. Using a Pye Unicam 8800 spectrophotometer, we took the visible-light absorption spectrum of a small fragment of the synthetic emerald overgrowth in a random orientation. The spectrum produced is typical of synthetic emerald: two broad bands with apparent maxima at about 430 and 610 nm, and a number of

Figure 4. Translucent, white, octahedral "lithium feldspar" crystals form as a by-product on and in the "Emeraldolite" overgrowth. Photomicrograph by John I. Koivula; magnified 30×.



sharp bands at 470, 476, 636, 660, 680, and 683 nm. "Cr lines" were easily seen with a Beck hand spectroscope.

Pleochroism. Although "Emeraldolite" is essentially opaque and very dark, we did see moderate pleochroism (very slightly yellowish green and bluish green) when all specimens were viewed through a dichroscope with reflected light.

Chelsea Color Filter Reaction. When bathed in white light from a fiber-optic illuminator and examined with a Chelsea color filter, the surfaces of all the "Emeraldolite" specimens appeared intense brownish red.

Hardness. Using a set of Mohs hardness points, we found that "Emeraldolite" was easily scratched with the corundum point (hardness 9), but the topaz point (hardness 8) did not produce a scratch even when a reasonable amount of pressure was applied. We therefore estimated the Mohs hardness to be approximately 8, which is within the expected range for synthetic emerald.

Toughness. The epitaxial growth process seems to begin with a short etching period that guarantees complete continuity between the crystalline lattice of the substrate and that of the overgrowth. This results in a very good toughness and mechanical solidity that would not be achieved if the emerald overgrowth had a random orientation. The overgrowth cannot be broken off the substrate, so the toughness of "Emeraldolite" is basically that of the substrate. If this latter contains big fractures, it will shatter when put in the flux; if it contains small fractures, the epitaxy will seal them, reinforcing the piece.

Microscopic Features. Using oblique illumination, we carefully examined the transparent overgrowth of the "Emeraldolite" samples with a gemological microscope. The features observed can be used to identify this material as a synthetic.

Specifically, magnification revealed several families of tiny parallel crystal faces that cover the flux synthetic overgrowth layer like a mosaic. In some few areas, the overgrowth had been chipped away, exposing the white beryl substrate (figures 2 and 5).

The morphology of the emerald crystals in the overgrowth is typical of emerald, with essentially prism faces and basal planes. The occurrence of bipyramidal faces is strongly related to the somewhat complicated end of the thermal synthesis cycle. These faces are less common in the "evaporation facies" obtained on the surface of the melt and on the walls of the crucible (Robert, 1987). A detailed description of the crystal shapes and associations is given in Robert (1988a and b). Note that the stress cracks typical of the hydrothermally grown Lechleitner synthetic emerald overgrowth were not seen in the flux overgrowth of "Emeraldolite."

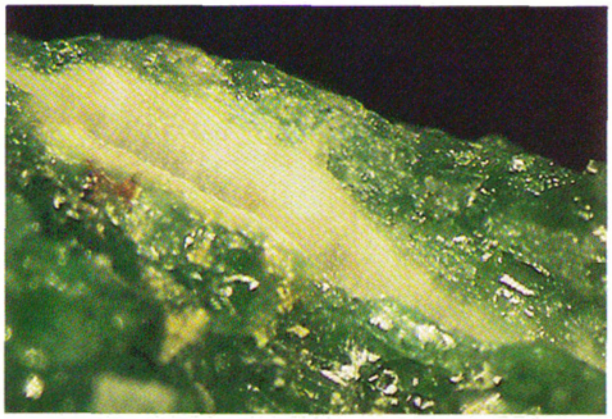


Figure 5. The 0.5-mm-thick flux synthetic emerald overgrowth layer contrasts with the underlying white beryl substrate. Photomicrograph by John I. Koivula; magnified 6×.

The small, colorless octahedral crystals of "lithium feldspar" that were seen to fluoresce on the surface of the samples were also seen inside the synthetic emerald overgrowth. This "lithium feldspar" crystallizes in the tetragonal system, and its crystal structure is currently under study.

In the synthetic emerald layer, we also observed comparatively large primary flux inclusions of an off-white to brown color (figure 6), as well as high-relief spherical to subspherical voids that greatly resemble the ordinary gas bubbles common to most glasses (figure 7). The latter may be partially open at the surface, forming crater-like pits. Although the flux inclusions were typical of those observed in flux-grown synthetic emeralds (Gübelin and Koivula, 1986), the bubble-like features have not been seen before in synthetic emeralds and are more characteristic of inclusions found in the Knischka synthetic ruby (Gübelin, 1982), also a flux product.

Figure 6. These primary flux inclusions were commonly observed in the "Emeraldolite" overgrowth. Photomicrograph by John I. Koivula; magnified 20×.

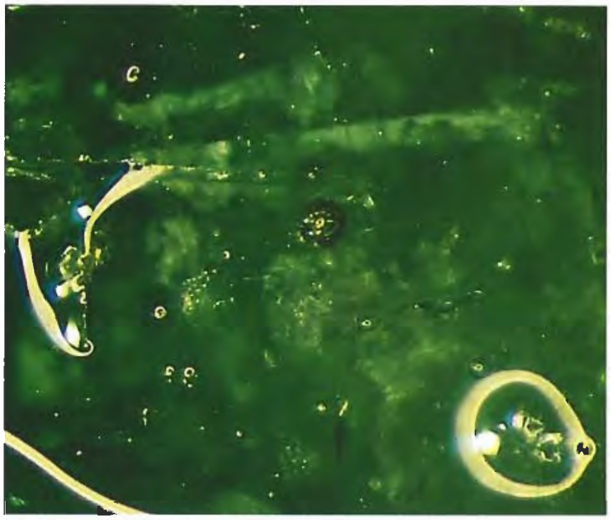


Figure 7. High-relief spherical to subspherical voids are commonly seen in the "Emeraldolite" overgrowth layer. Photomicrograph by John I. Koivula; magnified 50×.

CHEMICAL ANALYSIS

Using an energy-dispersive electron microprobe, Dr. Henry Hänni and George Bosshart, both at the time with the Swiss Foundation for Research on Gemstones (SSEF), analyzed the chemistry of the "Emeraldolite" epitaxial overgrowth. The range of compositions obtained is shown in table 1.

Note in particular that the concentration levels of Cr^{3+} are significantly higher than those found in most natural emeralds (approximately 1 wt.%; Hänni, 1982), but are lower than those found in the Lechleitner synthetic emerald overgrowth (7.64 to 13.20 wt.%; Schmetzer et al., 1981). These high concentrations of Cr^{3+} are responsible for the dark green color. The low concentrations of magnesium also contrast with the high values (more than 0.8 wt.% MgO) found in natural emeralds. Concentrations of Na_2O in "Emeraldolite" compare favorably with those of synthetic emeralds (less than 0.2 wt.%) and contrast with the 0.4 wt.% usually found in natural emeralds (Hänni, 1982).

TABLE 1. Chemical composition of the "Emeraldolite" synthetic emerald overgrowth.[a]

Oxide	Weight %
SiO_2	66.88 – 67.28
Al_2O_3	16.58 – 18.21
TiO_2	nd – 0.06
FeO	0.28 – 0.34
MgO	0.17 – 0.25
MnO	nd – 0.13
Cr_2O_3	1.76 – 4.15
V_2O_5	nd – 0.12
Na_2O	bdl

[a] *Chemical analyses performed by Henry Hänni and George Bosshart, SSEF, on an electron microprobe equipped with an energy-dispersive spectrometer. Details of the operating conditions can be obtained from the analysts. nd = not determined; bdl = below detection limits.*

The higher concentrations of Mg and Na in nature are due to Mg^{2+} substituting for Al^{3+} in the beryl crystal structure, the charge deficit being compensated by the presence of a Na^{+} ion nearby. This mechanism does not occur during the growth of the "Emeraldolite" layer or any flux-grown synthetic emerald because Mg and Na are not voluntarily introduced in the growth environment.

CONCLUSION

Manufactured in France, "Emeraldolite" is an overgrowth of deep green flux synthetic emerald on opaque white natural beryl. It is based on a principle similar to that of the Lechleitner synthetic emerald overgrowth on transparent to translucent near-colorless natural beryl. Its unique appearance makes it easy to separate from any other natural gem or synthetic material. In addition, one can find in the synthetic emerald overgrowth characteristics typical of a flux-grown synthetic emerald.

"Emeraldolite" has been used by jewelry manufacturers in its original state, without polishing, because its numerous crystal faces reflect light well. The material can, however, be polished, and lends itself to intarsia and sculpture, as well as to cabochons.

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Gem Trade LAB NOTES

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AZURITE

The West Coast laboratory recently had an opportunity to examine several collection-quality specimens of azurite, the theme mineral of the 1991 Tucson Gem & Mineral Society Show. These fine specimens came from several different localities.

Azurite is a copper carbonate hydroxide, with the chemical formula $Cu_3(CO_3)_2(OH)_2$. Its name, in allusion to its color, is from the Persian word *lazhward,* which means blue. Azurite is soft, with a Mohs hardness of 3 ½ to 4. Its specific gravity normally ranges from 3.77 to 3.89, although some porous material may be as low as 3.30. The refractive indices for azurite are 1.730 and 1.836, and it is biaxial positive. Faceted azurite is extremely rare; it is generally excessively dark, almost black, even in small gemstones.

Azurite is widely associated with copper ores. Major sources of azurite in the United States are the copper-mining districts at Bisbee and Morenci, in Arizona; it also occurs at several localities in Nevada, New Mexico, Utah, and California. Other notable deposits include Tsumeb, Namibia; Chessy, France; and Morocco, China, Mexico, Australia, the Soviet Union, Romania, and Zaire.

Azurite crystallizes in the monoclinic system, and can vary widely in habit and be highly modified. Among the most attractive specimens are the nearly spherical aggregates or rosettes that exhibit numerous deep blue subparallel sharp-edged crystals (figure 1). Azurite is almost invariably found in conjunction with malachite; some of these specimens can be quite exceptional (figure 2). *RK*

Figure 1. This fine azurite cluster (10 × 7.6 cm) is reportedly from one of the world's earliest exploited copper deposits, near Lyon, Chessy, France.

Editor's Note: The initials at the end of each item identify the contributing editor who provided that item.

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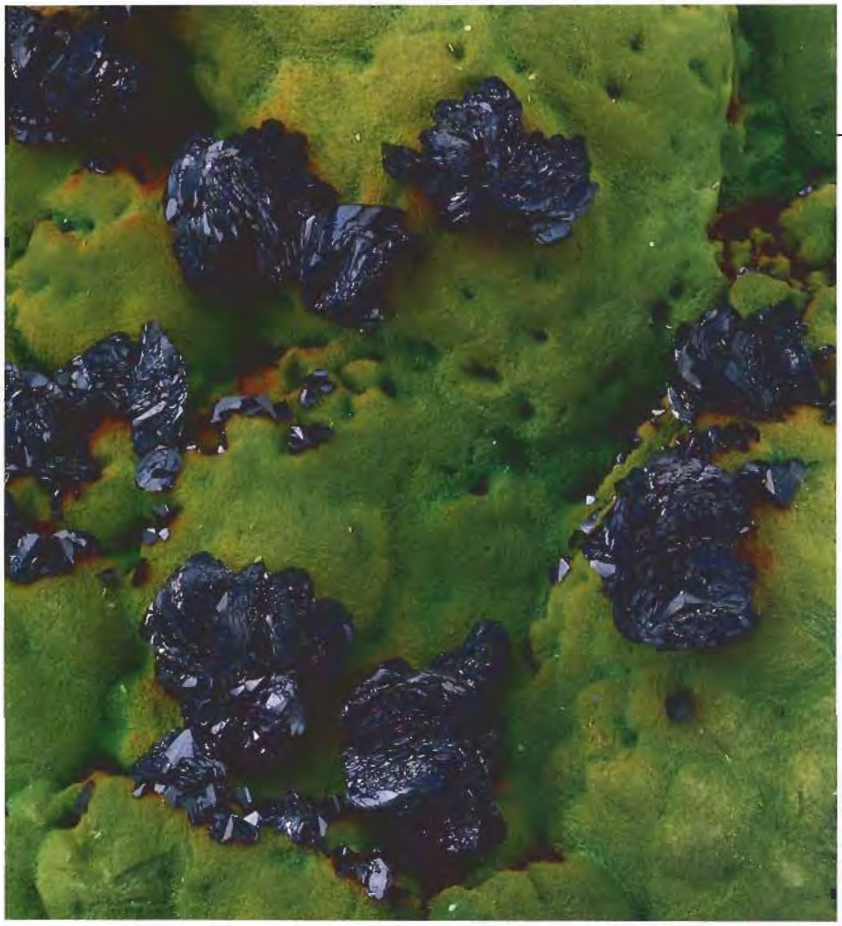


Figure 2. This section of a 22-cm-long azurite specimen reportedly from Bisbee, Arizona, shows the rosettes of deep blue crystals (the largest cluster measures 1.9 cm) that are common from this locality. Here, they emerge from a bed of iron-stained malachite, which often occurs in association with azurite.

CUBIC ZIRCONIA

Simulating a Fancy Yellow Diamond

Yellow cubic zirconia can effectively imitate a fancy yellow diamond. Some years ago, a large yellow cubic zirconia, fashioned to look like a 10-ct cushion octagon modified brilliant, was submitted to the East Coast laboratory (see *Gems & Gemology*, Winter 1985, p. 234). Recently, the East Coast lab was asked to examine the two side stones in a lady's ring; one proved to be a natural-color yellow diamond, but the other was a cubic zirconia.

Spectroscopy is the most useful test for determining the origin of color in a diamond. A Beck hand-held type of spectroscope revealed the Cape series of bands—at 415, 453, 466, and 478 nm—present in the natural-color type Ia yellow diamond. Although cubic zirconia does not contain a 415-nm absorption line, the yellow CZ in this ring did display two prominent absorption bands in the same area as the 453-nm and 478-nm bands. This confirms the need for caution when examining diamond-like materials in this color range.

Other tests helped prove the identity of the imposter. The girdle of the CZ showed the typical attempt to simulate the bruted girdle of a diamond, but it did not approach the frosted appearance of diamond. The orange fluorescence to long-wave U.V. radiation is typical of cubic zirconia, although it has also been seen in some natural-color yellow diamonds. Because the thermal conductivity of CZ is lower than that of diamond, the reaction to the needle on the thermal conductivity tester was minimal. In addition, this stone had a chipped culet with an appearance atypical of diamond. Last, the strong dispersion of CZ (0.60) is noticeably greater than that of diamond (0.44); because the cubic zirconia and diamond were in relatively close proximity in this ring, the difference in dispersion was readily apparent. *DH*

DIAMOND

Fancy Intense Yellow

Ever since the laboratory first encountered a Sumitomo synthetic yellow diamond in the course of routine testing four years ago, we have routinely tested all intense yellow diamonds with both long- and short-wave U.V. radiation. Readers may recall that Sumitomo synthetic yellow diamonds do not fluoresce to long-wave U.V., but do fluoresce a chalky greenish yellow to short-wave U.V. (see Shigley et al., "The Gemological Properties of the Sumitomo Gem-Quality Yellow Synthetic Diamonds," *Gems & Gemology*, Winter 1986, pp. 192–208). In addition, because they are type Ib diamonds, they do not exhibit any absorption lines in the hand-held spectroscope, which are present in many type Ia's.

Thus far, with the exception of the 0.80-ct round-brilliant-cut stone referred to in the above article, all the faceted Sumitomo synthetic diamonds we have seen have been small (less than 0.25–0.30 ct) square step cuts, having been fashioned from the squarish tablets prepared and sold by Sumitomo for use as heat sinks for electronic applications. Although we would be surprised at this time to encounter any other shape, we do test all small intense yellow diamonds, regardless of shape. While writing this note, we learned that Sumitomo has manufactured a few gem-quality synthetic yellow diamond crystals in excess of 9 ct (J. Shigley, pers. comm., 1990). However, the firm still maintains that it has no plans to market crystals to the jewelry industry.

Recently, the East Coast laboratory received for examination a brooch (figure 3) that contained a

Figure 3. Two of the fancy yellow diamonds in this brooch of 0.5–1.0 ct stones fluoresced to short-wave, but not to long-wave, U.V.

Figure 4. The similarity in appearance between a Sumitomo synthetic yellow diamond (here, the 0.19-ct stone in the center) and the natural fancy yellow diamonds in the brooch shown in figure 3 is striking. The stone at the lower left is one of the two that fluoresced to short-wave U.V. radiation.

number of fancy yellow marquise- and pear-shaped brilliants. We were surprised to observe that two of the marquise shapes (each approximately half a carat) did not fluoresce to long-wave, but did fluoresce greenish yellow to short-wave, U.V. radiation. Because of the settings, we could not determine if these stones had the color zoning that is sometimes visible in the Sumitomo synthetic diamonds. However, infrared spectroscopy established that these two stones were not pure type Ib diamonds, as all gem-quality synthetic yellow diamonds encountered to date have been. They were a mixture of types Ib and Ia, a strong indication of natural origin. Figure 4 shows a magnified view of a section of the brooch with a 0.19-ct Sumitomo synthetic diamond placed in the center for comparison. The stone at the lower left is one of the two that fluoresced to short-wave U.V. *RC*

Treated Green

In recent months, the laboratories on both coasts have received increasing numbers of fancy-color diamonds for examination, many over 5 ct. Some of these diamonds had obviously been treated to enhance their color. This was the case with a half-carat dark green round brilliant seen in the West Coast laboratory, which showed a color concentration around the culet with magnification (figure 5). This "umbrella effect" is characteristic of cyclotron bombardment. Usually, this type of treatment does not penetrate very deep into the stone, as evidenced by the restricted color concentration in the area of bombardment. However, this particular treated green diamond differed from others that we had seen before, in that another zone of darker color concentration became visible when oblique lighting was used. This zone, which followed the periphery of the stone (figure 6), actually extended in a definite plane from the crown area into the pavilion, toward the culet.

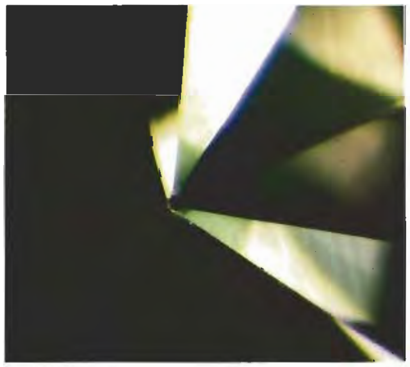


Figure 5. The distinct zone of color around the culet of this green diamond indicates cyclotron treatment. Magnified 15×.

The stone did not fluoresce to either long- or short-wave U.V. radiation. The absorption spectrum, as observed with a GIA GEM hand-held type of spectroscope unit, showed weak Cape lines at room temperature. When the stone was cooled with a refrigerant, an additional faint, but distinct, line at 592 nm became visible. *KH*

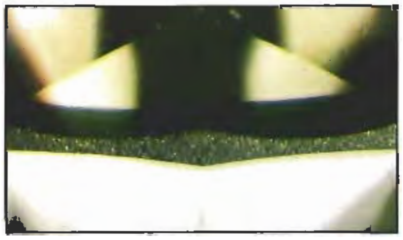


Figure 6. Oblique lighting revealed an additional color zone around the girdle of the stone in figure 5; such a zone had not been observed before in a cylcotron-treated diamond. Magnified 15×.

PEARLS

Dyed Black Cultured, Origin of Color

The GIA Gem Trade Laboratory routinely examines gray to black cultured pearls to establish whether or not their color is natural. Proof of natural color, as in those black cultured pearls grown in the area around Tahiti, lies in the reaction to long-wave U.V. radiation. Like the *Pinctada margaritifera* shell in which they are grown, natural-color Tahitian cultured pearls appear brownish to brownish red when exposed to long-wave U.V. in a dark room. On the other hand, all dyed black cultured pearls seen to date, whether treated with silver nitrate or by another unidentified dye process, either do not fluoresce at all or fluoresce a dull green.

X-radiography may also provide useful information. Typically, the layer of conchiolin in a cultured pearl provides marked contrast between the shell bead center and the overlying nacre in an X-radiograph. In a cultured pearl treated with silver nitrate, however, silver tends to concentrate in the area of the conchiolin; because silver is opaque to X-rays, the X-radiograph of a cultured pearl treated with silver nitrate may show a light ring around the nucleus, or it may show almost no contrast between the nucleus and the nacre.

During the past year, we have encountered a number of gray to black and brown cultured pearls that clients have submitted as "Tahiti" pearls. Figure 7 shows one of three such undrilled 10-mm cultured pearls that were recently seen in the East Coast laboratory. Unlike natural-color Tahitian pearls, these three fluoresced a distinct yellow to long-wave U.V. radiation. The X-radiograph (figure 8) shows that two of these beads have good contrast between the nucleus and the nacre, while the third specimen has a very thin nacre. With magnification, as seen in figure 9, we observed a dark fingerprint pattern on the surfaces of two of the beads that was unlike anything we had seen before. Whatever dyeing method was used does not require that the pearls be drilled, and the color may be confined to a relatively thin surface stain.

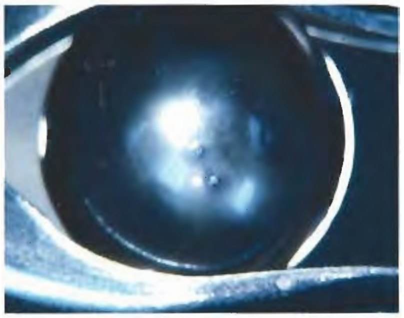


Figure 7. This 10-mm dyed black cultured pearl fluoresced yellow to long wave U.V. radiation.

Although we were unable to retain these cultured pearls long enough to analyze the coloring agent, similar pearls examined by X-ray fluorescence in the GIA Research Department were found to contain, surprisingly, the metallic element tellurium. RC

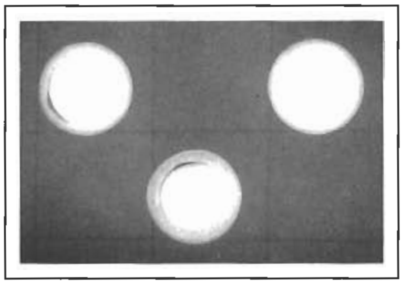


Figure 8. As revealed in this X-radiograph, one of the dyed black cultured pearls has a very thin deposition of nacre, but the other two show strong contrast between the nacre and the nuclei.

Figure 9. A fingerprint pattern (of dye?) was observed on the surface of two of the three dyed black cultured pearls. Magnified 60×.

Uncommon Cultured

The East Coast laboratory was asked to identify the beads in the earrings shown in figure 10. All proved to be cultured pearls. The button cultured pearls are unusual in that they have lentil-shaped nuclei. In addition, the single black cultured pearl showed a reversal pattern (a ring that is opaque, rather than transparent) in the X-radiograph, which is probably due to the use of silver salts.

Figure 10. The button-shaped cultured pearls in these earrings contain unusual lentil-shaped nuclei. The single black cultured pearl was found to be dyed.

Lentil-shaped nuclei are uncommon; we have mentioned them only once before in *Gems & Gemology* (Summer 1984, p. 109). At that time, we learned that off-round nuclei are seldom used in the culturing process because they greatly increase the mortality rate of saltwater mollusks. Incidentally, the near-colorless brilliants in these earrings are zircons. RC

Unheated RUBY with a Glass Filling

We often associate the presence of glass fillings in rubies with heat treatment, since glass is sometimes used to fill the spall cavities that may occur on the surface of a stone during heating.

Recently, we observed a glass-filled cavity in a 1.12-ct ruby submitted to the East Coast laboratory (figure 11). The presence of numerous crystals and pristine needles, without surrounding stress cracks or other evidence of heating, strongly indicates that the stone had not been

Figure 11. A glass-filled cavity is readily apparent in this 1.12-ct faceted ruby, which showed no other evidence of heat treatment. Magnified 15×.

heat treated to improve color or clarity. However, since some glasses melt at a low temperature, one such glass could have been easily applied to this stone without producing any indications of heat treatment in the stone itself.

The glass filling fluoresced a chalky yellow to long-wave U.V. radiation and contained a large gas bubble. *DH*

SYNTHETIC RUBY, with a Glass Filling

Figure 12 shows what appears to be a modern bar pin, but with an Art Deco design influence, that contains four well-matched red cabochons (each approximately 8.50 × 7.00 × 4.90 mm). When examined with a hand-held type of spectroscope, all four showed the absorption spectrum typical of natural and synthetic ruby. Three of the four contained fine intersecting needles, along with undisturbed subhedral crystals, which proved that these three stones were natural in both origin and color. However, close examination of the fourth cabochon, second from the left in the pin, revealed curved striae and gas bubbles. When we viewed this cabochon through the back, we noted that the bubbles were confined to a shallow cavity that had been filled with a glass-like material (figure 13). The curved striae are typical of a flame-fusion synthetic.

On the basis of our ongoing encounters with filled rubies, we recommend that our readers not only continue to use the techniques outlined in the article "Natural Rubies with Glass Filled Cavities," by Robert E. Kane (*Gems & Gemology,* Winter 1984, p. 187), but that they also be on the lookout for synthetics with this type of treatment.

Tom Moses

Figure 12. The cabochon that is second from the left in this bar pin was found to be synthetic ruby; the other three stones all proved to be natural ruby.

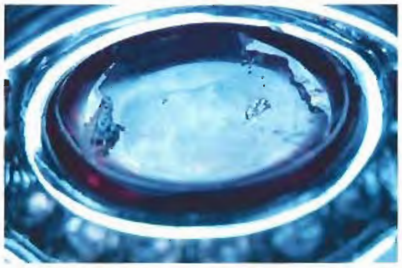


Figure 13. The synthetic ruby in the pin shown in figure 12 has a glass-filled cavity. Magnified 15×.

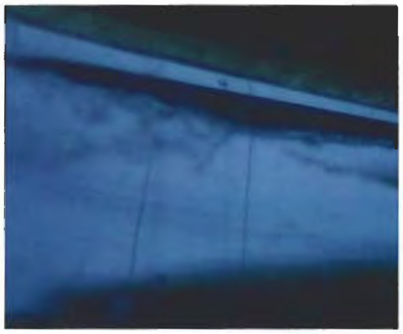


Figure 14. Natural-appearing needle-like inclusions can be seen against a background of curved growth lines in this flame-fusion synthetic sapphire. Magnified 30×.

SYNTHETIC SAPPHIRE

Flame Fusion, with Needle-Like Inclusions

The East Coast laboratory recently had the opportunity to examine a 1.77-ct cushion antique mixed-cut flame-fusion synthetic sapphire that contained some needle-like inclusions. Although these inclusions were very "natural" looking, the presence of curved growth lines, also visible in figure 14, left no doubt that the stone was synthetic. On previous occasions, the lab has observed natural-appearing inclusions in synthetic ruby and synthetic blue sapphire (see *Gems & Gemology,* Spring 1989, p. 38, and Summer 1984, p. 111, respectively).

When the stone was viewed in certain directions, the needle-like inclusions were more prominent than the curved striae and gas bubbles. As seen with higher magnification in figure 15, the needle-like inclusions

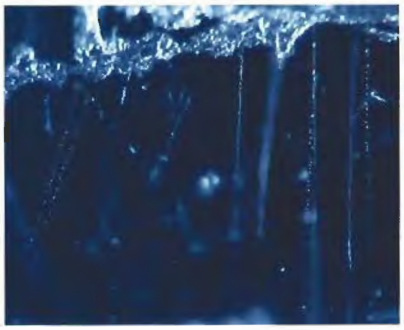


Figure 15. Higher magnification (63×) reveals that the "needles" in figure 14 are actually strings of tiny gas bubbles.

are actually strings of tiny gas bubbles. The inclusions seen in this stone are an uncommon mix for a synthetic sapphire, which is usually an "easy" identification. This should serve as a reminder that no identification should be taken lightly.

Nicholas DelRe

Orange or Yellow

Historically, the distinction of natural from synthetic orange ("padparadscha") and synthetic yellow sapphire has been the most difficult of the sapphire separations. Some stones contain virtually no identifying inclusions, and curved striae may not be readily visible in synthetic sapphire in this color range (R. T. Liddicoat, Jr., *Handbook of Gem Identification*, 1977). Even today, there are synthetic yellow and synthetic orange sapphires that prove difficult to identify. For these determinations, we are now using a blue filter with the microscope in a technique that was initially reported by B. W. Anderson and was later described by R. Hughes in an ICA Lab Alert and a brief *Journal of Gemmology* article (Vol. 21, No. 1, 1988, pp. 23–25).

This technique involves placing a translucent, medium dark blue plastic filter (just under 3 mm thick) over darkfield or transmitted illumination. The stone is then positioned in a stone holder over the blue-filtered, diffused illumination and is examined in different directions. Curved yellow to orange color banding frequently becomes visible (figure 16) with this combination of color contrast and diffused lighting. Curved color banding is often more apparent in synthetic yellow and synthetic orange sapphires with the blue filter technique than it would be without it.

RK

Figure 16. The use of a translucent, medium dark blue plastic filter over transmitted illumination accentuates the curved color banding in this 5.16-ct yellowish orange synthetic sapphire. Magnified 10×.

Imitation TURQUOISE

The following report was reminiscent of one in the Winter 1965 issue; it would appear that some things never change. The East Coast laboratory recently received a large piece of light, slightly greenish blue material for identification. Although the color was suggestive of turquoise, the R.I. of 1.56, hardness between 2 and 3, and S.G. of less than 2.57 eliminated natural turquoise as a possibility. The surface of this material was smooth, and magnification revealed a molded appearance on one corner.

With the permission of the client, we broke off several millimeter-size chips for closer examination. The effervescent reaction when one chip was placed in dilute hydrochloric acid indicated that the material was, or at least contained, a carbonate. However, the chip did not completely dissolve. After about 15 minutes the reaction ceased, leaving a rough, whitish surface quite different from the original. The whitish material that remained after the acid bath was easily scraped. These scrapings not only looked like plastic (figure 17), but when touched with a hot point they also gave off an odor characteristic of plastic. The smooth surface below the scraped area reacted again to hydrochloric acid.

The infrared spectrum taken on another chip yielded a curve that was indicative of calcite, thus confirming the carbonate identification. Although I.R. spectroscopy is often useful for identifying plastic treatment, the diagnostic plastic peaks fall at the same energies as broad peaks in the spectrum of calcite. Thus, the calcite spectrum of this piece hid any infrared evidence of plastic treatment.

Ilene Reinitz

Figure 17. Magnification (at 45×) of the scraped surface of the acid-treated chip of imitation turquoise revealed curls of the plastic binder.

Because of space constraints, we could not publish the Historical Note feature in this issue.

FIGURE CREDITS

Figures 1 and 2 are by Shane F. McClure. Nicholas DelRe supplied figures 3, 4, and 10–15. Figures 5 and 6 are by John I. Koivula. Dave Hargett is responsible for figures 7, 9, and 17. Figure 8 is by Tom Moses. Figure 16 is by Robert E. Kane.

GEM NEWS

John I. Koivula and Robert C. Kammerling, *Editors*

DIAMONDS

De Beers announces world's largest synthetic diamond crystal. Scientists at the De Beers Diamond Research Laboratory (DRL) in Johannesburg, South Africa, have successfully synthesized a 14.2-ct good-quality industrial monocrystal diamond (figure 1). This is believed to be the largest synthetic diamond yet manufactured. Over 500 hours of high-temperature, high-pressure running was required to produce the diamond, which called for prolonged maintenance of the delicately balanced conditions necessary for successful synthesis. This synthetic crystal is considerably larger than the normal industrial monocrystals, which are laser sliced into components for high-tech diamond tools such as high-pressure anvils, scalpel blades, heat sinks, and radiation counters.

According to Dr. Robert Caveney, director of research at DRL, "Synthesizing a stone of this size is extremely expensive and would not in the normal course be commercially viable. However, it is necessary to experiment and test our technology and equipment, to continually push the boundaries further outward, and this was part of such an exercise." De Beers continues to emphasize that crystals of this nature are produced only in the course of experimentation and strictly for industrial purposes.

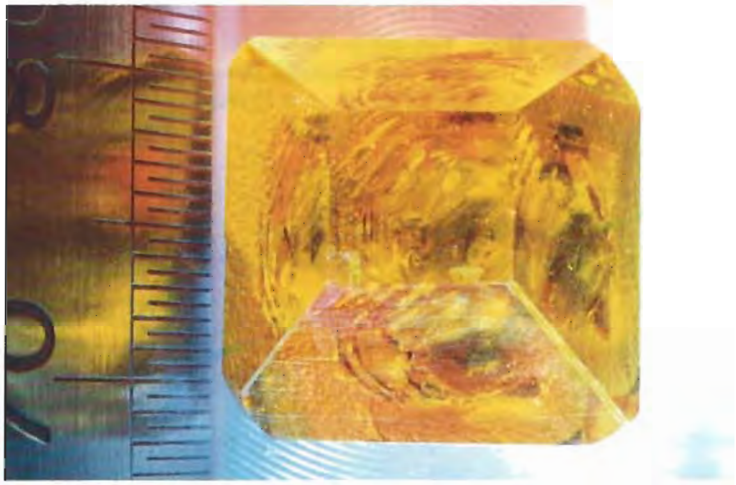


Figure 1. This 14.2-ct good-quality industrial monocrystal synthetic diamond is reported to be the largest synthetic diamond yet manufactured. Photo courtesy of De Beers Industrial Diamond Division (Pty.) Ltd.

Previous largest synthetics have also been products of De Beers Industrial Diamond Division technology. In the early 1970s, a 6.75-ct synthetic diamond was manufactured; and in 1987, an 11.14-ct stone was produced (illustrated on page 191 of the Winter 1987 issue of *Gems & Gemology*).

In addition to Dr. Caveney, members of the DRL research team that successfully synthesized this diamond include: Moosa Adia, assistant director of research; Robbie Burns, head of large monocrystal development; and Vesna Cvetkovic, Carlton Dodge, Lorraine Donatos, and Dennis Welch.

China-cut diamonds sold in Singapore. Diamonds cut in factories in Shanghai were sold at the first Shanghai Diamond & Jewelry Trade Fair, held August 16–18, 1990, in Singapore. A total of 646 ct of the 1,400 ct offered sold at the fair. Individual stones ranged from 0.03 to 3.0 ct; 596 ct ranged from 0.20 to 0.50 ct, while about 50 ct were over 1 ct. The stones were described as being of good make, F to K color, and VVS to VS clarity. (*Jewellery News Asia,* September 1990)

Guyana mining development. An agreement has been reached whereby Ivanhoe Capital Corp. can acquire a 65% interest in Golden Star Resources' Mazaruni alluvial diamond properties in Guyana, South America. According to the agreement, Ivanhoe will provide up to $C4 million in funding for exploration and development. The three properties are located in the Kurupung-Enachu region about 200 km southwest of Georgetown. (*Mining Journal,* September 7, 1990)

COLORED STONES

Possible foreign participation in Afghan mining. Afghanistan is well known as an important source of a number of gem materials, notably lapis lazuli, tourmaline, kunzite, and emerald. A recent report indicates that vast gold reserves have been discovered in that country as well: Deposits estimated to contain 20 tons of gold have been uncovered by Soviet geologists along the northeastern border of Badakhshan, with an additional 15 tons identified in the region's Samthi area.

In an effort to raise funds for mining projects, the Afghan government is expected to amend its constitution to permit foreign investment in mineral resources. While the primary goal may be to develop a gold-mining industry, the proposed legislation could also open up the country to more extensive gemstone mining. (*Diamond Intelligence Briefs,* August 1, 1990)

Novel assembled stone. Some unusual assembled stones have been manufactured to exhibit or enhance optical phenomena. These include cat's-eye opal triplets and "star" stones produced by cementing a thin metal plate etched with three sets of intersecting lines to the base of a synthetic corundum cabochon.

Nanette Forrester of American Lapidary Artists, Los Angeles, showed us what could be described as a new "high-tech" type of assembled stone: quartz cabochons backed by computer chips. When these stones were illuminated from above, some exhibited fairly distinct four-rayed stars as well as subtle interference colors (figure 2).

Ms. Forrester subsequently donated two of these unusual composites to GIA for further examination. Magnification revealed that the asterism was caused by reflections of light from the tightly spaced microcircuitry of the computer chip, which formed complex patterns that intersect at 90°. The tight spacing also produced a diffraction-grating effect, resulting in the interference colors.

Denton J. Anderson of Gemological Services, Denver, Colorado, created and produces these novel "gems." He told us that the computer chips are cut from silicon disks that are 10 cm (4 in.) in diameter and about 1.2 mm thick. They are then topped with a cabochon of hardened glass or quartz (attached with an epoxy resin). Finally, a gold paint-like substance is applied to the back.

Figure 2. These novel assembled stones have been constructed from silicon chips and quartz. Photo by Robert Weldon.

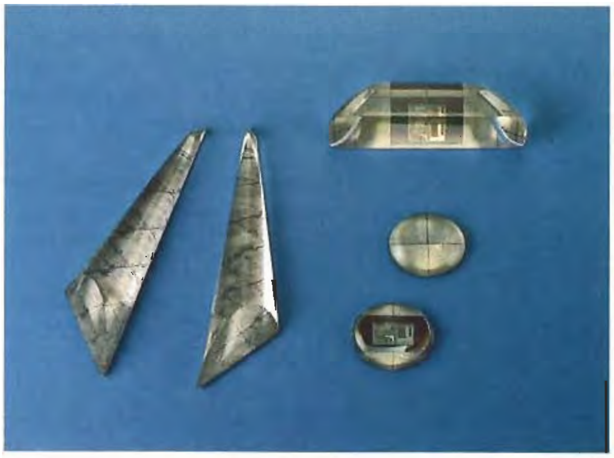


Figure 3. This craftsman in San Miguel de Cozumel uses a lathe-driven cotton buff to polish a piece of Caribbean black coral. Photo by Robert C. Kammerling.

Black coral industry on the Mexican Caribbean. Coral is an organic material that has long been used for ornamental purposes. Black conchiolin coral is less commonly seen than the calcareous varieties; the best-known source is Hawaii, but it has also been found elsewhere in the Pacific Ocean as well as in the Indian Ocean and the Persian Gulf. The types of black coral found in Hawaii belong to the conchiolin species *Antipathes dichotoma* and *Antipathes grandis.*

On a visit to the Mexican Caribbean during the summer of 1990, one of the Gem News editors observed the black coral industry centered on the island of Cozumel. Essentially a cottage industry, numerous "black coral factories" (many no more than small gift shops catering to the tourist trade) were noted on the island as well as in towns along the adjacent mainland coast.

The Mercado de Artesanias "Gonzaloz," in the town of San Miguel de Cozumel, was typical of one of these small "factories." The facility consisted of three individuals working at outdoor benches in front of a small shop where the finished products were sold. First, a hand-held jeweler's saw was used to cut off the desired length of coral for fashioning. The piece was then shaped on a small grinding wheel, and the surfaces were smoothed with coarse-grit emery paper. The pieces were polished on a lathe-driven cotton buff with what appeared to be

Figure 4. Modern, large-capacity equipment is used by S.A.P. Mining Co. to process the gemiferous gravels it mines near Bo Phloi in the Kanchanaburi district. Photo by Robert C. Kammerling.

jewelers' rouge (figure 3). Small detailing and piercing were done by hand using a coarse metal needle.

According to the article "The Black Coral of Cozumel" (by N. Steinhilber, *Lapidary Journal*, January 1981) and promotional literature obtained at one of the shops, noted French oceanographer Jacques Cousteau discovered the black coral at depths of 65 m (about 200 ft.) while studying Palancar reef off Cozumel's southwest coast in 1960. The coral requires approximately 50 years to grow to an average of 3 cm long and 5 mm wide. Today, it is recovered primarily by divers from caves and crevices at depths of 95 m.

Cozumel's black coral is a gorgonacean coral, *Gorgonia* species, unlike the Hawaiian *Antipathes* black corals. For additional information on the various types of black coral, see H. S. Pienaar, "African Star Coral, A New Precious Stylasterine Coral from the Agulhas Bank, South Africa," *Journal of Gemmology*, Vol. 17, 1981, pp. 589–601.

The editor was surprised to find numerous specimens of apparently good-quality material while exploring beaches on the southeast coast of Cozumel Island. The January 1981 report previously cited provided a possible explanation, as the author of that article had had similar good fortune in the same area after violent storms had hit the island. It is quite possible that Hurricane Diana, which struck Yucatan only two days earlier, had assisted in this editor's harvesting.

Update on sapphire mining in Kanchanaburi. Thailand's Kanchanaburi Province, located approximately 100 km (60 mi.) west of Bangkok, is a well-known source of sapphires. Small-scale commercial mining activity has taken place continuously for over 30 years in Bo Phloi, which is about 40 km north of Kanchanaburi City.

Activity in this area expanded significantly in the late 1980s, with the introduction of heavy excavating equipment. A report in the April 1990 issue of *JewelSiam* carried a brief interview with the provincial governor, who said that the province has adequate reserves to meet "strong demand" for the next 15–20 years. He also identified that there are 50 mines in the province, of which about 20 are operating profitably.

In January 1990, one of the Gem News editors had an opportunity to visit a large, mechanized operation of S.A.P. Mining Co. The site visited is reached by driving 3 km north of Bo Phloi on route 3086, then traveling about $^3/_4$ km west on an unpaved local access road. Company president Paiboon Pimpisitthavorn and other executives provided information and a tour of their facilities.

This operation uses from 300 to 500 employees, most of whom are recruited locally. At the time of the visit, the firm had identified 72 km^2 of productive area, and approximately 1,000 acres were being worked. Before excavation begins at a particular site, cores are drilled into the sapphire-bearing gravel layer, a secondary deposit weathered from the surrounding basaltic mountains. If this layer is found to be at least 3–5 m thick, the area is worked; if not, it is held in reserve for possible future development.

A promising site is mined by first stripping the overburden—typically 15 m thick—with heavy equipment. The gem-bearing gravels, called *kasa*, are then transported by truck to the on-site processing plant (figure 4), where they are stockpiled to insure continued production even during the rainy season, when flooding often halts mining. (Admirably, because of ecological concerns, excavated areas are refilled with overburden and prepared for agricultural cultivation. Water is also recycled, and no chemicals are used.)

Processing of the gravels begins by washing them with high-pressure water cannons to remove clay and sand and then passing them through a coarse screen to remove larger rocks. The remaining material is transported first to one jig, a cone-shaped rotating grid, for further separation, and then to another, which uses the principle of gravity separation to produce a final concentrate. The final sorting and extraction of gem materials is done by hand. Black spinel, black pyroxene, and red garnet are also recovered.

A visit to the sorting rooms at the site revealed that most of the sapphire recovered was medium to dark blue, with some green and a few (2%–3% of total sapphire yield) light yellow stones. The yellow material can be heat treated to produce light "lemon" yellow to bright yellow to "cognac" orangy brown stones. Some of the sapphire rough is sold as-is to dealers who visit the mine site. Other material is examined by S.A.P. employees, then heat treated and cut in-house.

Some of the faceted stones were examined at the mining facility. Although these stones were somewhat less saturated (more "grayish") than heat-treated Sri Lankan sapphires, they were closer in appearance to the Sri Lankan material than to the dark, inky sapphires people have come to associate with "Thai" sapphire.

The editors thank Messrs. Paiboon Pimpisitthavorn, Ampan Jarukuosol, and Chaiyaporn Chanpen, of S.A.P. Mining Co., for their hospitality. Thanks also to Ms. Songlot Bhayakaporn and Thomas J. Ba Ross, S. P. Color Stones Co., Bangkok, for arranging the visit.

Peace pact for Colombian emerald region. According to Ron Ringsrud of Constellation Gems, Los Angeles, the two major factions that had been fighting in the main emerald-mining region of Colombia signed a peace pact on September 8, 1990, in Chiquinquirá, Boyacá. As of the end of 1990, the pact appears to have halted the often-violent confrontations that took place not only in the Muzo region but also in the streets of Bogotá, the capital and main emerald-trading center. A physician who spent 1989 in the Muzo-Cosquez region estimated that, on average, 120 people died every month as a direct result of the conflict.

Contrary to numerous published reports, Mr. Ringsrud's contacts insist that the violence in the area has always been related to the emerald trade, not to drugs. The misperception arose in 1987, when the leader of one of the warring townships joined forces with drug cartel chief Rodriguez Gacha (known as "El Mexicano") in an attempt to take over control of the Muzo mine through terrorism. This ended with Gacha's violent death in May 1989.

Recently, there has been significant progress in the organization of dealers and exporters in Bogotá. A new Emerald Trade Center is scheduled to open in late 1991, and a Colombian Association of Emerald Exporters was recently formed. Emerald production is expected to rise, and miners and dealers alike are more optimistic about the future of the emerald industry in Colombia than they have been in years.

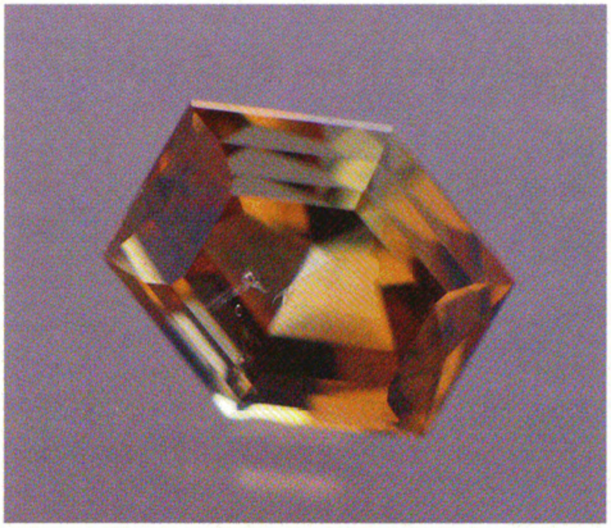
Unusual color-zoned garnet. A number of gem materials commonly display color zoning. Some of these, such as bi- and tri-colored tourmaline, may be cut intentionally to display and emphasize the individual colors; others, such as amethyst, with zones of colored and colorless areas, will be cut in such a way that the colorless areas are masked, producing a stone that "faces up" with uniform color.

Garnets are usually colored uniformly. However, Dr. Byron Butler of World Gems/G.S.G., Scottsdale, Arizona, recently sent us for examination the 1.42-ct garnet shown in figure 5. This modified hexagonal step cut, reportedly from an African locality, displayed strong color zoning in light brownish yellow and medium brownish orange that was only partially masked face-up by the cutting.

Gemological examination of the stone revealed the following properties: transparent; singly refractive; green with some reddish orange "flashes" through the Chelsea filter; very weak brownish red fluorescence to long-wave U.V. radiation, with a similar but slightly chalky reaction to short-wave U.V. and no phosphorescence to either wavelength; no visible absorption features noted with a desk-model spectroscope. Magnification revealed small, colorless, rounded protogenetic birefringent crystals of what may have been apatite; healed fractures were associated with some of these crystals.

We encountered one particularly puzzling gemological property: R.I. readings of 1.738 on the lighter section

Figure 5. Color zoning such as that shown by this 1.42-ct stone is very unusual for garnets. Photo by Maha Smith.



of the stone, and 1.748 on the darker portion. Careless testing could lead one to believe that the stone was doubly refractive with a 0.010 birefringence.

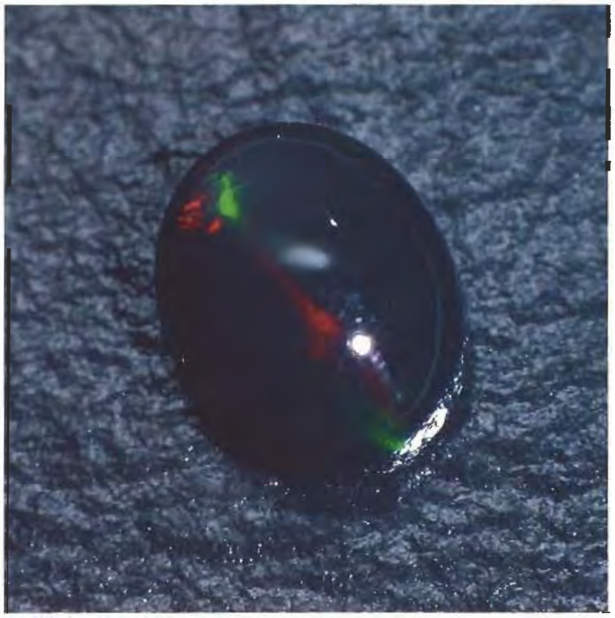
We concluded that this was a color-zoned grossular garnet. It is quite possible that a greater concentration of the chromophore on the darker section of the stone was also responsible for the higher R.I. reading obtained there.

Heavy liquids studied in Australia. Heavy liquids containing organic compounds have long been used in gem identification and in mineral separation, including the separation of diamond from sands. Concerns relating to occupational health and safety, as well as the complex controls required, have limited the large-scale use of heavy-liquid separation.

The Australian Mineral Industries Research Association (AMIRA) is embarking on a two-year study aimed at identifying relatively nontoxic heavy liquids for use in mineral separation. According to the proposal, a range of inorganic compounds—especially the polyanions—are to be investigated to determine their application in producing heavy liquids as solutions in water or other safe solvents. (*Mining Magazine*, July 1990)

Black cat's-eye opal. The Fall 1990 Gem News column described a yellow opal that exhibited true chatoyancy and in earlier columns we have discussed assembled cat's-eye opal triplets. Recently, Neal Dwire of Neal Dwire Gemstones, Tucson, Arizona, showed us an attractive chatoyant black opal (figure 6).

Figure 6. This 2.16-ct black opal exhibits play-of-color in the form of chatoyant bands. Photo by Robert Weldon.



This 2.16-ct oval double cabochon (9.79 × 7.79 × 5.12 mm) was mined in Jalisco, the major opal-producing state of Mexico. The stone was acquired from another dealer who had had it in his personal collection for several years.

The opal appears opaque and almost black when viewed face-up in reflected light; in intense transmitted light, such as that provided by a fiber-optic illuminator, it appears translucent with a dark orange-brown body color. The base exhibits broad areas of play-of-color in green, yellow, and orange, while the dome shows three chatoyant bands of color, one across the dome and the other two near the base (the latter two are not visible in figure 6). The top band is red in the center and green on either end; both side bands are predominantly green, one with a slightly yellowish orange center and the other with a blue area at one end.

Magnification with darkfield illumination revealed minute, short stringers of whitish particles; direct transmitted light revealed a mottled layer that was vaguely reminiscent of the structure seen in tortoise shell. The opal had a spot R.I. of 1.44; gave a singly refractive reaction in the polariscope; was inert to both long- and short-wave U.V. radiation; appeared brownish orange through the Chelsea filter; and exhibited an absorption cutoff below 500 nm, transmitting virtually nothing in the blue region.

The specimen also had a specific gravity of 2.02, rather low for opal. This, combined with the high transparency and the knowledge that porous opal from Jalisco may be treated, caused us to suspect enhancement. Near-infrared spectroscopy, performed by Dr. Emmanuel Fritsch of the GIA Research Department, revealed no indication of either polymer impregnation or carbonaceous enhancement (such as smoke or sugar treatment). We therefore concluded that this was a natural cat's-eye black opal. It is the first such stone from Jalisco that either editor has seen. Opals with this type of chatoyancy have been reported from Idaho.

In addition to Dr. Fritsch, the editors would like to thank Sam Muhlmeister, of the GIA Research Department, and Christopher P. Smith, of the GIA Gem Trade Laboratory, for assistance in examining this stone.

Exceptionally large white opal. Steven Sodokoff, of San Francisco Diamond Exchange, recently gave the editors the opportunity to examine an exceptionally large, gem-quality opal (figure 7). The stone, a free-form cabochon, measures approximately 5-1/2 × 4 × 1-5/8 inches (14.0 × 10.2 × 4.1 cm) and weighs approximately 1 lb. 10 ozs. All of its surfaces are polished and there are no areas of matrix. Mr. Sodokoff reports that the original rough was recovered in 1976, from the Boi Morto mine (about 3.5 km north-northwest of the town of Pedro II) in Piauí State, Brazil. It was cut by Scott Cooley, and is being called "Galaxy."

The opal is translucent with a brownish white body color. Face-up it displays a predominantly pinfire play-of-color across its entire surface. When the stone is examined from directly overhead, approximately 30% of the top surface displays a predominantly orange play-of-color, while the remainder shows primarily green with lesser amounts of yellow flashes as well as some violet and red.

What is even more unusual for a stone this size is the fact that the opal appears gemmy throughout: Play-of-color is also seen from the sides and base of the stone, the latter predominantly green pinfire.

It is interesting to note the pronounced layering in the stone. The layers run roughly parallel to the base of the cabochon.

Color-change cobalt spinel. Efraim Katz of African Gem Cutters, Miami Beach, Florida, loaned us an interesting spinel for examination. The 16.41-ct rectangular cushion-shaped mixed cut (15.72 × 13.51 × 10.58 mm), appears medium dark violetish blue in fluorescent light and medium dark purple in incandescent illumination (figure 8).

Gemological investigation revealed some interesting properties: R.I. of 1.714 (lower than what is typical for blue spinel); red appearance through a Chelsea filter; bright red transmission luminescence; moderate to strong chalky red fluorescence to long-wave U.V., none to short-wave U.V., and no phosphorescence; and, when examined through prism and diffraction-grating desk-model spectroscopes, a diffused absorption band at 454–461 nm, a faint fluorescent line at 552–554 nm, and a strong fluorescent line at 686 nm.

The U.V.–visible absorption spectrum recorded at the

Figure 7. This unusually large (14.0 × 10.2 × 4.1 cm) opal shows pinfire play-of-color throughout. Photo © GIA and Tino Hammid.

Figure 8. This 16.39-ct spinel appears medium dark violetish blue under fluorescent light (left) and medium dark purple in incandescent illumination (right). Photos © Tino Hammid.

Figure 9. This faceted and carved topaz sculpture weighs more than 35,000 ct. Photo by Robert Weldon.

GIA Research Department with a Pye-Unicam 8800 spectroscope revealed features known to be due to Co^{2+}, which is undoubtedly the cause of the predominantly violetish blue color. EDXRF analysis revealed the presence of minor amounts of chromium and possibly vanadium, one or both of which are probably responsible for the color change. The EDXRF analysis did not reveal any cobalt, probably because it is present in such a low concentration.

Large topaz sculpture. Gem minerals form in a number of geologic environments. Pegmatites – small igneous bodies representing the end phase of crystallization from a solidifying magma – are particularly interesting to the gemologist because of the sometimes huge, high-quality crystals that form in pockets within them. In fact, these pockets in pegmatites are sometimes referred to as "nature's jewel box."

Recently we had the opportunity to examine an exceptionally large topaz that was fashioned from a crystal that originated in a Brazilian pegmatite. The stone, a transparent very light blue-green sculpture that had been both faceted and carved, measures 24.6 × 10.6 × 15.8 cm and weighs approximately 35,000 ct (figure 9). The sculpture was fashioned by Lawrence Stoller and Glenn Lehrer, of Marin County, California. It has properties typical of blue-green topaz, including several eye-visible two-phase inclusions and one eye-visible three-phase inclusion.

Edward Swoboda, co-owner with Stoller and Lehrer of the gem, informed us that the original rough was a 79-lb. (35 kg), slightly waterworn, singly terminated crystal recovered from the Barra Vermelha area of Minas Gerais more than 40 years ago. Mr. Swoboda obtained the crystal in the 1950s. He had the stone sawn in the 1970s and cut a 20,000+-ct gem (known as the "Princess") from one portion. The sculpture recently cut by Stoller and Lehrer represents one of the largest fashioned specimens of any gem species.

The artists found the stone to be a real challenge, especially the large front viewing face. Said Stoller, "This topaz played by its own rules. We could not apply the same techniques that we use in cutting smaller topaz gems." Added Lehrer, "The process of cutting and polishing took place over a two-year period. We found that the difficulties began at the final polishing stage." Invariably, they encountered scratching when the polished surface would pit and then the material from these pits would drag across the face. Several polishings were required of the large front face in particular.

Cat's-eye bicolored tourmaline. Bicolored tourmaline occurs with some frequency, the often distinct color zones resulting from changes in the environment of the growing crystal. However, such changes may also be noted as differences within the inclusion scenes in the different color zones.

Recently, Ralph Mueller of Ralph Mueller & Associates, Scottsdale, Arizona, loaned us a 20.65-ct bicolored tourmaline with a sharp chatoyant band at the juncture of the two color zones (figure 10). Examination with magnification revealed that the hollow tubular inclusions running parallel to the c-axis were confined to the blue portion of the stone, stopping abruptly where the pink coloration begins.

The editors thank Robert Weldon for bringing this stone to their attention.

More gems from the USSR? In a move that could result in more gemstone production in the USSR, Wales-based Robertson Consultancy Group has entered into an exclusive agreement to market Soviet mineral deposits.

Figure 10. Careful orientation by the lapidary placed the chatoyant band of this 20.65-ct bicolored tourmaline along the division of the two color zones. The inclusions that cause the band are actually confined to the blue portion of the stone. Photo by Robert Weldon.

The firm will work with the Soviet Ministry of Geology to provide foreign mining concerns with data for assessing project potential. Although the Soviets reportedly prefer joint ventures, it appears that there is no longer any legislation that would preclude 100% foreign ownership. Seminars, exhibitions, and field trips are being planned to help interested parties gain an understanding of Soviet operating conditions and mining laws. (*Mining Journal*, July 20, 1990)

ENHANCEMENTS

Diffusion-treated sapphire update. The Summer 1990 issue of *Gems & Gemology* contained a comprehensive article on blue diffusion-treated sapphires. Although this article discusses and illustrates the identification of loose sapphires so treated, the same identification techniques described can also be used quite effectively in detecting mounted stones. Robert Crowningshield, of the East Coast GIA Gem Trade Laboratory, provided us with a photograph of a diffusion-treated stone mounted in a ring. As can be seen in figure 11, the combination of immersion and diffused illumination reveals the color concentrations along facet junctions that are a key identifying feature of this enhancement.

"Rainbow" quartz: A new enhancement. In the Fall 1990 Gem News column we provided an update on colorless quartz gems on which a thin film of gold had been

Figure 11. Immersion and diffused illumination reveal the characteristic color concentrations along facet junctions that prove that this ring-set sapphire has been diffusion treated. Photo by Nicholas DelRe.

Figure 12. "Rainbow" quartz is reportedly produced by allowing molecules of silver/platinum to adhere to the external surface of the quartz. This cluster weighs 17.86 grams. Photo by Robert Weldon and Maha Smith.

Figure 13. The base of this 2.78-ct synthetic ruby (face up) and that of this 2.53-ct synthetic blue spinel (face down) have been rough-ground to give these cabochons a more natural face-up appearance. Photo by Robert Weldon.

applied. These treated stones display both the blue to greenish blue transmission color of gold and surface iridescence.

The Gem News editors recently became aware of another, similar surface treatment that is being applied to colorless quartz, including single crystals, crystal clusters (figure 12), and some fashioned pieces. According to promotional literature provided by TransGem Corp. of West Bend, Wisconsin (vendor of this material as well as "Aqua Aura" quartz), "Rainbow" quartz is produced by "allowing molecules of silver/platinum to adhere to the natural electric charge which surrounds the quartz crystals. The extremely thin, transparent bond breaks light into a rainbow of colors."

Like "Aqua Aura" quartz, "Rainbow" quartz exhibits moderate to strong superficial iridescence in surface-reflected light. It differs from "Aqua Aura," however, in that it does not alter the apparent body color of the quartz, leaving it essentially colorless. EDXRF analysis of the sample, by Sam Muhlmeister of the GIA Research Department, did not show the presence of platinum or silver. This may be due to the fact that the applied layer is so thin that it is not detectable by this method.

Figure 14. The jewelry "stones" pictured here are all glass imitations of jadeite. Photo by Robert Weldon.

Figure 15. The 4.07-ct cabochon of "Imori Stone" glass on the right bears a strong resemblance to some pectolite from the Dominican Republic, as exemplified by the 28.59-ct specimen on the left. Photo by Robert Weldon.

Figure 16. Sold as "purple onyx," this 8.87-ct purple dyed quartzite could be mistaken for sugilite. Photo by Robert Weldon and Maha Smith.

Jade "processing." It appears to be a somewhat widespread practice to wax- or paraffin-coat many ornamental gem materials to improve their apparent luster. Nephrite and jadeite, the two jades, are often seen so treated.

The prevalence of this practice was brought home to the editors when glancing through a Hong Kong trade publication, *Jewellery Review.* The magazine included a one-page pictorial on how a jade hololith bracelet is produced. The first step in this eight-step process is cutting a slab of appropriate thickness. In step 2, the center of the bracelet is drilled out with a cylindrical bit. In steps 3 through 6, the bracelet takes its final form through four grinding operations, followed by polishing (step 7). The final step, most interestingly, is described as "waxing;" the accompanying illustration shows a heavily encrusted bracelet being removed from a pot of liquefied wax. (*Jewellery Review,* Vol. 2, 1990)

SYNTHETICS AND SIMULANTS

Natural-appearing synthetic cabochons. While looking through a "turmali" box of inexpensive flame-fusion synthetics at a local gem show, one of the editors spotted some oval cabochons that had a reduced transparency not normally seen in flame-fusion synthetics. Two of the cabochons were purchased for examination: a 2.78-ct synthetic ruby and a 2.53-ct synthetic blue spinel.

Standard gemological testing confirmed the identities of the two specimens. Visual examination and magnification verified the cause of the reduced transparency: While both synthetics were essentially inclusion-free, they had irregularly shaped, rough-ground frosted bases (figure 13). The cabochon cut contributed to the rather natural appearance of the stones, as included material of lower transparency is often cut in this fashion rather than faceted.

We remember hearing several years ago about a clever deception being used on some nice-colored faceted Sri Lankan sapphires. These stones had had their pavilion facets rough-ground to increase light scattering, giving them a "velvety" appearance like that exhibited by fine sapphires of Kashmir origin. They were then bezel-set to conceal the deception and passed off as Kashmir sapphires.

Thailand cutting CZ. In addition to being a major cutting center for colored stones and an increasingly important country for diamond cutting, Thailand is also fashioning significant amounts of cubic zirconia. In 1989, Thailand exported 13,256 kg (66,280,000 ct) of polished CZ, according to the Thai Department of Business Economics. The major market was the United States, which imported 4,326 kg. Both figures represent an approximately 13% increase by weight over 1988. (*Jewellery News Asia,* September 1990)

Glass imitation jadeite. From time to time, the Gem News editors see interesting glass imitations. Recently, one of the editors spotted some attractive imitations of "Imperial" jadeite (figure 14) being offered by street vendors both in the Chinatown area of Los Angeles and in Hong Kong.

The color of the piece fashioned as a saddle-cut hololith ring was fairly uniform and similar to that of very fine green jadeite. Another piece, a "carved" circular disk set in an imitation gold bale for use as a medallion, exhibited a less saturated color in a mottled pattern, a color distribution common in jadeite jade. Magnification revealed the gas bubbles and swirled striae (schlieren) typical of glass imitations in all pieces.

A glass imitation pectolite? Pectolite is a translucent to opaque greenish blue ornamental material that often shows one or more fibrous radial patterns. It has been marketed under the trade name Larimar.

"Imori Stone" is a partially devitrified glass into which fibrous inclusions are induced to give it a fibrous appearance overall. "Imori Stone" has been produced in a number of colors, with the greenish material used to imitate jade. In the course of studying "Imori Stone," we noted that it also occurs in colors that make it look quite similar to pectolite. Figure 15 shows a cabochon of this glass imitation next to a cabochon of pectolite.

Dyed quartz imitation of sugilite? One of the more novel stones we have examined recently is a semitranslucent, dark purple oval single cabochon (figure 16) that was purchased as "purple onyx." The stone was donated to GIA by Ed Barker, whose father obtained it in New Mexico. The material is being set in Indian jewelry and sold in considerable quantities.

Standard gemological testing identified the gem as a quartzite. While the color appears uniform in overhead illumination, strong transmitted light reveals a dense mass of dark purple color concentrations in fractures surrounding what seem to be essentially colorless grains. The stone appears brownish orange through a Chelsea color filter and is inert to both long- and short-wave U.V. radiation. Spectroscopic examination revealed a very weak, diffused absorption band at approximately 491–503 nm, a prominent band at 529–572 nm, and some extremely weak general absorption through the yellow-green region. A slight purple discoloration was produced on an alcohol-dipped cotton swab rubbed across the stone's base; an acetone-dipped swab produced a similar but darker and more noticeable discoloration.

While this dyed quartzite may be marketed as "purple onyx," it could easily be mistaken visually for manganoan sugilite. Since receiving the original specimen from Mr. Barker, we have seen more of this material in the trade.

GEMOLOGICAL ABSTRACTS

Dona M. Dirlam, Editor

DIAMONDS

Study of prospecting mineralogy of spinel group in kimberlites in China. Q. Shuying, D. Chujun, and G. Yuemin, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 89–91.

The authors demonstrate the use of spinel-group minerals as a prospecting aid in the search for diamond-bearing kimberlites. By plotting the composition of spinels on an Al-Cr-Fe (or Ti) ternary diagram, they illustrate how spinels from diamond-bearing kimberlites differ in composition from spinels associated with diamond-poor kimberlites. They also demonstrate the similarity of spinel composition between diamond-bearing kimberlites from the Yakutia region of the Soviet Union and those in China. *JES*

COLORED STONES AND ORGANIC MATERIALS

The American connection. J. Culp Zeitner, *Lapidary Journal*, Vol. 44, No. 2, May 1990, pp. 59–70.

A number of gem materials have been named for their associations with American places and people, as was acknowledged at the recent CFMS/AFMS National Show in California. Most of these names are variety and trade names. Ms. Zeitner provides some interesting information on the derivation of some well-known (and not so well-known) minerals. Often they are named after a person: bixbite (an early term for red beryl), after a gem and mineral dealer; liddicoatite (a calcium lithium aluminum tourmaline), after Richard T. Liddicoat; kunzite, after George Frederick Kunz; morganite, after J. P. Morgan; and pumpellyite (chlorastrolite), which is the state stone of Michigan, after Raphael Pumpelly of Keweenaw. Names derived from localities are even more numerous: danburite, from Danbury, Connecticut; or benitoite, after San Benito County, California. Three photos, two in color, accompany this interesting article. *WRV*

This section is designed to provide as complete a record as practical of the recent literature on gems and gemology. Articles are selected for abstracting solely at the discretion of the section editor and her reviewers, and space limitations may require that we include only those articles that we feel will be of greatest interest to our readership.

Inquiries for reprints of articles abstracted must be addressed to the author or publisher of the original material.

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names. Opinions expressed in an abstract belong to the abstracter and in no way reflect the position of Gems & Gemology *or GIA.*

An American gem geography. D. Federman, *Modern Jeweler,* Vol. 89, No. 6, June 1990, pp. 61–67.

Highlighted in this article are some of the major gem deposits of the United States. Mr. Federman briefly discusses the locations and mining histories of U.S. deposits of turquoise, freshwater pearls, tourmaline, diamond, sapphire, ruby, peridot, opal, and amethyst in chronological order of discovery. In addition, there are several beautiful photographs of these American gemstones used in jewelry. Also provided is a full-page map of North America with major gem localities in the 50 United States indicated. Mr. Federman points out two additional sources of information on this subject, acknowledging that this article is intended only to introduce the reader to the vast and varied occurrences and histories of American gem treasures and their role in the world market. *CPS*

Examination of an interesting cultured blister pearl. R. Kammerling, J. Koivula, and R. Kane, *Australian Gemmologist,* Vol. 17, No. 5, 1990, pp. 174–175.

While in China, senior author Robert Kammerling purchased an intriguing half shell with a large blister-pearl image of the goddess Kwan Yin. Inserting objects in mollusks to produce unusually shaped blister pearls has been practiced in China for centuries. This article concentrates on the kinds of materials that are used to produce these blister pearls. Although lead is the most familiar, detailed examination and observation of this image revealed that the material was plastic. This is the first time that this type of insert and its methods of detection have been reported. Accompanying the report are three photographs and two X-radiographs that help substantiate the conclusions. *RW*

Golden labradorite. J. D. Lindberg, *Lapidary Journal,* Vol. 44, No. 3, June 1990, pp. 20–24.

Mexico yields large, facetable, nonphenomenal crystals of this feldspar species. Mr. Lindberg reports that Benny Fenn has some sizable faceting material and has cut some large gems, including a 92-ct Portuguese cut (pictured in color). One black-and-white photo shows "two or three pounds" of material in a double handful of eight crystals. A basic description of the material includes refractive indices (one inadvertently omitted) and specific gravity, as well as crystal habit and inclusions. The only reference to the locality of this material is the mountainous area dividing Chihuahua and Sonora, Mexico. *WRV*

Minerals and mineral parageneses of charoitites as a reflection of their genesis characteristics. K. A. Lazebnic and L. V. Nikishova, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 60–61.

Charoitites are a rare type of rock that contain 35%–95% of the mineral charoite. This rock has become an important ornamental gem material because of its unusual purple color and its peculiar texture. The genesis of this rock type still remains a subject of controversy. The authors suggest that charoitites are of metasomatic origin, that is, they result from mineral formation that took place by simultaneous solution and deposition, and not by magma crystallization. As evidence, the authors cite the unusual mineralogy and textures of these rocks, their chemical uniqueness from other magmatic rocks, the acicular or fibrous crystal habit of the minerals, and the framework crystal structures of these minerals that would allow the diffusion of chemical constituents to bring about the metasomatism. *JES*

Mtorolite. G. Phillips and G. Brown, *Australian Gemmologist,* Vol. 17, No. 5, 1990, pp. 205–207.

Mtorolite is the name given to a green chrome-colored chalcedony found near Mtoroshanga, Zimbabwe. The authors begin by describing the history of the deposit and then provide the results of their examination of specimens held in the museum of the Gemmological Association of Australia's Victorian Branch.

The specimens investigated had the following properties: mottled green to white chalcedonic structure; hardness of 7; 2.56 S.G. for light green and 2.57 for dark green material; uneven to subconchoidal fracture; 0.004 form birefringence; pink to red through the Chelsea filter, reaction correlating to depth of body color; very weak milky green to long-wave U.V. radiation and weak milky green to short-wave; brown-red in transmitted white light; general absorption with some transmission in the green and red regions. The one internal feature noted was "mossy patches."

The authors also review the gemological properties reported in the literature for this material, some of which are not identical to (although they are compatible with) the results of their testing. Additional detail is provided as to the location and occurrence of the material. With respect to the latter, they note that great similarities exist between the mode of formation of mtorolite and the green chrysoprase chalcedony from Marlborough in central Queensland. *RCK*

New crystallochemical and genetic data for turquoise. L. K. Yakhontova, I. I. Plyusnina, T. V. Soboleva, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 121–122.

Turquoise from deposits in Middle Asia and Armenia was investigated to clarify the origin of these deposits. Two main stages of turquoise formation could be distinguished: a hydrothermal stage where turquoise formed as a vein mineral with quartz and pyrite, and a supergene stage where turquoise crystallizes from solutions during weathering. *JES*

Ein ungewöhnlicher Granat aus Ostafrika (An unusual garnet from East Africa). H. Bank and U. Henn, *Zeitschrift der Deutschen Gemmologischen Gesellschaft,* Vol. 38, No. 4, 1989, pp. 161–163.

A brownish orange 64.47-ct garnet from East Africa shows an R.I. of 1.739 and an S.G. of 3.74. On the basis of its gemological properties, it is most likely a grossular (hessonite), but, according to the authors, it could also be a pyrope-almandine or a pyrope-spessartine ("malaya"). U.V.–visible absorption spectroscopy and energy-dispersive microprobe analysis show this garnet to be a pyrope-spessartine with significant almandine and grossular components, the latter contributing to the low R.I. *EF*

GEM LOCALITIES

The Brazilian emeralds and their occurrences: Socotó, Bahia. D. Schwarz, T. Eidt, and P. A. Couto, *Journal of Gemmology,* Vol. 22, No. 3, 1990, pp. 147–163.

The Socotó emerald deposits first opened in 1983 and quickly became one of Brazil's major sources. Production figures through 1986 are provided in conjunction with those of nearby Carnaíba. A discussion of regional and local geology reveals the typical nature of these emerald deposits: an ultramafite body approximately 3,650 m long and 200 m wide, penetrated by pegmatite veins accompanied by metasomatically altered zones in which the emerald mineralizations occur. Accessory minerals include molybdenite, scheelite, powellite, phenakite, chromite, asbestos, and sulfides.

Reported values for Socotó emeralds are R.I.'s of n_e = 1.579–1.582 and n_o = 1.587–1.590, birefringence of −0.007–0.009, and density range of 2.67–2.72 g/cm^2. Results of microprobe analyses for 20 emeralds and a variety of inclusions are given (but details of the analytic conditions are not provided). Study of approximately 100 specimens with the microscope revealed a considerable variety of mineral inclusions, including mica, talc, chlorite, actinolite, allanite, apatite, quartz, feldspar, carbonates, tourmaline, hematite/goethite, limonite/lepidocrocite, molybdenite, pyrite, chromite, and beryl, as well as growth tubes and channel-like cavities, densely included core zones, color striae and zoning, fluid (two- and three-phase) inclusions, and fractures. Regional and geologic maps and 21 photomicrographs illustrate the article. *CMS*

Diamonds from Kimberley, Western Australia. J. D. Grice and G. L. Boxer, *Mineralogical Record,* Vol. 21, No. 6, 1990, pp. 559–564.

This article presents a brief review of the discovery and mining of the diamond deposits in the Kimberley region of Western Australia. Emphasis is given to the Argyle AK1 mine, which is currently the largest producer of diamonds in the world. The extraordinary aspect of these deposits is the association of diamonds with lamproite as the host rock, rather than kimberlite. This type of occurrence has prompted a revision in diamond exploration methods throughout the world.

While the host rocks are different, there appear to be no differences in diamonds from lamproites and kimberlites based on statistical studies of crystal size, morphology, color, distribution, inclusions, and surface features. Details of the characteristic features of these diamond crystals are presented, including a brief mention of the pink diamonds that have attracted considerable attention in the gem market. *JES*

Famous mineral localities: De Kalb, New York. G. W. Robinson, *Mineralogical Record,* Vol. 21, No. 6, 1990, pp. 535–541.

Transparent, light green crystals of gem-quality diopside from this locality have been known since the late 1800s. This article describes the geology, mineralogy, and mining history of this famous mineral occurrence in upstate New York. The diopside crystals are found in pockets or cavities in calcium-silicate host rocks (quartz-tremolite schist to massive diopside). The crystals themselves range up to 7 cm across, and represent some of the best crystals of this mineral species ever found. The locality was unworked for many years, but small-scale mining now produces mineral specimens for collectors on a limited basis. Several crystals and one faceted stone are illustrated. *JES*

Famous mineral localities: Murfreesboro, Arkansas. A. L. Kidwell, *Mineralogical Record,* Vol. 21, No. 6, 1990, pp. 545–555.

This well-illustrated article describes the geology and mining history of the diamond-bearing deposit near Murfreesboro, Arkansas. The occurrence of kimberlite in Arkansas has been known since the mid-1800s, but it was not until 1906 that the first diamonds were discovered. Since that time, this deposit has had an interesting history involving changes in land ownership and various attempts to mine diamonds on a profitable basis. Currently, the deposit is owned by the state of Arkansas and managed by the state Department of Parks and Tourism, which allows visitors to search for diamonds for a small daily fee within the "Crater of Diamonds" State Park.

The diamonds are found in a micaceous peridotite, first described as a kimberlite but more recently shown to have closer chemical and mineralogic affinities to the diamond-bearing lamproites of Western Australia. Seven peridotite bodies occur within or near the state park, although not all are known to contain diamonds.

The diamond crystals themselves represent complex forms of the isometric system, with the trisoctahedron and hexoctahedron more common than the octahedron and dodecahedron. Most of the crystals have curved faces and edges. Between 1972 and 1988, some 13,000 diamonds were found by visitors to the state park. Of these, 60% were classified as white (i.e., near colorless), 21% brown, 17% yellow, and 2% other colors. About 10% of these could be considered fine gem quality on the basis of clarity. Nearly 40 diamonds weighing 5 ct or more have been reported, including a 40.25-ct crystal discovered in 1924 that was faceted into a 12.42-ct stone.

The article concludes with a description of present mining operations in the state park, and a note regarding current exploration efforts in the area by several mining companies. Although there are no exact production records before 1972, when the property became a state park, a knowledgeable local geologist estimated that a total of approximately 400,000 diamonds have been recovered. *JES*

A Kenyan gemstone from the feldspar family: Further observations. C. R. Bridges, G. Graziani, and E. Gübelin, *Australian Gemmologist*, Vol. 17, No. 5, 1990, pp. 177–183.

This article reports on a follow-up investigation of gem-quality feldspar recovered from a pegmatite on Kioo Hill, Kenya, about halfway between Nairobi and Mombasa. The feldspar occurs in association with vermiculite, quartz, schorl tourmaline, altered garnet, and kyanite. Recovery is carried out using blasting material and simple hand tools.

The gem-quality material, ranging from colorless to blue or green, generally occurs within large, opaque white feldspar crystals. It has a vitreous luster; 6–6 $^1/_2$ Mohs hardness; mean refractive indices of α = 1.531, β = 1.535, γ = 1.539, with a corresponding birefringence of 0.008; 2V angle of 89°; S.G. of 2.63 + 0.01; very weak pleochroism in colorless and bluish green; inert through the color filter; very weak to faint whitish fluorescence to long-wave U.V. radiation and inert to short-wave U.V. Magnification revealed some healing fissures, two-phase fluid inclusions, and flakes and "parcels" of vermiculite. X-ray diffraction and chemical analyses were also carried out. Optical observations verified the absence of the internal reflections that produce a schiller effect in some feldspars.

The authors conclude that the material has a bulk composition predominantly of albite, with anorthite varying from approximately 5 to 11 mol.%, and that it is a peristeritic plagioclase feldspar which formed at relatively low temperatures. *RCK*

New aspects of the emerald workings in Colombia. D. Schwarz, *Australian Gemmologist*, Vol. 17, No. 5, 1990, pp. 168–170.

Beginning with a brief history of the Colombian emerald mines, the author provides an update on activity at the various sites at the time of a personal visit in early 1989.

The Muzo area was being worked by two mining companies: COEXMINAS and TECMINAS. The former had converted almost entirely to underground mining; the procedure is briefly described. According to the government-run ECOMINAS, all mining in the area will be underground within the next few years. The author notes that because this produces far less workable "waste rock," the shift to underground mining will have a negative effect on the *guaqueros* who work the mine tailings.

Yacopi, a new mine located about 15 km south of Muzo, was producing large quantities of pale-colored material. Poor security prevented a visit to Cosquez, while information on Peñas Blancas was not available because the area was controlled by guerillas. Production at Chivor was erratic, with no mining at the time in the Buenavista area. Activity at Gachalá was limited almost entirely to repair and clearance work.

The article includes three tables of official government production statistics which, as the author notes, do not give the whole picture, since much material is smuggled out of the country. The author speculates that most of the smuggled material is sent to the United States. *RCK*

The Pharoahs' forgotten emerald mines. O. Grubessi, C. Aurisicchio, and A. Castiglioni, *Journal of Gemmology*, Vol. 22, No. 3, 1990, pp. 164–177.

The emerald mines exploited by the ancient pharoahs, perhaps as early as 2000 B.C., were worked by the Egyptians until the 13th century A.D.; later, it appears, they may have been worked by the Turks. Around 1750, however, all activity at the mines stopped, and all records and knowledge of their location was lost. Rediscovered in the 19th century and periodically explored since then, the mines have never again been commercially exploited. The authors report on the information and samples acquired on a recent expedition by Angelo and Alfredo Castiglioni. Ancient caravan paths lead to the Sikeit region, where remains of temples and miners' residences still exist. The nearby mountains are pockmarked with the abandoned entries and cavities of the Djebel Zabarah mine.

The authors report analytic results for an unspecified number of Zabarah emerald specimens, including chemical analyses, basic physical properties, unit-cell parameters, and infrared spectral features. Comparison with data for emeralds from eight other localities and two synthetic crystal–growing processes revealed chemical similarity to emeralds from Habachtal, Austria, with substitution of Mg for Al in the octahedral site; unit-cell and infrared features are consistent with the chemical data. Since Habachtal emeralds were not known in ancient times, the otherwise distinctive characteristics of the Zabarah emeralds should be useful archaeologically. The 12 illustrations include locality photos, infrared spectra, and comparative data graphs. *CMS*

Sapphirine from the Kolonne area, Sri Lanka. R. R. Harding and E. G. Zoysa, *Journal of Gemmology,* Vol. 22, No. 3, 1990, pp. 136–140.

This brief report provides the geologic setting for sapphirine occurrences in the Kolonne region of Sri Lanka, as well as R.I.'s, S.G.'s, birefringences, and thorough chemical analyses of two gem-quality blue sapphirines from the area. The authors point out striking similarities between sapphirine and serendibite. The latter occurs in the same area and, while not yet encountered in cut form, does provide a potential problem in identification. Apparently, only X-ray diffraction or chemical analysis can provide a conclusive distinction between the two.

The tabulation of properties for these two minerals provides a puzzling set of R.I.'s, apparently high and low values, which suggest a range of chemical compositions for both minerals that is not discussed; a complete listing of all indices would have been more useful and less confusing.

Illustrations of sites and samples, a geologic sketch map, and tables of chemistry and properties round out the rest of this admirable and thorough note. *CMS*

Titanite crystals from the Harts Range, Central Australia. D. McColl and O. V. Petersen, *Mineralogical Record,* Vol. 21, No. 6, 1990, pp. 571–574.

Well-formed gem-quality crystals of titanite have recently been found in the Harts Range, 200 km northeast of Alice Springs, in Central Australia. This area is known as a source of several gem minerals, including sapphirine, kornerupine, and ruby. The titanite occurs in a narrow vein of feldspar-rich rock, within occasional vugs up to 20 cm in diameter. The crystals are tabular, and each displays a number of crystallographic faces. The more perfect crystals are yellowish brown and 3 to 4 cm long. Chemical composition and unit-cell data are also presented. *JES*

INSTRUMENTS AND TECHNIQUES

Cathodoluminescence of diamonds. J. Just, Abstract, 15th General Meeting, International Mineralogical Association, June 28–July 3, 1990, Beijing, China, pp. 182–183.

The author describes the use of cathodoluminescence as a technique for diamond identification. A majority of diamonds exhibit some degree of cathodoluminescence, which can be determined with a scanning electron microscope. Use of this technique allows one not only to identify diamond, but also to assess a specimen's crystallinity. Furthermore, the author points out, these techniques can provide information on the growth conditions of a crystal, and can thus be used to distinguish natural from synthetic diamonds. *JES*

Current issues and problems in the chemical vapor deposition of diamond. W. A. Yarbrough and R. Messier, *Science,* Vol. 247, 1990, pp. 688–696.

Yarbrough and Messier provide a status report on the chemical vapor deposition (CVD) of synthetic diamond—in particular, synthetic diamond and diamond-like carbon thin films—addressing points that were not discussed in detail by Angus and Hayman in their 1988 review paper. Because specifics of the growth mechanism are still largely unknown, the authors review commonalities among the numerous variations of the CVD growth technique.

The Raman microprobe and X-ray diffraction analysis are the principal techniques used to characterize the coatings. Although there are still technical barriers to quantifying the amount of nondiamond component in certain films, progress has been made in understanding the morphology and orientation of synthetic diamond crystals in the films. There is also interest in the nucleation of synthetic diamond on nondiamond substrates and the adhesion of the resulting films, but considerable uncertainty remains as to the precise mechanism involved. A more fundamental question is still open, too: Why does synthetic diamond form instead of graphite? A number of reaction schemes have been proposed, but none fits all the experimental data available. Also, why don't other carbon polymorphs form?

The authors conclude by discussing the importance of the prospect that from the CVD metastable growth of synthetic diamond, we may learn how to grow other metastable, well-crystallized materials with interesting properties, such as cubic boron nitride. *EF*

A dark-field illuminator for gemmological microscopes. T. Linton and G. Brown, *Australian Gemmologist,* Vol. 17, No. 5, 1990, pp. 171–172.

This report by the Instrument Evaluation Committee of the Gemmological Association of Australia begins with a brief summary of the virtues of using darkfield illumination in gemstone microscopy. It then proceeds to describe and evaluate a Japanese-manufactured darkfield illuminator designed for use with microscopes that do not already incorporate a similar lighting system.

The authors found the instrument easy to assemble, install, and use, enabling the effective examination of even relatively nonreflective inclusions in dark-colored gems. Their only real criticism was that the semi-matte upper surface of the illuminator's mask produced some confusing reflections from the surfaces of some high–R.I. gems.

This abstracter feels that such a microscope accessory would certainly be a valuable tool for those gemologists whose microscopes do not incorporate darkfield illumination. Given the current gem identification challenges provided by synthetic and enhanced gems, however, one would be better advised to obtain a good stereoscopic binocular microscope with integral darkfield capability. *RCK*

JEWELRY ARTS

The Georges & Victoria: Jewelry as a social statement. A. G. Kaplan, *Jewelers' Circular-Keystone,* Vol. 161, No. 2, February 1990, Heritage Section, pp. 270–278.

Excerpted from Mr. Kaplan's next edition of *The Official Guide to Antique Jewelry,* this article presents a basic overview of the styles, motifs, and gems that were characteristic of jewelry from the Georgian and Victorian periods, which encompassed most of the 18th and 19th centuries.

Mr. Kaplan delineates the period 1714 to 1830 as Georgian and briefly describes a few styles that were popular during that time, including naturalistic jewels, engraved gemstones and cameos, and the classically derived Directoire style. He also mentions the development of paste imitation gems and pinchbeck imitation gold to satisfy the rising middle class.

The Victorian period, which spanned from Queen Victoria's coronation in 1837 through 1900, has been broken into three subperiods: Early Victorian or Romantic (1837–1860), Mid-Victorian or Grand (1860–1885), and Late Victorian or Aesthetic (1885–1890). Sentimental jewelry, Gothic revival jewels, and designs that reflect the impact of the Great Exhibition of 1851 are referred to as Early Victorian styles; archeological jewelry, massive gold, and mourning jewelry typify the Mid-Victorian period; a lighter touch in metalwork and colored stones are sketchily cited as characterizing the Late Victorian period.

While it is impossible to include everything in an article that is this broad in scope, the author has provided a general introduction to these periods. Thirteen color photographs illustrate the text. *EBM*

Hair jewelry: Much more than mourning. A. London and P. London, *Jewelers' Circular-Keystone,* Vol. 161, No. 2, February 1990, Heritage Section, pp. 282–285.

The authors became fascinated with hair jewelry in 1976, when they visited a small exhibit in Bennington, Massachusetts. This visit inspired them to research the history of this unusual artform.

Originating in Norway, the practice of incorporating hair into jewelry spread through Scandinavia to Germany and eventually to France, England, and America. Used primarily in memorial jewelry, made to commemorate the passing of a loved one, the style blossomed into widespread popularity during the 19th century. In 1861, Queen Victoria went into deep mourning after the death of her husband, Prince Albert. For the next 25 years, only mourning jewelry was acceptable for British court dress. Rings, lockets, bracelets, brooches, and earrings incorporating the hair of loved ones were produced in profusion; hair jewels became so popular that they were even mass produced. In fact, women were cautioned to make their own pieces to ensure that the hair used really did belong to their loved one.

Besides the historical aspects of hair jewelry, the article also covers the ways that hair was prepared to be worked into jewelry and early advertisements that relate to the making of hair jewelry.

Six color plates show examples of hair jewels to illustrate this interesting article. Unfortunately, although two books are mentioned as having information about how to make hair jewelry, no other bibliographic references are provided. *EBM*

Vitreous paste gem carving. N. Tagliamonte and L. Tagliamonte, *Lapidary Journal,* Vol. 43, No. 12, March 1990, pp. 28–33.

Stone carving is about as old as humanity itself and the carving of gem materials has become an art. Carved gems are used not only for personal adornment, but also as a symbol of a person's power and status.

This excellent article tells the history of paste gem carvings with an emphasis on its roots in Aquileia, a Roman colony founded in 191 B.C. (The Romans developed the use of vitreous materials for their carvings, since glass was readily available, economical, and versatile.) Reasons for the popular uses of glass carvings are given, and authors Tagliamonte describe the mastery of various paste carving artists through time. Other eras covered are the "Dark Ages," with the beginning of the famous Venetian glass, and the "Golden Age," during which glass was used by such notables as Cartier and Tiffany. Three photographs of carvings representative of various eras help the reader understand the beauty and talent involved in the glyptic arts. *RW*

JEWELRY RETAILING

Private right to act against false advertising strengthened. R. J. Jacobs-Meadway, *Jewelers' Circular-Keystone,* Vol. 161, No. 3, March 1990, pp. 184–185.

The Lanham Act, which gave any person or company the right to sue for the misrepresentation of goods, has recently been revised. These latest amendments empower the honest jeweler to fight back against competitors who consistently seek an unfair competitive edge, underkarat their goods, and/or misrepresent the quality of their colored stones.

Not only does the prohibition attack misrepresentations, but it also attacks statements that might mislead or deceive. For example, if a diamond is advertised as "the finest there is," this implies that the stone is "D-flawless." If the stone is of lesser quality and this is not disclosed to the customer, the customer could sue the jeweler for not providing true top quality at the advertised price. Even though the stone might be a "fine" stone, or the "finest" for the price, the advertisement might be misleading and may injure the competitor.

The Lanham Act is not considered an appropriate legal recourse for small independent businesses, though. Section 43(a) of the Lanham Act is considered to be the most helpful to jewelers. It promotes fair dealing of competitors as well as protects consumers from deceptive trade practices. *KBS*

PRECIOUS METALS

Le fasi di lavorazione per trasformare il lingotto in un prezioso oggetto d'oro [The stages by which ingots are transformed into precious gold articles]. V. d'Anna, *Joy Oro,* Vol. 4, No. 1, 1990, pp. 16–19.

This article briefly outlines the processes needed to transform a gold ingot into a gold jewelry item. Ms. d'Anna discusses the different stages, from alloying the gold to rolling it into wire and sheets. The author emphasizes that for every gold item produced, even a mass-produced item like a chain, each step must be supervised; thus, even "industrial" manufacturing should be considered a craft. This article is printed bilingually in Italian and English. Twelve color photographs illustrate the text. *RT*

SYNTHETICS AND SIMULANTS

Knischka-created rubies. G. Brown and S. M. B. Kelly, *Australian Gemmologist,* Vol. 17, No. 5, 1990, pp. 199–204.

This Gemmology Study Club Report begins with a comprehensive review of the literature on the synthetic rubies produced by Prof. P. O. Knischka of Steyr, Austria. It then proceeds to describe the authors' examination of three specimens believed to represent post-1986 commercial production: a 0.63-ct oval faceted gem, a 4.36-ct "ebauchated" crystal (i.e., one with rough chiseled faces), and a 1.20-ct crystal.

The specimens ranged from medium, slightly purplish pinkish red to dark purple-red or bright "firey" red. Dichroism was strong in purplish red or red (ordinary ray) and orange-red (extraordinary ray). The samples were transparent with a vitreous luster. Refractive indices were 1.760–1.768, with a birefringence of 0.008. Through the Chelsea color filter, the samples appeared a bright fluorescent red, the same reaction produced by exposure to long-wave U.V. radiation. The short-wave reaction was either a slightly duller red or inert. The absorption spectrum was typical of that for ruby; specific gravity was 4.0.

Inclusions noted were as follows: (1) swirling grayish "cloudiness" or "treacle;" (2) rounded high-relief flux glass remnants containing a contraction bubble; (3) low-relief cavities, some with two-phase fillings; (4) platinum platelets and "needles;" (5) obvious parallel growth banding or zonal structures; (6) white flux infilling partially healed conchoidal fractures; and (7) multiple, high-relief, rounded, stretched, and distorted "bubbles," which are possibly remnants of colorless flux glass. Interestingly, a two-phase negative crystal breaking the surface of the 4.36-ct crystal mirrored the ebauchated external faces of the host.

The authors conclude from the gemological evidence that these specimens were either of the self-nucleated variety ("Type 4") or ebauchated crystals grown on Verneuil seeds ("Type 5"), and that at least some of the current production is grown in platinum crucibles charged with white polycrystalline flux. The report is well illustrated with color photographs and photomicrographs. *RCK*

Synthesis of diamond from graphite-carbonate systems under very high temperature and pressure. M. Akaishi, H. Kanda, and S. Yamaoka, *Journal of Crystal Growth,* 1990, Vol. 104, pp. 578–581.

Synthesis of large, single-crystal synthetic diamonds at high temperatures and pressures has been successfully demonstrated using a variety of metals (Fe, Co, Ni, etc.) as solvent-catalysts. However, the use of nonmetallic catalysts has also been reported in industrial patents. The present study was undertaken to investigate these claims.

Using a mixture of graphite and the carbonates of Li, Na, Mg, Ca, and Sr, tiny diamond crystals were synthesized at high pressures (7.7 GPa) and temperatures (2150°C). These crystals, up to 20 μm, were transparent and colorless but poorly formed. The authors concluded that carbonates have a strong solvent-catalytic effect on the transformation of graphite to diamond. Although many scientific and technological problems remain, this study points the way toward the possible development of growth methods capable of producing transparent, high-quality colorless synthetic diamonds without metallic inclusions or other features indicative of a laboratory growth environment.

Note: In a second article, the authors report successful results at the same temperatures and pressures using graphite-sulfate and graphite-hydroxide systems. See M. Akaishi, H. Kanda, and S. Yamaoka (1990) High pressure synthesis of diamond in the systems of graphite-sulfate and graphite-hydroxide, *Japanese Journal of Applied Physics,* Vol. 29, No. 7, 1990, pp. L1172–L1174. *JES*

TREATMENT

Coloration in electron-irradiated beryl. W. F. Rink, P. F. Gielisse, and H. S. Plendl, *Journal of Gemmology,* Vol. 22, No. 1, 1990, pp. 33–37.

Near-colorless beryl is often treated in order to create a yellow color. After irradiation with 3 MeV electrons from a Van de Graaff accelerator, two defects are created: a Maxixe-type color center that gives rise to a blue component, and an $O^{2+} \rightarrow Fe^{3+}$ charge transfer that provides a yellow component. The blue component disappears on heating, but the yellow color remains. The main interest of the article is in the details given regarding the irradiation procedure, since the color centers mentioned are already well known. *EF*

MISCELLANEOUS

Mineralogy of volcanoes. F. H. Pough, *Lapidary Journal,* Vol. 43, No. 10, January 1990, pp. 74–80.

This second in a four-part series examines differences among volcanoes and discusses why various minerals are associated with certain types of lava flows. The article also points out some of the cataclysmic activities that volcanoes display. Dr. Pough reminds us that these activities are still ongoing, and encourages us to be careful when venturing forth on Vulcan's slopes: "On hot lava flows, keep your trouser bottoms tucked inside your boots; unseen cracks sometimes blast invisible hot gas. You won't sink; the lava is denser than you. . . ." The author continues to build on the modes of formation under which many minerals, including gem materials such as peridot and some garnets, are born. Dr. Pough includes five of his own color photographs. *WRV*

The Mining Law of 1872: Reforming it will drastically change the future of American mining. S. Voynick, *Rock & Gem,* Vol. 20, No. 12, December 1990, pp. 26–32.

When first instituted May 10, 1872, the purpose of the General Mining Law was to open land development in 19 western states. Originally, one billion acres of federal land were available for prospecting and mining; today, 400 million acres remain due to the establishment of national parks, wildlife refuges, military and federal training areas, etc. Recently, environmentalists, mineral-royalty interests, and land-use reformers have pushed for a major overhaul of the Mining Law. Mr. Voynick provides a detailed history of the Mining Law to present day, as well as related withdrawal acts; discusses H.R. 3866, the proposal that would supersede it; and presents a fairly unbiased account of arguments for and against the reform act. This well-written, informative, and comprehensive article will be of interest to anyone concerned about the legal aspects of mining in the U.S. *RT*

New tomb of royal splendor. W. Alva, *National Geographic,* Vol. 177, No. 6, June 1990, pp. 2–11.

When in 1988 the news of the pre-Columbian treasures uncovered at Sipan, Peru, reached the world, archaeological history was fast in the making. The Moche treasures were touted as the "richest in the New World," and were compared to the treasures of Tutankhamun in Egypt. Located along 250 miles of Peru's northern coast, the Moche culture has produced the finest metalwork in the Western hemisphere. As time went on, further chapters of this astonishing tale continued to unfold. The latest is written by Alva, as a sort of sequel to his original article ("Discovering the World's Richest Unlooted Tomb," *National Geographic,* October 1988). Here, the talented photography of Nathan Benn pulls you right into this unbelievable story, as you gaze on images of gold burial masks, effigies with lapis lazuli inlays, and finely crafted gold necklaces and pottery. It is a breathtaking catalog of some of the most exciting goldwork produced in pre-Columbian times. *RW*

Rocks depicted in painting and sculpture. R. V. Dietrich, *Rocks & Minerals,* Vol. 65, No. 3, 1990, pp. 224–236.

This article is an overview of artistic representation of rocks in painting and sculpture throughout history. The earliest example is the Blue Monkey fresco from Crete, dated approximately 1600 B.C. During the Renaissance, the best-known artists depicting rocks were Leonardo da Vinci, Giovanni Bellini, and Albrecht Durer. In the 18th and 19th centuries, artists who created noteworthy examples include Paul Cezanne, Claude Monet, Winslow Homer, and Vincent van Gogh. During this century, we have examples by René Magritte, Salvador Dali, and Georgia O'Keeffe.

The color photographs of the paintings are especially interesting. Photographs of paintings that are referred to in this excellent article but not shown can be found in the art books listed in an extensive appendix. *Ron Conde*

An Urban view of jewelry. L. Urban, *Jewelers' Quarterly,* Vol. 28, No. 4, 1989, pp. 50–51.

In the quick-paced '80s and '90s, does the jewelry designer have time to take a beautiful photograph of his or her jewelry? Urban states that "one of the most disappointing things about some jewelry photography is the 'line it up and shoot it quick' approach." And yet, a beautiful photograph of an exquisite piece of jewelry is always a pleasure to behold. Urban suggests that photographic recording can be made to look pleasurable and alluring, if not by learning some photographic essentials yourself, then by hiring a photographer to do the work for you. Even though the costs may seem prohibitive at first, a good photograph library could provide a jeweler/designer with years of inexpensive advertising.

The article also discusses general protocol when working with a professional photographer. A sidebar at the end of the article gives tips on "What Makes a Good Jewelry Photograph." *RW*

BOOK REVIEWS

Elise B. Misiorowski and Loretta B. Loeb, Editors

GEM TESTING, 10th Edition

*By Basil W. Anderson, revised by E. Alan Jobbins, 390 pp., illus., publ. by Butterworths, London, 1990. US$49.95**

Gem Testing was first published in 1942, and Basil Anderson was exceptionally well qualified to write it. He was a pioneer in establishing what is probably the first commercial gem-testing laboratory, but, more than that, he was an exceptionally creative scientist. During his many years as director of the Precious Stone Laboratory of the London Chamber of Commerce, he added significantly to the gem tester's arsenal. Before Basil Anderson, the spectroscope was not regarded as a gemological instrument. His long series of articles on spectroscopy in the *Gemmologist* magazine was a classic, and added materially to the literature on gemology and to the effectiveness of the gemologist in all kinds of identification problems.

Not only was Basil Anderson an exceptional scientist, but he was also an outstanding teacher and a gifted writer. Most of his writings were highly technical in nature, but they were written to be easily assimilated by most gemologists, and often they were written with a twinkle. From time to time, when using *Gem Testing*, one encounters the light touch that characterized Anderson's writing.

Gem Testing was a beautifully written and very lucid text in Anderson's day. Alan Jobbins, editor of the *Journal of Gemmology* and former curator of Gems and Minerals at the Geological Museum in London, is an excellent writer and communicator in his own right. He has added chapters on gemstone enhancement and on the manufacture of synthetics and other substitutes, and he has updated the text where new developments warranted. But he has not made changes in Anderson's text where they were not essential.

For those few gemologists and students of gemology who are not already familiar with Anderson's great classic, *Gem Testing* approaches identification with the question: "Is this a diamond?—or a ruby?, or an emerald?" After 11 chapters on the properties of gemstones and the equipment available to detect or quantify them, Anderson wrote 17 chapters on specifics of how to identify all of the major and many minor gems and substitutes. His observations, accumulated over a lifetime in the gem laboratory, make available to everyone the experience of an especially insightful, meticulous, intelligent, and creative scientist.

I commend Alan Jobbins for updating a classic work very effectively, enhancing rather than detracting in any way from the qualities that have made *Gem Testing* a must for every gemologist's—and gemmologist's—library.

RICHARD T. LIDDICOAT
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ENGAGEMENT AND WEDDING RINGS: The Definitive Buying Guide for People in Love

*By Antoinette Matlins, Antonio Bonanno, and Jane Crystal, 269 pp., illus., publ. by Gemstone Press, South Woodstock, VT, 1990. US$14.95**

The authors have distilled a great deal of information into this book's large-size paperback format, and they present it to the layperson in a manner that is lively and well organized. While very little of the information will be new for the gemologist, others may find the book a useful reference guide.

Although the subtitle might lead potential readers to think that the book focuses only on diamonds, the eight parts actually contain a wealth of information for the consumer on many additional subjects, including colored stones, jewelry history, design, appraisals, and insurance. The difficult topics of grading reports and pricing are handled in a balanced, instructive fashion, with the advantages of shopping at a reputable jeweler clearly discussed.

The diamond sections cover everything from size and shape to the effects of clarity and color on price. They also explain the importance of cut and proportion. Unfortunately, some of the information may be excessive for the average consumer, and the inclusion of current price charts will date the book prematurely.

However, the part on colored stones includes notes on the more common gem materials and some of the more exotic stones seen on the market today, and, therefore, enables the book to be more than a one-time reference. Careful, accurate explanations of synthetics, simulants, misnomers, and treatments are also presented.

The book includes a good index, a bibliography, and a series of appendices detailing gemological associations and laboratories; many of the latter appear to be jewelry stores with Certified Gemologist Appraiser (CGA) or Master Gemologist Appraiser (MGA) titleholders on staff.

Although the text of *Engagement and Wedding Rings* is well

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*This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404. Telephone: (800) 421-7250, ext. 282.

illustrated with line drawings and black-and-white photos, the color section is disappointing. It consists mainly of badly reprinted advertising material, which is properly credited but does very little to enhance the usefulness of this volume.

Overall, this is a book for the interested consumer rather than the gemologist, but, because it is both accurate and well written, it makes an enjoyable guide for everyone.

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ISLAMIC RINGS AND GEMS – THE ZUCKER COLLECTION

*Edited by Derek J. Content, 551 pp., illus., publ. by Philip Wilson Publishers, London, 1987. US$115.00**

This massive tome covers a topic that hitherto seems to have been overlooked: Islamic goldwork and gem carving from the seventh to the 19th centuries. While there have been several articles written on various aspects of this subject, as well as passing references in many books peripherally related to it, this seems to be the first book to concentrate on this specific area.

Essentially, the work is a detailed description of a personal collection of Islamic gems and rings assembled by Benjamin Zucker. Derek Content and Ludvik Kalus prepared the descriptive catalogue of each jewel, which makes up the body of the book. The section that follows the catalogue, titled "The Craftsmen and Their World," analyzes the significance of the collection in four chapters. The first, Ralph Pindar-Wilson's excellent historic account of "Seals and Rings in Islam," is followed by Jack Ogden's "Islamic Goldsmithing Techniques in the Early Medieval Period" and Joseph Saden's "The Art of the Goldsmith Reflected in Medieval Arabic Literature." The fourth chapter is a glossary of Medieval Judeo-Arabic goldsmithing terms by Hadassa Shy.

Every aspect of the text is presented in English, Arabic, and Hebrew, undoubtedly a tremendous task. Each chapter is footnoted and has its own bibliography, making the book a very useful reference for future scholars. Black-and-white photos of the rings and gems are taken from various angles to show important features. A very important note concerning the orientation of the photographs is found on the publisher's page. Several of the pieces are also depicted in color, often magnified to show details of the spectacular workmanship and apparent quality. The only complaint that these reviewers had was that the quality of the photographs did not meet expectations in relation to the other qualities of the book.

The gems, frequently inscribed or carved as ring stones, seals, or talismans, include carnelian and other chalcedonies, lapis, turquoise, and malachite. Regrettably, fewer than one-third of the gem pieces described are shown in the 14-page color section, leaving these reviewers feeling teased and wanting more. Otherwise, this book is a milestone work on the subject and would be a welcome addition to the library of any appraiser, gem collector, or jewelry lover who is interested in the subject matter.

MICHAEL and PAT GRAY
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OTHER BOOKS RECEIVED

The Diamond Ring Buying Guide, How to Spot Value and Avoid Ripoffs, *by Renee Newman, 140 pp., illus., publ. by International Jewelry Publications, Los Angeles, 1989, US$12.95.** This highly informative guide is intended for the first-time shopper who knows very little about evaluating diamonds or jewelry craftsmanship, but it could also appeal to the enthusiast craving more information about diamonds. The scope of the book ranges from general facts about diamonds to more technical grading terms. It also contains pertinent information on different cutting styles, as well as on gold and other alloys, to help the consumer make intelligent purchasing decisions.

Other topics covered include how to select the right setting, the pricing of quality, and how to choose a personal jeweler. The author uses photos to explain clarity and cut grades, as well as the different tests involved in identifying diamond simulants. Self-tests at the end of every chapter prompt the reader to focus on the significant points covered.

The Diamond Ring Buying Guide is a useful book for the first-time diamond purchaser, the gemologist who needs a good review on diamonds, and the retailer seeking more information to give to customers.

KAREN BABCOCK STARK

Le Lapis Lazuli, Son Histoire, Ses Gisements, Ses Imitations (Lapis Lazuli, Its History, Deposits, and Imitations), *by Claire da Cunha, 139 pp., illus., publ. by Le Rocher, Monaco, 1989.* This attractive study of lapis lazuli as a gem material is the first book entirely dedicated to this gem. It is structured into three main parts. In the first, Ms. da Cunha concentrates on ancient sources and uses of lapis lazuli. In the second part, she provides detailed descriptions of the modern sources of lapis, an exhaustive study of the structure and chemistry, as well as an extensive review of identification procedures, from classic gemological methods to such sophisticated techniques as electron microprobe analysis and Raman and cathodoluminescence spectroscopies. The author concludes the volume with a complete list and description of the various lapis lazuli treatments, synthetics, and imitations.

Several useful experiments and observations that have never been previously published are of particular note. Although the book is written entirely in French, it is illustrated by numerous informative figures (e.g., color photographs, detailed maps, and spectra) that will be useful to all gemologists. The author's thoroughness in describing this fascinating gem reflects her many years of experience teaching gemology.

EMMANUEL FRITSCH

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SUBJECT INDEX

This index gives the first author (in parentheses) and *first page* of the article, Gem News (GN), or Gem Trade Lab Notes (GTLN) section in which the indexed subject occurs. The reader is referred to the author index for the full title and the coauthors, where appropriate, of the articles cited. The pages covered by each issue are as follows: Spring (1–114), Summer (115–176), Fall (177–246), Winter (247–324).

Indexes prepared by Dona Dirlam

AUTHOR INDEX

This index lists, in alphabetical order, the names of authors of all articles that appeared in the four issues of Volume 26 of *Gems & Gemology*, together with the inclusive page numbers and the specific issue (in parentheses). Full citation is provided under the first author only, with reference made from joint authors.