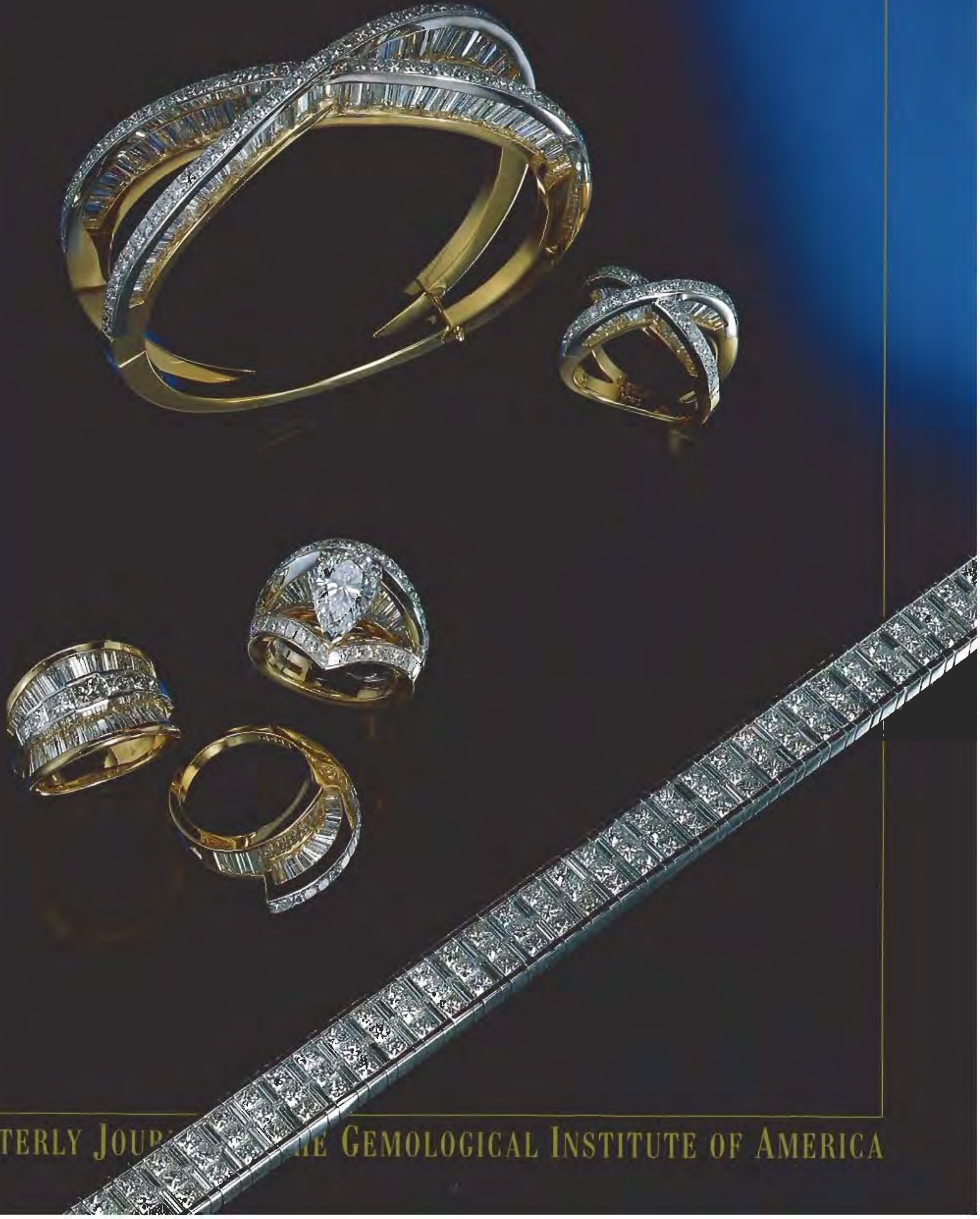
GEMS & GEMOLOGY

VOLUME XXX FALL 1994



THE QUARTERLY JOU HE GEMOLOGICAL INSTITUTE OF AMERICA

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FALL 1994 VOLUME 30 NO. 3

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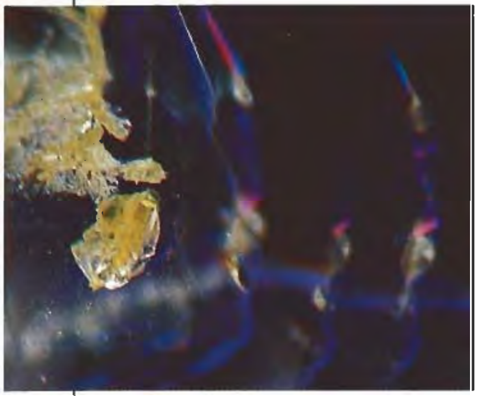

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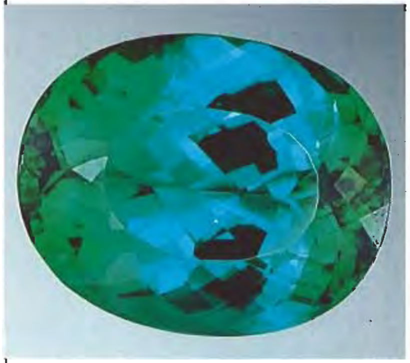

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ABOUT THE COVER: In the five years since Gems & Gemology *published the first comprehensive article on fracture-filled diamonds, many tens of thousands of stones treated by this method may have entered the market. Now, more than ever before, the jeweler-gemologist must be able to identify filled diamonds and know how to work with them. The lead article in this issue addresses the effectiveness of fracture filling, key identification techniques, and the results of research into how some filled stones react to certain conditions of jewelry manufacturing and wear. It is the most complete research report published to date on this important topic.*

This information is critical to protecting the integrity of untreated diamonds, like those shown on the cover. All of this jewelry was designed and manufactured by Martin Gruber Designs for Nova, Van Nuys, California. The pear-shaped diamond (2.71 ct) ring is courtesy of Tivol Jewelers, Kansas City, Missouri. The Cross Over Fantasy bracelet contains 208 diamonds with a total weight of 18.40 ct; the three-row platinum Mystery bracelet has 199 diamonds with a total weight of 21.77 ct; and the rings have a total of 17.27 ct of diamonds.

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Subscriptions
Gail Young
Jin Lim
(800) 421-7250 x201
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Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in this 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.

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OUR FUTURE: FORTHRIGHT OR FRACTURED?

William E. Boyajian
President, Gemological Institute of America

In my two decades at the Gemological Institute of America, I have never seen a subject so grip the industry as fracture filling in diamonds. Long a sacred icon, diamond has joined its fellow gems as the object of an impermanent treatment that can enhance the appearance, and thus the salability, of mostly lower quality stones.

The widespread distribution of filled diamonds in the trade is being met with delight by some—and horror by others. What began almost as a curiosity in the 1980s, with Zvi Yehuda's first product, has evolved into a major industry concern surrounded by a ground swell of emotion. Although no one knows the true impact of fracture filling on the long-term viability of the diamond market, perception is often reality in the minds of both tradespeople and consumers. Certainly, we can be sure that this form of treatment will not go away.

At GIA, it is not our role to challenge the ethics of marketing such a product, despite its possible impact on the industry at large. Our role has always been, and continues to be, the intelligent scientific documentation of new products and processes, and the reporting of these findings to the trade. As shown by the lead article in this issue—a landmark study and truly a team effort—our goal is to probe objectively, analyze carefully, and report thoroughly, information that is crucial to the trade's understanding of such gemological challenges. Further, it is to help the industry cope with these challenges by clearly stating what we can—and perhaps cannot—identify accurately and conclusively.

In the matter of filled diamonds, I am pleased to report that we have settled at least one vital concern about this treatment: It can be identified with standard gemological equipment and techniques. This article describes the techniques and illustrates the key features. It also explores a limitation of fracture filling—potential damage to filled stones with some routine manufacturing and cleaning procedures, and even with wear. Now, it is up to the trade to use this information and to commit to education and training derived from it.

Sooner or later, almost all jewelers will encounter fracture-filled diamonds, and not necessarily ones that are disclosed as treated. Anyone who does appraisals or repairs is particularly vulnerable. And anyone who thinks he or she is above this issue needs a serious reality check.

We continue our policy of refusing to grade fracture-filled diamonds in the GIA Gem Trade Laboratory, for reasons that are described fully in the article. And we remain convinced that accurate detection, full disclosure, and rational dissemination of information about the treatment process itself will help further ensure the industry's stability and prosperity, to the benefit of the trade and public alike.

Today's jeweler cannot hide from the issues and challenges of technology. Gemology is no longer optional: Jewelers must gain and use the knowledge available to protect their customers and themselves. At a time when the industry is restructuring and traditional jewelers are being squeezed by new retailing formats, this is yet another critical reason to have knowledgeable people behind jewelry counters. May it ever be so. ❑

AN UPDATE ON FILLED DIAMONDS: IDENTIFICATION AND DURABILITY

By Robert C. Kammerling, Shane F. McClure, Mary L. Johnson, John I. Koivula,
Thomas M. Moses, Emmanuel Fritsch, and James E. Shigley

The increasing numbers of fracture-filled diamonds present a major challenge to the diamond industry, especially with regard to detection and durability of the treatment in routine jewelry manufacturing and wear. This report focuses on recent products from Yehuda/Diascience, Koss & Shechter Diamonds (Genesis II), and Clarity Enhanced Diamond House (a subsidiary of Goldman Oved Diamond Co.). Like the Yehuda treatment, the latter two processes were found to be effective in improving the appearance of most of the samples examined for this study. Treated diamonds from all three firms were damaged by direct heating and by repolishing facets intersected by filled breaks. Some stones were adversely affected by some standard cleaning procedures and wear conditions. Although the lead-based glass filling materials may be detected by X-radiography and EDXRF spectroscopy, as well as by certain internal features, we found flash effects to be the most distinctive characteristic of fracture filling—observed in all the treated diamonds examined from all three firms.

ABOUT THE AUTHORS

Mr. Kammerling is director of identification and research, Mr. McClure is supervisor of identification services, Dr. Johnson is a research scientist, and Mr. Koivula is chief research gemologist, in the GIA Gem Trade Laboratory (GIA GTL), Santa Monica, California. Mr. Moses is director of identification and research in GIA GTL, New York. Dr. Fritsch is manager, and Dr. Shigley is director, of GIA Research, Santa Monica.

See acknowledgments at the end of the article.

Gems & Gemology, *Vol. 30, No. 3, pp. 142-177.*

One of the most controversial gemstone treatments to appear in the last decade is the filling of surface-reaching breaks in faceted diamonds. Jewelers, *diamantaires*, and gemologists at all levels of the industry must deal not only with the detection and durability of this treatment, but also with how properly to disclose the treatment to their customers. The trade has already been confronted with media exposés about misrepresentation in the sale of filled diamonds by some U.S. retailers (see, e.g., "Five on Your Side . . .," 1993; "Prime Time Live . . .," 1993).

Because more of these stones are now entering the market, it is increasingly likely that jewelers will encounter them in their day-to-day operations. Yet the challenge of identifying filled stones and working with them at the bench is further complicated by the fact that a growing number of firms are producing and/or marketing them, as loose stones and even in fashioned goods (figure 1). Thus, the present study was undertaken to investigate fracture-filled[1] diamonds from two well-publicized diamond treatment firms that began marketing these stones after publication of our original comprehensive study (Koivula et al., 1989), as well as recently treated stones from the firm (Yehuda) that we studied initially. The present article can be viewed as an update to our 1989 study, as we again focus on the issues of identification and durability.

BACKGROUND

The first commercially available diamond fracture-filling treatment was developed in the 1980s by Zvi Yehuda of Ramat Gan, Israel, with diamonds treated by this process marketed by Yehuda Diamond Co./Diascience Corp., New York. Briefly stated, this technique proceeds as follows: The diamonds are first cleaned, then "filled" with a molten glass at high temperatures (presumably under vacuum, to prevent diamond burning), cooled, and—last—cleaned again to remove the glass from the stones' surfaces (Nelson, 1994;

Figure 1. All of the 31 diamonds (about 0.13 ct each) in this strip bracelet had been fracture filled by Goldman Oved Diamond Company, New York, which also manufactured the bracelet. Photo by Shane F. McClure.

Nassau, 1994). Koivula et al. (1989) focused on the effectiveness of the Yehuda treatment, diagnostic features by which it could be detected using standard gemological equipment, and the durability and stability of diamonds treated in this manner. Results of a follow-up investigation of Yehuda-treated diamonds were briefly summarized by Koivula and Kammerling (1990).

Since publication of these reports, fracture filling has grown to become one of the first truly widespread treatments to be used on diamonds in the colorless-to-light yellow range, and it is also being used on fancy-colored diamonds. Even so, many jewelers still may not think to examine diamonds to determine if they are fracture filled.

Although it is virtually impossible to determine exactly how many such treated stones are in the marketplace, a number of statements indicate the magnitude of the situation. For example, in an advertisement for Yehuda-treated diamonds ("Yehuda diamonds offer great option . . .," 1994), jeweler Lloyd Drilling of Thurston Jewelers in Minneapolis, Minnesota, estimates that 20%–30% of the diamonds he sells are so treated. (When contacted by the authors in September 1994, Mr. Drilling clarified that this amounts to 30 filled diamonds annually, between 0.5 and 2.5 ct each.) In the same advertisement, Harris Fleishman of C. Harris Goldman in New York reports that over the last five years, Yehuda-treated diamonds have grown to account for about 50% of all diamonds sold by his firm. (According to our September 1994 personal communication with Mr. Fleishman, this represents about 3,000 filled stones per year.) He

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[1] *Throughout this article, we use the trade term* fracture filled *to describe diamonds in which surface-reaching separations such as cleavages, fractures, voids, laser drill holes, and other partings have been filled with a foreign substance. Although the "fracture filling" designation may not be strictly accurate, it is both widely used and understood in the trade.*

further estimates that 75% of all diamond merchants on 47th Street handle at least some "clarity-enhanced" stones. In mid-1993, Dror Yehuda indicated that "tens of thousands" of diamonds treated by his family's firm were already in the U.S. market (Brown, 1993).

It appears that these Yehuda-treated stones represent some of the larger filled diamonds on the market. According to Ron Yehuda (pers. comm., 1994), his family's firm prefers not to treat clients' stones smaller than 0.25 ct, and the number of such stones under 0.50 ct that the firm has treated is "negligible." Already-treated stones in the company's sale stock are primarily 0.50 ct and larger, with fully 50% of demand being for stones over 1 ct. He adds that these stones are marketed primarily in the U.S. and Canada, the two countries in which the firm has focused its efforts to date.

The proliferation of filled diamonds can also be explained by the fact that several other firms now offer commercial treatment services and/or diamonds already so treated. Two of these appear to be especially visible in the marketplace. Genesis II—Enhanced Diamonds Ltd., in New York, a division of the Israel-based firm Koss & Shechter Diamonds Ltd., offers its own product. Originally described in the firm's marketing literature (and often referred to in the trade) as "Koss clarity-enhanced diamonds," it has more recently been marketed in the U.S. under the trademark name of "Genesis II" clarity-enhanced diamonds ("A new stone is born . . .," 1994)—the name under which it was first marketed in Australia. In terms of the numbers of these stones on the market, a startling figure is provided by Managing Director Daniel Koss, who reports that in a three-year period his firm had treated "over half a million stones from 0.01 ct to 50 cts" (Shor, 1994). We have examined Koss-treated stones as small as 0.02 ct.

The other firm, Clarity Enhanced Diamond House, a division of Goldman Oved Diamond Company, New York, offers treatment services and also sells treated stones; the treatment is performed in Israel and New York (J. Oved, pers. comm., 1993). Goldman Oved has treated stones between 0.02 and 15.5 ct (J. Oved, pers. comm., 1994), and we have examined Goldman Oved–filled diamonds as small as approximately 0.13 ct (figure 1).

Other firms, such as Chromagem of New York, operate on a relatively smaller scale, selling filled diamonds that are treated by an independent chemist. Still other New York diamond treaters (such as S&I Diamond Drilling) provide filling services to the diamond trade only. Firms in other cities, such as Diamond Manufacturers in Los Angeles, are now treating diamonds (U. Uralevich, pers. comm., 1994). In addition, there are wholesale firms that market to the retail trade (in some instances, under their own trade names) diamonds treated only by others. For example, Doctor Diamond, a division of Kami & Sons, New York, markets "Doctor Diamond clarity enhanced diamonds" ("Clearly better . . .," 1994), which reportedly include diamonds treated by both the Yehuda and Goldman Oved firms (J. Oved, pers. comm., 1993).

In part because so many companies are now offering treated stones, some confusion has developed about the identifying features of filled diamonds. For example, claims have been made that Koss-filled diamonds exhibit little or no telltale flash effects (Shor, 1994); that the presence of certain flash-effect colors—purple, orange, blue, green, and red—identify a filled stone as being Yehuda treated (*Canadian Jeweller*, 1994); and that the optical properties of the Koss filler are such that the color of the diamond is unaffected, any cracks disappear completely (with no bubbles trapped inside the filler), and rays of light travel through the diamond "with no distortion or deflection whatsoever" (1994 Koss promotional brochure).

Claims have also been made concerning the stability and durability of various products. For instance, recent product literature by Koss states that Koss clarity-enhanced diamonds withstand temperatures to 450°C, acid-based cleaning, and "ultrasound treatment." Controversy has also arisen in this area, with recent research findings by gemologist Sharon Wakefield of Boise, Idaho, indicating that the filling material used in at least one of the treatment processes (Koss) may decompose when exposed to a short-wave ultraviolet lamp or ultrasonic cleaning (Wakefield, 1993, 1994a; Even-Zohar, 1994b). It is also relevant to consider what Quam (1993) has referred to as the "longer historical perspective": that is, with the passage of time, the durability of the filling materials may prove to be less than had been believed initially. Some additional confusion—and controversy—about the identification and durability of filled diamonds may be a consequence of the claims and counterclaims made in the trade press by firms providing treatment services (see, e.g., Yehuda, 1993, 1994a,b; Koss, 1993, 1994a,b).

With the proliferation of filled diamonds in the market, concerns have been voiced at all levels of the industry. The topic of diamond treatments—and their proper disclosure—was a major focus of discussions during the biannual congress of the International Diamond Manufacturers Association (IDMA) and the World Federation of Diamond Bourses (WFDB) in Antwerp in June 1993 (Rapaport, 1993; Bates, 1993a; Shor, 1993). In late 1993, as the result of a vote taken by its board of directors, the Diamond Club West Coast in Los Angeles issued a statement asking all major grading labs not to grade filled diamonds ("Labs asked . . .," 1994; Shapiro, 1994). A similar resolution was passed by the combined leadership of the IDMA and WFDB in Antwerp in June 1994 ("Diamond leadership . . .," 1994). Also at this latter meeting, a resolution passed that prohibits the filling of rough or the selling of filled rough (Even-Zohar, 1994a). Concern about nomenclature relating to filled diamonds has been voiced by the Diamond Manufacturers and Importers Association, which has asked the trade to refer to them as "treated" rather than "enhanced" (Roisen, 1994; Bates, 1994a).

Fracture filling was also addressed at the annual meeting of the International Confederation of Jewellery, Silverware, Diamonds, Pearls and Stones (CIBJO) in April 1994, the main topic of discussions being treatment disclosure (Bates, 1994c; "Annual CIBJO Conference," 1994). Joel Windman (1994), executive vice president of the Jewelers' Vigilance Committee, has warned jewelers of their potential liability if they do not disclose to customers both that a diamond has been fracture filled and that, as such, there may be durability considerations beyond those of untreated diamonds. Some of the best-known U.S. retail chains—including Zale Corp., Sterling, Carlyle & Co., Karten's Jewelers, and Helzberg's—and at least one major jewelry manufacturer (Suberi Brothers) have notified their suppliers that they will not accept filled diamonds (Bates, 1994b; Beasley, 1994; Shor, 1994; "Manufacturer places burden . . .," 1994). Jack Gredinger, president of the Independent Jewelers Organization (IJO), has gone so far as to call the treatment "an infectious disease that undermines jewelry retailers and wholesalers. It's the single most serious and important problem our industry has faced in years" ("IJO takes stand . . .," 1994). IJO has asked its member suppliers not to sell fracture-filled diamonds (Shuster, 1994).

This concern about fracture filling became a public issue in the United States when an exposé televised locally in August and September 1993 accused two St. Louis jewelers of selling filled diamonds without disclosing the treatment to customers ("Five on Your Side . . .," 1993). The report was subsequently broadcast nationwide ("Prime Time Live . . .," 1993), and was even addressed by a member of the U.S. House of Representatives (Everhart, 1993b). The exposé affected jewelers who were not involved in the incident (Everhart, 1993b–d; Bates, 1993b). Such problems have not been confined to the U.S. market: Last year, isolated instances of filled diamonds being sold without proper disclosure were reported in a number of countries, including the United Kingdom (Levy, 1993; Shor, 1993/1994) and Australia (Kusko, 1993/1994).

The current article presents the results of research on recent production from three of the most prominent commercial sources: Yehuda, Koss, and Goldman Oved. (Note: For consistency and simplicity, in the following discussions we will refer to the filled diamonds from Yehuda/Diascience as "Yehuda-treated" [or just "Yehuda"] stones, to the Koss & Shechter/Genesis II product as "Koss-treated" [or "Koss"]; and to the Goldman Oved/Clarity Enhanced Diamond House product as "Goldman Oved–treated" [or "Goldman Oved"] diamonds.) We will examine the effectiveness of these treatments, and provide techniques for identifying them. Of particular interest are the results of testing the durability and stability of some treated stones. As will also be discussed, the GIA Gem Trade Laboratory is continuing its policy of not grading such treated diamonds.

MATERIALS AND METHODS

Samples. For our primary gemological investigation, we obtained 67 diamonds that had already been filled: 18 Yehuda-treated diamonds, ranging from 0.31 to 1.68 ct; 24 Koss-filled diamonds, ranging from 0.02 to 0.82 ct; and 25 Goldman Oved–treated diamonds, ranging from 0.18 to 1.91 ct. Some of these were purchased by GIA directly from the manufacturer; others were obtained through third parties directly from the manufacturer. We also examined 31 Goldman Oved–treated diamonds that were mounted in a tennis bracelet loaned to the authors by Goldman Oved (again, see figure 1). These mounted diamonds were all approximately 3.3 mm in diameter and were estimated by formula to weigh about 0.13 ct each.

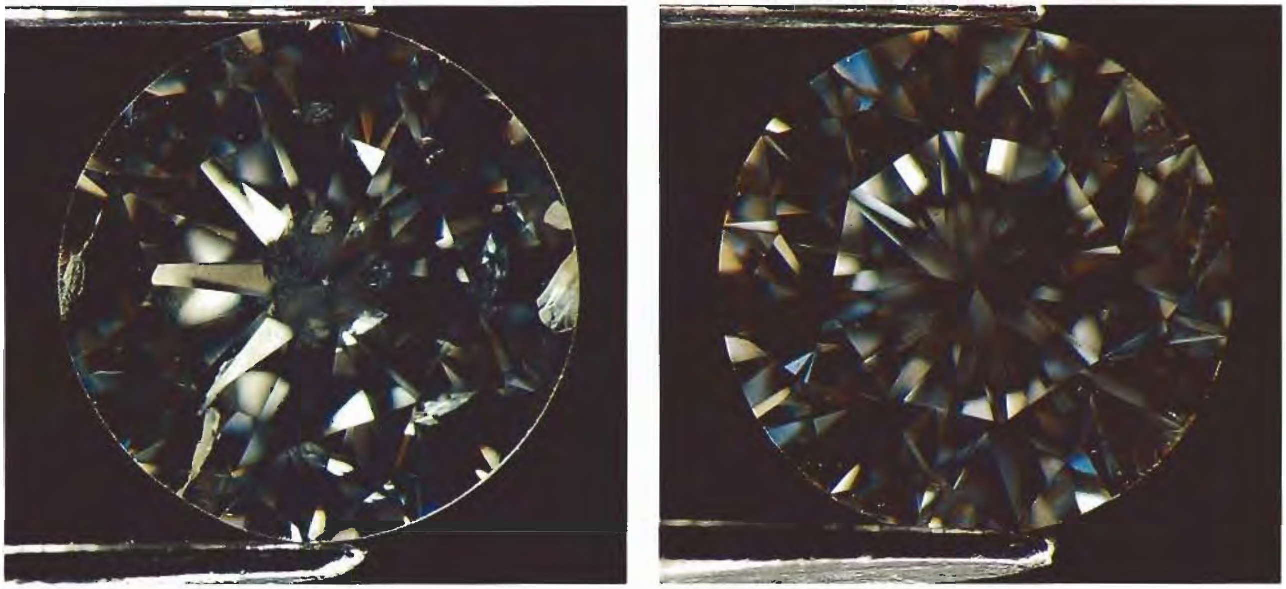


Figure 2. This 0.27-ct diamond (unfilled, left) was submitted to the Koss firm for treatment in 1992. It shows a noticeable improvement in appearance (right) after treatment. Photomicrographs by John I. Koivula.

X-radiography was performed on some of the same diamonds referred to above: three (0.32–0.40 ct) stones treated recently by the Yehuda firm, three Koss-filled diamonds (0.10–0.82 ct), and three Goldman Oved–treated diamonds (0.20–0.41 ct). EDXRF chemical analysis was performed on eight stones recently treated by Yehuda, five early Koss-treated stones, six commercially available Koss diamonds, and 11 Goldman Oved–treated diamonds.

In addition to the core 67 stones, we submitted five untreated diamonds (0.24–0.28 ct) in 1992—and nine (0.20–0.84 ct) in 1994 (see box A)—for treatment by Koss so that we might document them before and after filling, both photographically (figure 2) and for apparent color and clarity grades. The untreated stones were specifically chosen with fractures in certain orientations and positions. Six diamonds (0.20–0.41 ct) treated by the Goldman Oved process in 1994 were also photographed and "graded" for clarity and color before and after treatment (figure 3). All of these Goldman Oved stones were also examined in our primary gemological investigation.

We used selected treated diamonds for durability and stability testing. Three filled stones—a 0.31-ct Yehuda, a 0.29-ct Koss, and a 0.36-ct Goldman Oved—were subjected to steam cleaning. Ultrasonic cleaning was performed on 0.34-ct Yehuda, 0.29-ct Koss, and 0.32-ct Goldman Oved diamonds. Sizing and, subsequently, retipping were performed on mountings containing 0.37-ct Yehuda, 0.32-ct Koss, and 0.19-ct Goldman Oved diamonds. We subjected three filled diamonds (a 0.36-ct Yehuda, a 0.30-ct Koss, and a 0.36-ct Goldman Oved) to thermal testing in a furnace, and we had one treated diamond from each firm (a 0.37-ct Yehuda, a 0.45-ct Koss, and a 0.36-ct Goldman Oved) repolished. For ultraviolet testing, we selected two filled stones from each of the three firms: Yehuda (0.35 and 0.38 ct), Koss (0.29 and 0.30 ct), and Goldman Oved (0.29 and 0.38 ct). We exposed 0.32-ct Yehuda-, 0.32-ct Koss-, and 0.35-ct Goldman Oved–treated diamonds to daylight-equivalent illumination. Low-temperature testing was performed on 0.36-ct Yehuda-, 0.29-ct Koss-, and 0.20-ct Goldman Oved–filled diamonds. For durability and stability testing,we only used commercial stones obtained from the treaters directly or through third parties. We did not use any of the diamonds that were documented before and after filling.

Gemological Methods. A standard gemological microscope is sufficient to identify most fracture-filled diamonds. For this study, we performed microscopy using GemoLite Mark VII gemological microscopes with a 10×–63× magnification range, in conjunction with several illumination methods (separately and combined): darkfield, brightfield (direct transmitted), pinpoint fiber-optic, oblique overhead, and shadowing. With the exception of fluorescent oblique overhead lighting, all examinations used incandescent light sources. Where specific types of lighting are critical to the resolution of microscopic features, they are described in the appropriate portion of the "Microscopic Features" section below. Other standard gemological tests—for example, ultraviolet fluorescence and visible-light spectroscopy—were explored but found to be of no help in detecting the treatment.

Figure 3. This 0.30-ct diamond, which had highly visible breaks before fracture filling (left), showed significant improvement in apparent clarity—from I_3 to I_1—after treatment by Goldman Oved (right). Photomicrographs by Shane F. McClure.

Laboratory Methods. We used X-radiography and energy-dispersive X-ray fluorescence (EDXRF) chemical analysis, which require equipment usually found only in gem-testing laboratories, both to determine if these methods would reveal the presence of a filling and to learn more about the composition of the filling substances used.

Detection of filler by X-radiography depends on three factors: the thickness of the filler; the exposure geometry (we recommend X-raying diamonds in at least two mutually perpendicular orientations to increase the likelihood of positioning a filled fracture so that it can be detected); and experimental conditions such as film resolution, X-ray source intensity, and the like. For this study, X-radiography was performed using a Hewlett-Packard Faxitron unit with a tungsten anode and beryllium window, run at 30 to 60 kV and 2.5 mA. The distance from the X-ray tube window to the target was approximately 15 inches (38 cm). We used Fuji IX50 photographic film, with exposure times in air ranging from a few to about 30 seconds. In our experience, thin or subtle fillings are more likely to be seen on the developed film when lower energy conditions and longer exposure times are used.

For qualitative chemical analyses, we used a Tracor X-ray Spectrace 5000 EDXRF spectrometer, with operating conditions appropriate for the detection of heavy elements (35–40 keV, 0.35 mA, pumped vacuum, and 1.27-mm-thick rhodium filter). Light elements that might be constituents of the filler glass, such as boron and oxygen, cannot be detected by this method.

Durability Testing. The stones used in this phase of the investigation were obtained both directly and indirectly from all three treaters in 1994, to ensure that we tested the most current commercial products available. For these tests, we attempted to use equipment available to most jewelers. The mention of a particular brand of equipment here does not mean that other brands will not give comparable performance; nor should it be taken as an endorsement.

Steam Cleaning. We used two commercially available units: a Gesswein electric boiler and a Reimers model JR electric steam generator. The filled diamonds were first mounted in a four-prong head on a 14k gold solitaire ring and then subjected to cleaning at a distance of about one inch (2.5 cm) from the steam nozzle. Each diamond was directly exposed to steam for a total of 20 minutes at one-minute periods; all of the surfaces of each stone were exposed to the steam as they might be during a routine cleaning procedure. The intervals between steam exposures were just long enough for the steam pressure to build in the cleaning unit for the next exposure; pressure was maintained between 40 and 70 psi. We examined the diamonds visually—both with and without magnification—at five-minute intervals.

Ultrasonic Cleaning. We used a Gesswein Ultrasonic Cleaner model 87 containing BRC, a standard jewelry-cleaning solution. The unit was set at "high" and the heating element was turned on

BOX A: Fracture Filling Is an Evolving Field

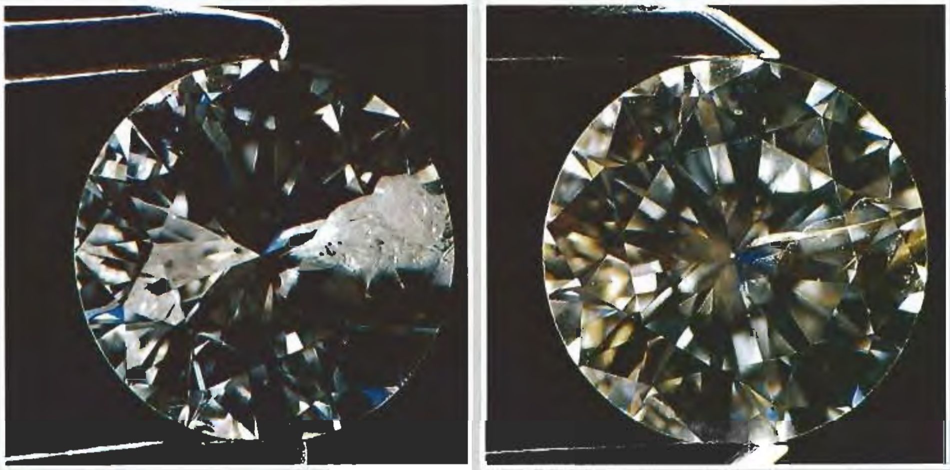
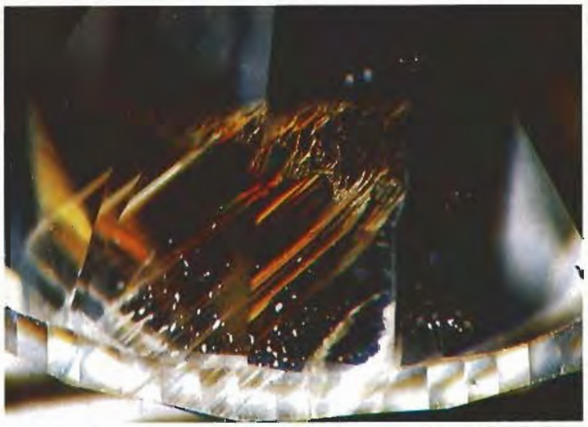


Figure A-1. Although the Koss firm considered the fractures in this diamond to be less than ideal for filling, the treatment was still quite effective in improving the stone's appearance, as can be seen in these photos of a 0.20-ct diamond before (left) and after (right) treatment. Photomicrographs by Shane F. McClure.

The stones that we examined in the body of this study may not be representative of all fracture-filled diamonds in the market now or in the future. The technology for fracture filling continues to evolve as producers try to improve their products.

So that the samples used for this study would reflect the most current technology, David Shechter of Koss & Shechter Diamonds attempted to treat additional diamonds for us in mid-1994, reportedly using two processes. One, based on halogen glasses, is the commercial process presently being used; the other, based on halogen-oxide glasses, is in an experimental stage (D. Shechter, pers. comm., 1994). Not all of the approximately 20 stones originally submitted for this phase of the project successfully took the treatment: For instance, five were returned by the firm untreated, with explanations that either (1) "the crack is too thick," or (2) "the fissure reaching the surface is broken" (D. Shechter, pers. comm., 1994; we interpreted the latter comment to mean that the surface-breaking entry point was a cavity rather than a narrow fracture). According to Mr. Shechter, his firm cannot get satisfactory results on diamonds with such features.

Figure A-2. Unlike the vast majority of the Koss-filled diamonds acquired for this study, this stone (submitted by the authors directly to Koss for treatment) displays orange and yellow flash colors in darkfield illumination. Photomicrograph by Shane F. McClure; magnified 29×.



Three round brilliants, ranging from 0.20 to 0.41 ct, were successfully filled by the first (halogen-based) process (figure A-1). Two other round brilliants (0.38 and 0.43 ct) were not filled successfully (i.e., completely) by this process but were included in the examination. As a group, these diamonds showed microscopic features that were inconsistent with those documented in Koss-filled stones purchased previously (including earlier in 1994) for the identification and durability-testing phases of this study.

The atypical features, as seen with magnification, are as follows: (1) *Flash effects:* Only orange and yellow were seen with darkfield illumination (figure A-2), and only blue and violet were seen with brightfield (figure A-3). (2) *Gas bubbles:* All of these stones exhibited gas bubbles which, unlike the other Koss-treated stones we examined, were relatively large and numerous. (3) *Flow structure:* Two of the five diamonds exhibited prominent flow structures in the filled breaks. (4) *Apparent color of filler:* A definite yellow cast was noted in some of the filled breaks. (5) *Crackled texture:* The fine, nearly parallel lines noted in the other Koss-treated diamonds were absent in this group of stones. In fact, as a group, the internal features in these diamonds were more reminiscent of those documented in early Yehuda-treated diamonds than those we have seen in other Koss-filled diamonds. However, EDXRF analysis revealed that all these stones, even the unsuccessfully (partially) filled ones, contain Pb and Br (i.e., unlike Yehuda-filled diamonds; refer to box C).

Four round brilliants (0.23 to 0.44 ct) were pro-

Figure A-3. Also unlike most other Koss-filled diamonds examined as part of this study, the brightfield flash colors in this group of stones (which were sent directly to Koss for treatment) were blue and violet. Photomicrograph by Shane F. McClure; magnified 33×.

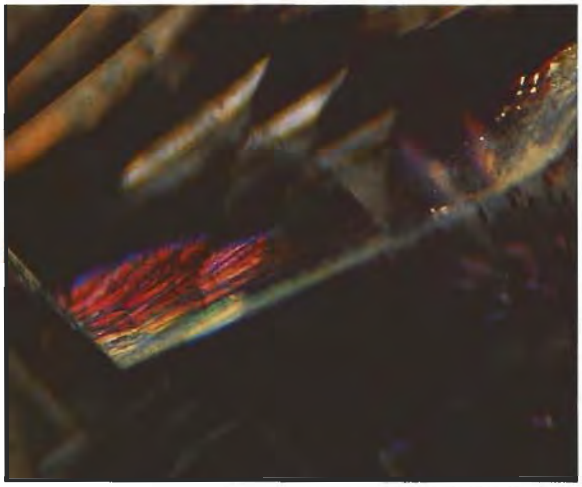


Figure A-4. The authors had not seen red flash effects in filled diamonds until they examined stones treated by S&I Diamond Drilling, as shown here. Photomicrograph by Shane F. McClure; magnified 30×.

cessed using the second (experimental) technique, but Mr. Shechter did not consider any of these to be filled successfully. Of these stones, the ones displaying any evidence of filled breaks had microscopic features consistent with those in the group described above. These also showed traces of Pb and Br in their EDXRF spectra.

Recently, it was reported in the trade press that the Koss firm was experimenting with additives to make the filling easier to detect by causing it to fluoresce yellow to ultraviolet radiation ("Koss to make fill more visible," 1994). However, no such fluorescent reaction—to either long- or short-wave UV—was noted in any of the Koss-treated diamonds, including the nine stones reported in this section. Even using cathodoluminescence, we detected no reaction from any of the filled diamonds.

TABLE A-1. Apparent color and clarity of nine round brilliant-cut diamonds before and after filling by Koss & Shechter Diamonds using two processes.[a]

Sample no.	Measurements (mm)	Weight (ct)	Before		After	
			Color	Clarity	Color	Clarity
Method 1						
1–1	4.84–4.89 x 2.90	0.41	**G**	**I$_3$**	**H**	**I$_2$**
1–2	4.65–4.69 x 2.90	0.41	**E**	I$_3$	**F**	I$_3$
1–3	3.78–3.81 x 2.26	0.20	**F**	**I$_3$**	**G**	**I$_2$**
1–4[b]	4.41–4.49 x 2.93	0.38	H	I$_2$	H	I$_2$
1–5[b]	4.57–4.63 x 2.97	0.43	G	I$_2$	G	I$_2$
Method 2						
2–1	3.97–4.00 x 2.45	0.23	F	I$_3$	F	I$_3$
2–2	4.06–4.10 x 2.44	0.25	D	I$_2$	D	I$_2$
2–3	4.72–4.81 x 2.94	0.44	**M**	**I$_3$**	**N**	**I$_2$**
2–4	4.79–4.87 x 2.62	0.37	E	I$_1$	E	I$_1$

[a] *All stones were graded independently at the GIA Gem Trade Laboratory (GIA GTL) for research purposes only. The GIA GTL does not offer this service for filled diamonds. Boldface type indicates where a grade had changed after filling.*

[b] *Not successful (according to manufacturer).*

To test the effectiveness of these treatments, we graded these nine stones before and after treatment, with results shown in table A-1. As can be seen from the table, these treatments improved the apparent clarity by one grade in three of the diamonds. However, they also *lowered* the apparent color by one grade in four of the nine stones, including all where treatment was considered "successful."

To get a better idea of what happens when the treatment is not successful, and to obtain some preliminary data on another treater's product, we selected eight diamonds that had been rejected as unsuitable by various diamond treaters. These were processed by Ivan Perlman of S&I Diamond Drilling, who provides diamond drilling and treatment services exclusively to the trade. These diamonds, ranging from 0.30 to 0.52 ct, were photographed and graded for clarity and color before and after treatment.

Although none of these diamonds was successfully (i.e., completely) fracture filled, we were able to document some of the features of stones treated by this process. The one relevant microscopic feature after treatment was a flash effect. In darkfield, all but one of the stones showed one or more of the following colors: orange, pink, yellow, blue, purple and red (figure A-4), with orange and pink being the most prevalent. In brightfield, the flash colors noted were blue-green, green, and greenish yellow. It should be noted that this was the first time we saw a red flash effect in a filled diamond from any treater.

(in the course of testing, the temperature ranged from 24°C [76°F] when turned on to a maximum of 60°C [140°F]). As with steam cleaning, the diamonds to be tested were first mounted in four-prong solitaire heads on 14k gold rings. The rings were hung by their shanks from a wire hook so that they were submerged in the cleaning solution. The stones were examined first after a five-minute cleaning, then after 30 minutes of cumulative cleaning, and then at additional 30-minute intervals for a total of three hours of ultrasonic cleaning.

Thermal Exposure. In our previous study of Yehuda-treated diamonds (Koivula et al., 1989), we retipped the four prongs on a ring set with a filled diamond. This common repair procedure exposed the filled stone to the direct heat of a jeweler's torch. For the present study, we again performed a retipping experiment. A MECO Midget torch with no. 40 tip was used with natural gas and oxygen. Each diamond was mounted in a 14k gold ring with a four-prong solitaire head; care was taken to avoid placing any prong directly over filling entry points. For each ring, both the diamond and the setting were firecoated with a denatured alcohol/boric acid slurry and two prongs were retipped, using 14k white gold soft solder with a flow point of approximately 740°C. After the two prongs on each ring were retipped, we examined the stones visually and with magnification to note any damage to the fillers. We then had the remaining two prongs on each retipped, with 14k white gold hard solder with a flow point of approximately 800°C, and we reexamined the fillings for damage.

We also tested the upper stability limit of the filling materials themselves. The three samples were set in a refractory boat, which was placed in the hot spot of a Blue M model M10A-1A Lab Heat Furnace during heating steps. We monitored temperatures with a Chromel-Alumel thermocouple. For the test, the temperature was set approximately 50°C below the desired temperature, the diamonds were placed in the furnace, and the temperature was raised the final 50°C. This process took about 30 minutes, after which we removed the stones and allowed them to cool on a refractory block before visual examination. When we saw no appreciable damage to the filler, we repeated the procedure, increasing the target temperature for each subsequent test. Initial testing was at 118°C, with subsequent testing at 240°, 340°, 390°, 455°, 480°, 525°, and 600°C.

Not all jewelry repair procedures require the direct application of heat to mounted stones. Therefore, to test the effect of indirect heating, we had a filled diamond from each of the three treaters mounted in a four-prong head on a 14k gold solitaire ring and then had each ring resized larger by one size.

First, for the sample from each firm, experimental conditions reproduced a scenario in which the jeweler knows that the diamond is filled and therefore exercises special care to keep the stone cool. This was done by first firecoating the diamond and mounting with the alcohol–boric acid slurry. The diamond and prong setting were then wrapped with strips of wet paper and the ring was sized. (Alternative procedures for protecting sensitive stones during jewelry repair include coating with commercially available gel-like insulating substances such as "Heat Shield" and "Cool Jewel," or keeping the stone immersed in water during the heating phases.)

In the second scenario, the jeweler either does not know that the diamond is filled or does not know that special care may be required in sizing a ring set with a treated stone. In this test, therefore, the sizing was performed with a firecoating but with no special effort made to keep the diamond from being heated. Because we did not note any damage from the first resizing experiment, we reused the same mounted stones for this test.

Repolishing. Past reports (e.g., Koivula et al., 1989; Crowningshield, 1992) have documented how the heat generated during repolishing of a diamond can damage the filling material. To investigate this further, we submitted one filled diamond (with one or more filled fractures breaking the table surface) from each of the three firms to a Los Angeles diamond manufacturer for repolishing of the table facet.

Daylight Equivalency Testing. We used an Oriel model 81150, 300-watt solar simulator to produce daylight-equivalent illumination. A xenon light source combined with a series of lenses and filters creates an output emission that approximates the daylight spectrum at 1.7× its intensity (Oriel Corp., 1982). We allowed the lamp to warm up for 30 minutes, after which we exposed each unmounted diamond, placed face up on a white refractory tile, to the light source for the specified period of time. Periodically, we removed each sample from the simulator, examined it visually and microscopically for any damage to the filler, and then returned it to the simulator for further exposure. Time intervals (cumulative) were 20 minutes and one, three, 10, 30, 60, 100, and 200 hours, corresponding to 34 minutes, 100 minutes, and five, 17, 51, 100, 170, and 340 hours of sunlight, respectively. We monitored the light intensity throughout the exposure period, using an Oriel model 81020 solar-simulator radiometer.

Exposure to Ultraviolet Radiation. We used the long-wave radiation source of a GIA GEM Instruments long-wave/short-wave unit, in conjunction with a GIA GEM ultraviolet viewing cabinet. With a median wavelength of 365.4 nm, long-wave UV radiation is not only a component of sunlight but is also the radiation source used in so-called "UV-A" tanning booths (the latter also presenting a scenario for exposure of a filled diamond to long-wave UV). After the lamp had warmed up for five minutes, we exposed each unmounted diamond to the long-wave UV source for the specified period of time, with the fracture facing the source of the radiation. Samples were periodically removed from the viewing cabinet, examined visually and microscopically for any damage to the filler, and then returned for further exposure. Time intervals (cumulative) were 20 minutes, and one, three, 10, 30, 60, 100, and 200 hours for three stones (three others were examined after a single 100-hour exposure). These exposures correspond to almost six, 17, 50, 170, 500, 1,000, 1,700, and 3,400 hours exposure to daylight.[2] We confirmed that short-wave ultraviolet light was effectively filtered out by observing a short-wave-fluorescing material (scheelite) after each exposure.

Low-Temperature Testing. We performed low-temperature testing first by simulating the type of cooling and warming that might occur when filled-diamond jewelry was worn in a cold climate, going from heated buildings to the outdoors and back. The test stones were placed in a cold corner of the freezer compartment of a standard frost-free refrigerator for 30-minute intervals. At the end of each cooling period—there were a total of 15 cooling sessions for each filled diamond—we removed the diamonds from the freezer and allowed them to warm to room temperature, at which point we examined them visually and with a microscope.

In the second low-temperature testing procedure, we exposed the same unmounted filled diamonds to the type of rapid cooling—to approximately −71°C (−96°F)—to which they would be exposed when sprayed with a refrigerant prior to examination with a desk-model spectroscope, a procedure available to many jeweler-gemologists. We placed each stone on the stage of a desk-model spectroscope and subjected it to the pressurized refrigerant chlorodifluoromethane (Chemtronics brand "Freez-It") for approximately five seconds. We then allowed the diamond to warm to room temperature and examined it with the unaided eye and the microscope. We repeated this routine five times for each diamond.

EFFECTIVENESS OF THE FILLING TREATMENTS

The effectiveness of the Yehuda filling process in improving the apparent clarity of diamonds has been well documented (see, e.g., Koivula et al., 1989; Koivula and Kammerling, 1990). In summary, the Yehuda process can drastically reduce the eye visibility of treatable features. However, because filled breaks may still be seen with magnification, the improvement in apparent clarity is only about one grade, and never more than two grades (table 1). In addition, some of the diamonds exhibited a drop in apparent color grade after treatment due to the inherent color of the filling material.

The Koss filling procedure is also very effective in improving the faceup appearance of diamonds (again, see figure 2). Despite this, only two of five stones submitted directly to Koss in 1992 by GIA researchers for "before-and-after" comparison showed sufficient improvement to warrant a higher apparent clarity grade (again, see table 1). However, examination of all five stones by X-ray fluorescence spectroscopy revealed lead (Pb) but not bromine (Br) in the filler, unlike the Koss-treated stones obtained by third parties for characterization of diagnostic features and durability testing. Consequently, we do not believe that any of the stones GIA submitted

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[2] *The light intensity (in watts/cm^2) was estimated as follows: The source was a 4-watt mercury (Hg) arc lamp, with a special fluorescing screen to convert short-wave to long-wave UV radiation. Assuming 50% efficiency in the conversion from power in to Hg light out, 50% efficiency in the conversion from Hg light to long-wave UV radiation, and 33% efficiency due to geometric effects (i.e., one-third of the light is sent through the window and not absorbed on other surfaces within the lamp housing), then one-third watt is delivered through a 4.7 × 7.0 cm window, for an integrated flux of 10 mw/cm^2. Average sunlight has a total irradiance of about 0.6 mw/cm^2 at wavelengths below 365 nm (data integrated from Oriel Corp., 1982), so our long-wave UV source is about 17 times as powerful as sunlight in this spectral region.*

TABLE 1. Apparent color and clarity of sample round brilliant-cut diamonds before and after filling by Yehuda, Koss, or Goldman Oved.[a]

Sample no.	Measurements (mm)	Weight (ct)	Before		After	
			Color	Clarity	Color	Clarity
Yehuda[b]						
1	6.21–6.28 x 3.72	0.92	**L**	**Below** $\mathbf{I_3}$	**M**	$\mathbf{I_3}$
2	3.76–3.81 x 2.43	0.22	K	I_1	K	I_1
3	6.21–6.28 x 3.74	0.90	**K**	I_3	**L**	I_3
4	5.24–5.31 x 3.09	0.51	I	$\mathbf{SI_1}$	I	$\mathbf{VS_2}$
5	4.22–4.28 x 2.34	0.25	**E**	$\mathbf{I_1}$	**F**	$\mathbf{SI_2}$
6	4.06–4.18 x 2.39	0.25	**I**	I_1	**J**	I_1
Koss[c]						
1	4.05–4.12 x 2.60	0.28	J	$\mathbf{I_1}$	J	$\mathbf{SI_2}$
2	4.17–4.24 x 2.56	0.28	J	$\mathbf{I_1}$	J	$\mathbf{SI_2}$
3	4.13–4.18 x 2.61	0.27	F	I_2	F	I_2
4	3.95–4.00 x 2.57	0.26	**H**	I_1	**H/I**	I_1
5	4.09–4.14 x 2.37	0.24	M	I_1	M	I_1
Goldman Oved						
1	3.88–3.91 x 2.30	0.20	F	$\mathbf{I_3}$	F	$\mathbf{I_1}$
2	4.79–4.83 x 2.95	0.41	E	$\mathbf{I_3}$	E	$\mathbf{I_2}$
3	4.24–4.27 x 2.61	0.30	F	$\mathbf{I_3}$	F	$\mathbf{I_1}$
4	4.32–4.37 x 2.63	0.30	F	$\mathbf{I_2}$	F	$\mathbf{I_1}$
5	4.48–4.55 x 2.75	0.35	L	$\mathbf{I_2}$	L	$\mathbf{I_1}$
6	4.55–4.61 x 2.80	0.36	E	$\mathbf{I_2}$	E	$\mathbf{I_1}$

[a] *All stones were graded independently at the GIA Gem Trade Laboratory (GIA GTL) for research purposes only. The GIA GTL does not offer this service for filled diamonds. Boldface type indicates where a grade had changed after filling.*

[b] *Original material manufactured by Yehuda; these results are from Koivula et al. (1989). In a later study of 34 Yehuda-filled diamonds (Koivula and Kammerling, 1990), four showed no change in color or clarity grade; 11 lost one grade in color without improving in clarity grade; and one lost two grades in color without improving in clarity grade. Eight stones that improved by one clarity grade dropped by one color grade; and one dropped by two color grades. Nine stones (believed to be more representative of the current Yehuda production) improved in apparent clarity by one grade (eight stones) or by two grades (one stone) without changing their apparent color grades.*

[c] *These stones were apparently not typical commercial products; see text.*

directly to Koss for filling treatment are the typical Koss product.

Examination of the Goldman Oved–treated "before-and-after" samples demonstrated that this treatment is also very effective in reducing the eye-visibility of surface-reaching breaks. In all cases, the filling improved the apparent clarity by one or two grades (again, see figure 3). Furthermore, in no instance did we note a drop in the apparent color grade of the stones as a result of filling. The results of this phase of the investigation are also shown in table 1.

MICROSCOPIC FEATURES OF FRACTURE-FILLED DIAMONDS

In all stones examined during the current study, the fact that the diamond had been fracture filled could be determined by careful microscopic examination. The key features are described below. It is important to note that not all of the features described will be found in every stone. However, at least one of the features was detected in each stone tested.

Flash Effects. In the first Yehuda-treated stones we examined (Koivula et al., 1989), we noted a yellowish orange flash-effect color, in darkfield illumination, that changed to an "electric" blue when the stone was rocked so that the background became bright due to secondary reflection. During subsequent research, we observed a second pair of flash-effect colors in Yehuda-treated diamonds: a vivid pinkish purple seen in darkfield that became a bright yellowish green against a brightfield, secondary-reflection effect (Koivula and Kammerling, 1990).

In the most recent group of Yehuda stones examined, the colors noted in darkfield ranged from violet to purple to pink, with some filled breaks showing, for example, violet in one area and pink in another at a single angle of observation (figure 4). In brightfield, the flash-effect colors—again, often more than one from a single viewing angle—ranged from a vivid bluish green to greenish yellow (figure 5). In both brightfield and darkfield, we observed a flash-color change in all or part of the filled break when we rocked the stone back and forth very slightly. The color flashes in these more recent

Figure 4. Many of the recent Yehuda-treated diamonds display more than one vivid flash-effect color at a single viewing angle. The most predominant colors seen with darkfield illumination in recently treated stones are pink, violet, and purple. Photomicrograph by Shane F. McClure; magnified 28×.

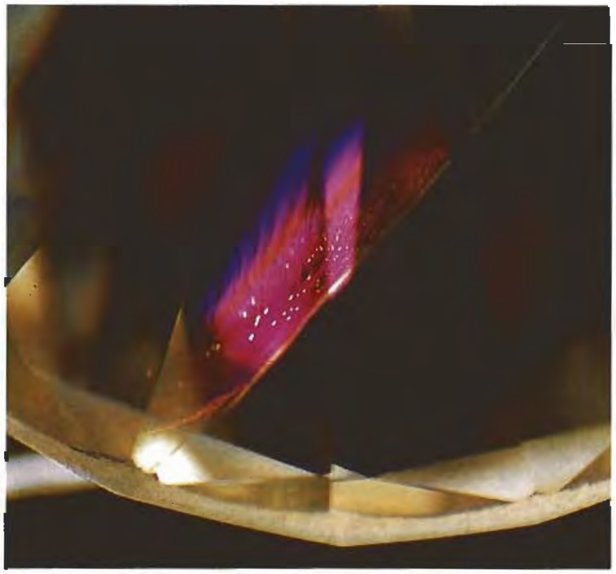
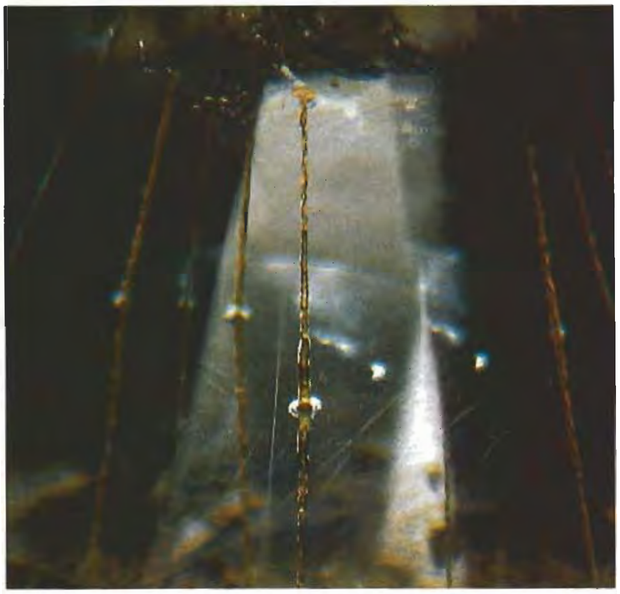


Figure 5. Brightfield flash-effect colors in the newest generation of Yehuda-treated diamonds range from bluish green to greenish yellow. Photomicrograph by Shane F. McClure; magnified 28×.

Figure 7. Koss-filled diamonds may also exhibit multicolored flash effects at a single viewing angle. Here (in darkfield illumination) we see pink, purple, and the less common desaturated slightly pinkish orange. The flash colors in the Koss stones we examined were usually less vivid than those seen in the Yehuda products. Photomicrograph by Shane F. McClure; magnified 40×.

Yehuda-treated diamonds were equal to or greater in intensity than color flashes seen in the earliest Yehuda-treated stones. We also noted for the first time some flash effects associated with filled laser drill holes (figure 6).

Figure 6. For the first time, and only in diamonds treated recently by the Yehuda process, the authors saw flash effects along laser drill holes. Note the subtle orange and blue flash colors here. Photomicrograph by Shane F. McClure; magnified 40×.



We saw flash effects in all of the Koss-treated diamonds we examined. Most prevalent were a vivid pink and an equally saturated purple noted in darkfield illumination. As with the newer Yehuda-treated stones, at some viewing angles we could often see both pink and purple flashes in different parts of a single filled break; less frequently, we also noted a less saturated, slightly pinkish orange flash (figure 7). In a very few stones, we observed yellow and violet flash effects against dark backgrounds. In brightfield illumination, the most prevalent flash colors were bluish green and yellow (figure 8)—often at the same time in different portions of a filled break—although in some instances the color was a "pure" green. In general, the flash colors noted in Koss-treated stones were less intense than those seen in Yehuda-treated diamonds. However, in all cases—including stones as small as 0.02 ct—they could be detected using the standard gemological microscope's base-illumination (darkfield/brightfield) system.

Flash effects were also noted in all of the Goldman Oved–treated diamonds. Predominant colors in darkfield illumination were violet, purple, and pink. Less frequently, we saw a blue and (rarely) a green flash effect. When only one color was noted in darkfield, it was violet. Typically, however, we saw two or more colors at one time, the most common combination being violet and purple (figure 9).

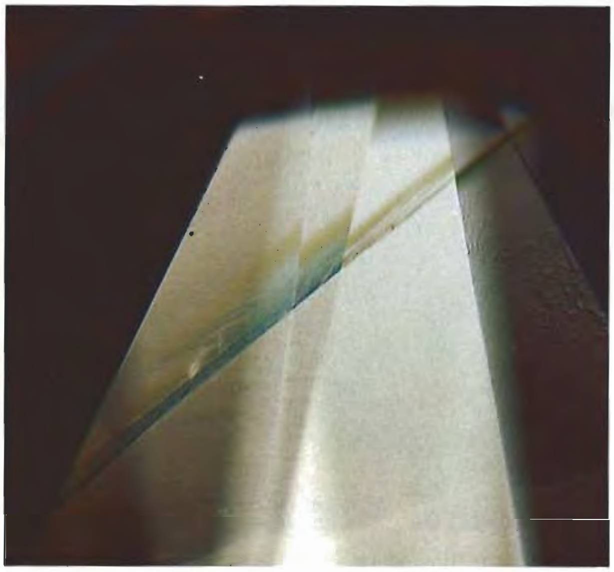


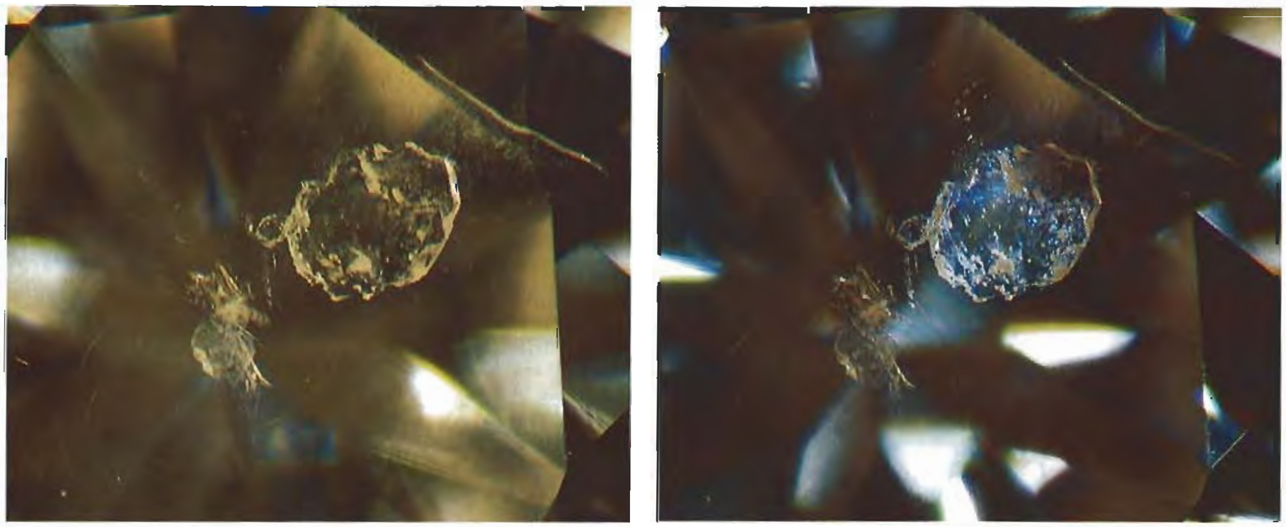
Figure 8. Flash colors noted in Koss-filled diamonds with brightfield illumination were typically bluish green and yellow—similar in hue to those seen in the Yehuda stones, but less saturated. Photomicrograph by Shane F. McClure; magnified 40×.

Figure 9. The most common darkfield flash colors seen in Goldman Oved–treated diamonds were violet, purple, and pink. Photomicrograph by Shane F. McClure; magnified 31×.

In brightfield illumination, we noted green, yellow, and, less frequently, bluish green. In some filled breaks, only one of the colors was seen; in others, more than one could be detected at a single angle of observation, similar in hue and saturation to those seen in the Koss-treated stones. In general, of the three products, the Goldman Oved–treated stones had the most subtle flash effects. Although standard darkfield/brightfield illumination was sufficient to see flash effects in all of the loose Goldman Oved–treated diamonds, we could detect this feature only with intense fiber-optic illumination in some of the mounted stones (figure 10).

In general, mounted stones may prove a great challenge to the gemologist trying to detect flash effects. Mountings limit both the directions in which the stone can be viewed and the amount of light that reaches internal features. Fiber-optic lighting, along with careful microscopic examination, may be essential in these instances (figure 11; see also, "Techniques to Identify Fracture Filling"

Figure 10. This mounted Goldman Oved–treated diamond showed no evidence of a flash effect in darkfield illumination (left). With oblique lighting from an intense fiber-optic light source, however, the flash effect becomes clearly visible (right). Photomicrographs by Shane F. McClure; magnified 40×.



below). For more on the optics of the flash colors, please refer to box B.

Flow Structure. A filled break may look as if a glassy substance has flowed into it, an appearance unlike anything seen in unfilled breaks. This feature was very subtle or absent in the most recent group of Yehuda-treated stones and in the Koss-treated diamonds. However, it was very subtle to fairly prominent in several of the Goldman Oved–treated diamonds (figure 12). Often, this feature can be detected only with intense fiber-optic illumination.

Trapped Bubbles. Although these voids in the filling substance (i.e., areas of incomplete filling) can be fairly large and noticeably flat, they are typically small and may occur in groups in an overall fingerprint-like pattern. Such trapped bubbles have been noted in all "generations" of Yehuda-treated stones examined by the authors.

In one stone in the most recent group of Yehuda-treated stones, we saw three-dimensional two-phase inclusions in an area of diamond intergrowth that was traversed by a filled fracture (figure 13). We believe these inclusions to be voids (such as negative crystals) that have been partially filled.

We saw at least some gas bubbles in all of the Koss-treated diamonds, although often these were extremely small and were detected only with high magnification and supplemental lighting (figure 14). Some filled breaks contained larger, flattened bubbles. In no instance did we see any of the complex,

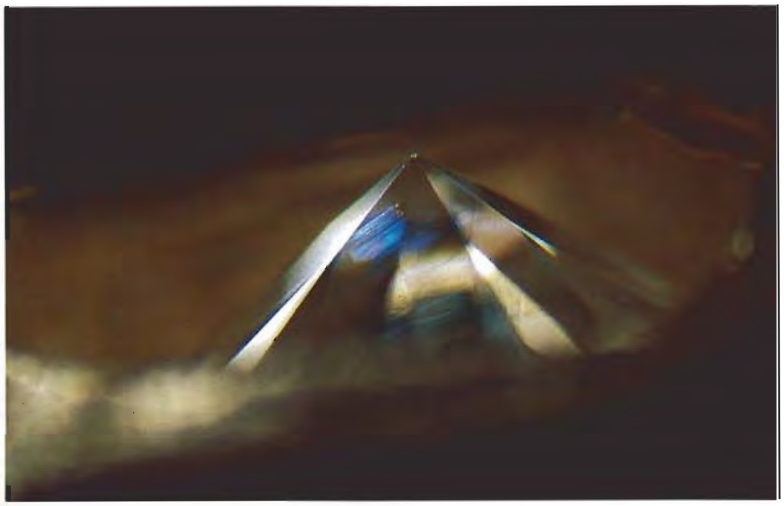


Figure 11. Only with a thorough examination under magnification, in conjunction with fiber-optic illumination, could we detect this flash effect in a filled fracture near the culet of a bezel-set Goldman Oved–treated diamond in the strip bracelet shown in figure 1. Photomicrograph by Shane F. McClure; magnified 40×.

Figure 12. A fine, transparent flow structure was detected in several of the Goldman Oved–filled diamonds examined for this study. Photomicrograph by Shane F. McClure; magnified 40×.

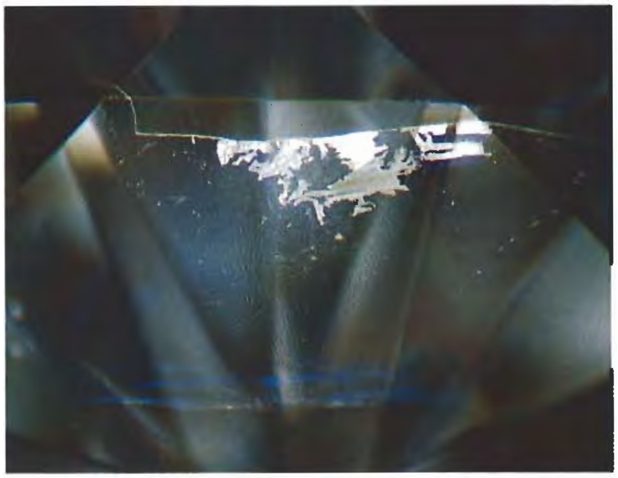
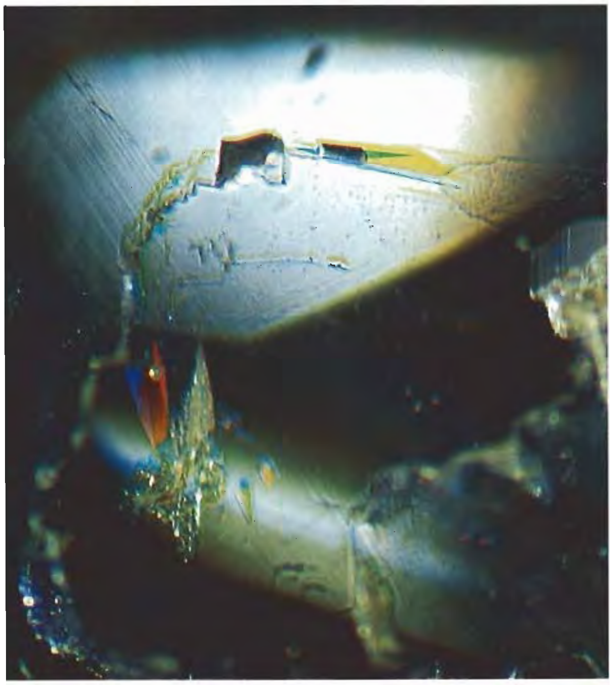


Figure 13. These two-phase inclusions exhibiting multicolored flash effects were seen in one of the Yehuda-treated diamonds. Note the appearance of opposing flash colors—such as blue and orange—at the same viewing angle. This may be due to angled crystal faces inside the partially filled internal void. Photomicrograph by Shane F. McClure; magnified 40×.



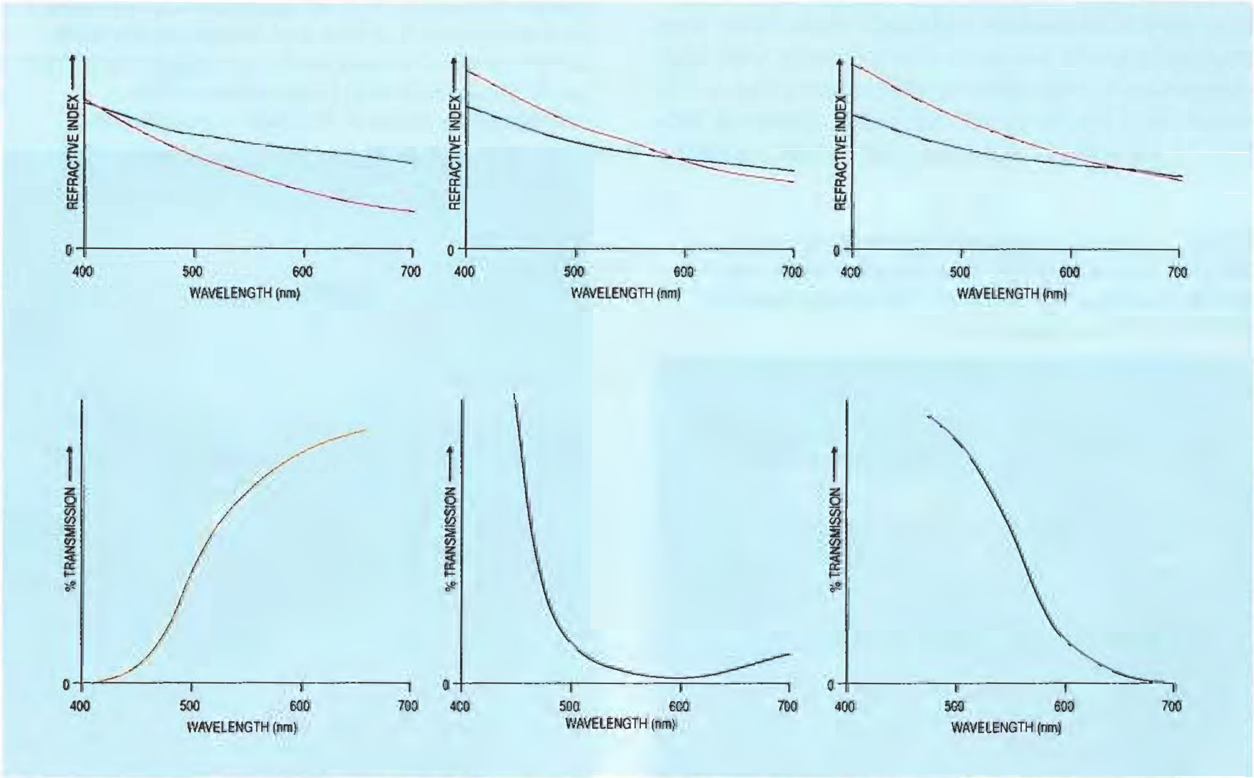
BOX B: The Optics of the Flash Effect

The first "flash effect" colors documented in Yehuda-filled diamonds were blue (when the background was bright) and orange (when the background was dark). Other flash effects were subsequently observed in products from this firm: yellow-green against a bright background and predominantly purple against a dark background (Koivula and Kammerling, 1990; Crowningshield, 1993). Other darkfield colors seen to date are: saturated pink, saturated purple, and less-saturated, slightly pinkish orange (Koss); and violet, purple, pink, "pure" blue, and green (Goldman Oved). Brightfield colors we have documented are: bluish green, yellow, and "pure" green (Koss); and green and yellow (Goldman Oved).

Initially, it was thought that the orange/blue flash colors were an interference effect, like the colors seen in natural iridescent fractures (Koivula et al., 1989); however, flash colors are more saturated and restricted in hue than interference colors, and the colors do not shift with polarization. Nelson (1993) stated that, because of these differences, the flash color cannot be due to an interference mechanism. He suggested that the flash colors are instead due to the difference in dispersion between diamond and the fracture-filling material. *Dispersion* occurs when refractive indices differ for different wavelengths of light (see examples in figure B-1). Dispersion is mathematically defined as the difference between R.I.'s for one substance (and one direction of light) between 486.1 nm (in the blue-violet) and 656.3 nm (in the red; Bloss, 1961). The value of dispersion for diamond, for example, is 0.044. A dispersion curve represents the variation of R.I. with wavelength.

In general, liquids and glasses have higher dispersions than do solids with the same R.I. Dispersion can be used to determine accurately the R.I. of a solid (the method of "colored Becke lines"); this technique was developed by Christiansen (1884, 1885) and can

Figure B-1. If a solid and liquid have the same R.I. at a wavelength in the violet region (left, top), only non-violet light is reflected (left, bottom), resulting in yellow darkfield flash colors; if they have the same R.I. in the red (right, top), non-red light is reflected (right, bottom), resulting in blue darkfield flash colors; if they have the same R.I. in the middle of the visible spectrum (center, top), darkfield flash colors are blue, or red, or purple, as other colors are not reflected (center, bottom). Figure adapted from Dodge, 1948, figure 2, p. 543.



be found in many textbooks on optical microscopy (see, e.g., Bloss, 1961). The darkfield color immersion method developed by Dodge (1948) is a variation on Christiansen's technique that provides another possible explanation for fracture-filling colors. Consider a colorless solid surrounded by a liquid with higher dispersion, but a similar refractive index (measured at the sodium D line, 589.3 nm). According to Dodge, differential refraction of light crossing liquid-solid interfaces produces spectral colors in brightfield illumination, and more intense "subtractive" colors in darkfield illumination. (That is, the spectrum of a darkfield color should equal the spectrum of the light source minus the spectrum of the brightfield flash.) Examples of pairs of dispersion curves and darkfield-color (subtractive) spectra are illustrated in figure B-1 for three cases: when the R.I.s for the stone ("solid") and filler ("liquid") match in the violet region of the spectrum (yellow darkfield flash color); in the yellow region (red, blue, or purple darkfield flash colors); and in the red region (blue darkfield flash color). Dodge comments that this mechanism also works when the dispersion of the liquid is less than that of the solid; that is, a fracture filling with a dispersion greater than that of diamond is not necessary.

The wavelength at which R.I.'s match for a solid and a liquid appears to be preferentially transmitted. Thus, Nelson (1993) found that the filling material for Yehuda-filled diamonds (with yellow-green brightfield/purple darkfield flash colors) has the same R.I. as diamond (2.421) at 560 nm (yellowish green). Also, according to Dodge, the *greater* the difference in dispersion between a liquid and a solid, the *brighter* the colors appear. Given that the Yehuda flash colors are the brightest and the Goldman Oved flash colors are in general the least obvious, the absolute difference between dispersions of filler and diamond is probably lowest for Goldman Oved, intermediate for Koss, and highest for (new) Yehuda.

Also, if darkfield colors are "subtractive" in nature, then as the color of the light source changes, the darkfield flash colors should change in the same direction. To test this, we handed a fracture-filled (Yehuda) diamond with eye-visible flash color to an experienced diamond color grader, who found that the flash color shifts from purple to violet (that is, from more red to more blue) as the illuminant color temperature changes from 3000 to 6500K (from light richer in radiation in the red region of the spectrum to light richer in blue and UV radiation).

In summary, according to this model, brightfield colors are restricted to spectral hues (i.e., red, orange, yellow. . . violet) and darkfield colors are the result of subtracting these hues from the color of the light source.

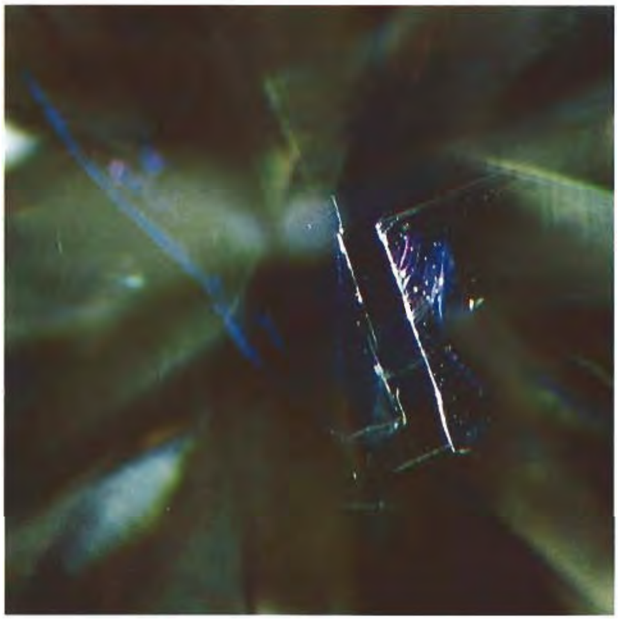
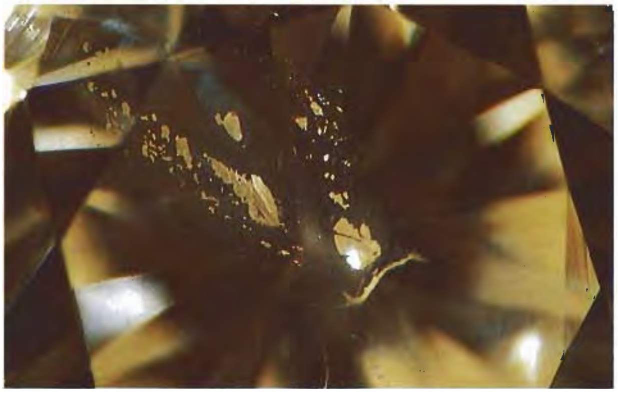


Figure 14. Many of the gas bubbles seen in Koss-treated diamonds are so small they look like pinpoints and can be detected only with fiber-optic illumination. Photomicrograph by Shane F. McClure; magnified 40×.

fingerprint-like patterns of bubbles noted in some of the earlier Yehuda-treated stones (Koivula et al., 1989).

We also saw bubbles in virtually all of the Goldman Oved–filled diamonds. In some instances, they were very few and extremely small, appearing essentially as bright, pinpoint inclusions. In other instances, they were relatively large and easily resolved as gas bubbles at fairly low magnification (figure 15).

Figure 15. Some of the Goldman Oved–treated diamonds displayed relatively large gas bubbles in their fillings. Photomicrograph by Shane F. McClure; magnified 33×.



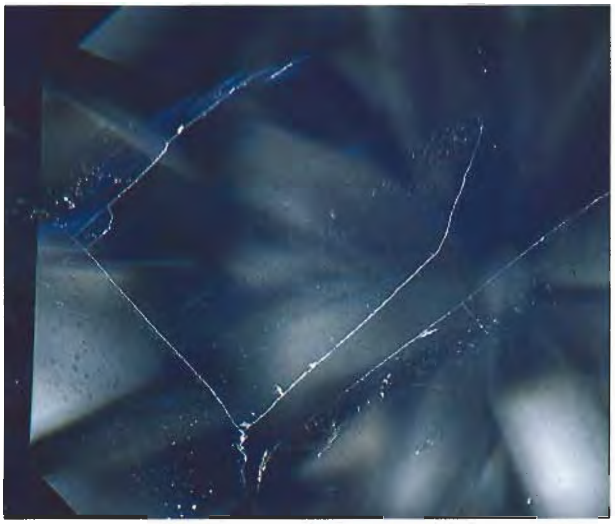


Figure 16. Areas of incomplete filling at the surface, which usually resembled fine white scratches, were present in most of the filled stones (here, by Goldman Oved) examined for this study. Photomicrograph by Shane F. McClure; magnified 38×.

Figure 17. A crackled texture was noted in some of the thicker areas of filling in Yehuda-treated diamonds. Photomicrograph by Shane F. McClure; magnified 40×.

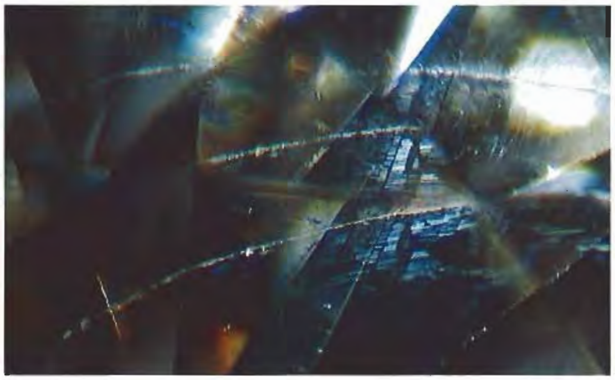


Figure 18. Extremely fine, nearly parallel whitish lines—possibly minute fractures within the filling material—were visible in some of the Koss-filled diamonds with fiber-optic illumination. Photomicrograph by Shane F. McClure; magnified 40×.

Incomplete Filling at Surface. In most of the Yehuda-filled breaks, we also noted extremely shallow areas of incomplete filling at the surface of the stone. In many instances, these had the appearance in darkfield illumination of fine white scratches. This feature may be the result of removal of a very small amount of the filler during a cleaning step performed by the manufacturer after treatment. Similar features were noted in virtually all of the Goldman Oved–treated diamonds we examined (figure 16). They were seen least frequently in the Koss stones, along the surface entry points of many of the filled fractures.

Crackled Texture. We detected cracks in the filling material, often with a web-like texture, in the thickest filled fractures of the more recent Yehuda-treated stones (figure 17), just as we had for previous Yehuda products. We also noted crackled areas in filler within laser drill holes.

We did not detect crackled texturing in any of the Koss-filled stones. However, this feature has been seen only in relatively thick filled areas, and the Koss firm reports that diamonds with wide breaks are unsuitable for filling treatment (D. Shechter, pers. comm., 1994). What we did note in some Koss-filled breaks were extremely fine, nearly parallel whitish lines that may be minute fractures within the filler (figure 18). This feature, however, was very subtle and only seen with intense fiber-optic illumination. We did not detect a crackled texture in any of the Goldman Oved–filled fractures, although we did see some crackling in the substance partially filling a surface cavity.

Apparent Color of Filler. In relatively thick areas of the first Yehuda-treated diamonds we examined

Figure 19. Relatively thick areas of filling in Yehuda-treated diamonds showed a distinct yellow color. Photomicrograph by Shane F. McClure; magnified 40x.

(Koivula et al., 1989), the filler appeared light brown to brownish yellow or orangy yellow. Such color was not apparent in filled stones we examined later, and we speculated that the effect may have been reduced or eliminated by the manufacturer (Koivula and Kammerling, 1990). However, in the most recently examined Yehuda-treated stones, the yellow body color of the filler was quite noticeable in thicker filled fractures, cavities (figure 19), and laser drill holes.

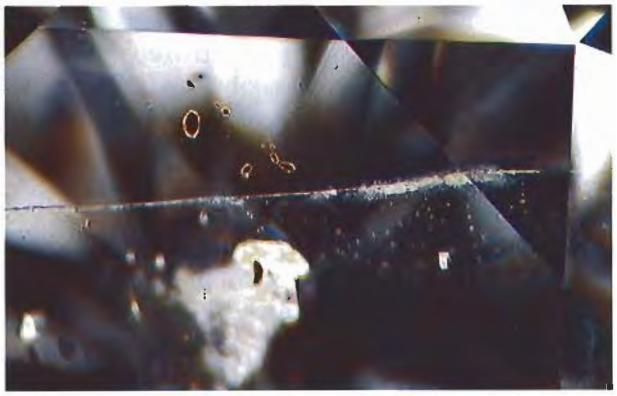


Figure 20. Some Yehuda-treated diamonds exhibited whitish material near the site where the filler entered the breaks. This material may be filler residue. Photomicrograph by Shane F. McClure; magnified 40×.

Figure 21. Cloudy areas within the filler were a common feature in Goldman Oved–treated diamonds. Photomicrograph by Shane F. McClure; magnified 40×.

We did not see any indication of inherent filler color in any of the Koss-treated diamonds (although there was a drop in apparent color grade of the diamonds described in box A) or the Goldman Oved–treated stones. For more on filler color, refer to box C.

Cloudy Surface Markings. A few of the Yehuda-treated stones examined in 1990 had cloudy, circular, surface markings that we had attributed to residue from the treatment process (see Koivula and Kammerling, 1990). In the most recent group of Yehuda-filled stones, we detected what appeared to be filling residue around the entry points of some filled breaks (figure 20). None of these surface indications of treatment were noted in any of the Koss- or Goldman Oved–treated diamonds.

Cloudy Filled Areas. In the most recent group of Yehuda-treated diamonds, we noted one feature not previously encountered in this firm's products: areas of reduced transparency ("white clouds") in a few of the filled breaks. Possible causes include groups of extremely small gas bubbles (the same mechanism that reduces the transparency of some amber), partial devitrification of the filling material, or a change in oxidation state of one or more of the filler's constituents.

Less commonly, we noted some cloudy areas in the filling material of Koss diamonds, typically near the surface entry points but also deeper in the breaks. Such "white clouds" were seen in at least one filled break in almost all of the Goldman

Figure 22. This X-radiograph of a fracture-filled diamond illustrates the extremes of filler visibility by this testing technique. Obvious white areas are evident on the perimeter of the stone, while the L-shaped filled break in the center is barely discernible. X-radiograph by Karin Hurwit.

Oved–treated diamonds we examined (figure 21). In many Goldman Oved–treated stones, we saw this feature before we detected a flash effect.

To summarize, with magnification and various lighting conditions, we detected flash effects in all of the sample treated diamonds. Other features associated with the presence of a filler in breaks include flow structures, trapped bubbles, a crackled texture, cloudy areas, and a white or cloudy appearance at the surface of the fracture.

X-RADIOGRAPHY

Although this technique is not directly available to most gemologists, X-radiography is particularly useful when the microscopic features in a filled diamond are somewhat ambiguous. It also helps document the extent of treatment where the filling material has been damaged, as in jewelry repair procedures involving heat (see, e.g., Hargett, 1992). In addition, it could prove to be a useful test in screening parcels of diamonds.

In most of the early Yehuda-treated diamonds, the filling material was more opaque to X-rays than was the host diamond and thus appeared as white areas on the X-radiograph (Koivula et al., 1989). Two of the three Yehuda stones tested for the current study yielded clear evidence of filling—again, in the form of X-ray-opaque white areas—on the exposed X-ray film. "White" filling areas—some faint and others quite sharp—were seen on the X-rays of all three Koss-filled diamonds. One of the Goldman Oved–treated diamonds showed clear evidence of filling (figure 22), while indications in the other two stones were present but very faint.

Several years of experience with this method have shown us that the orientation of the filled breaks relative to the X-ray film can significantly affect the outcome. Filled areas are most noticeable when the plane of the break is essentially perpendicular to the film, which results in the greatest absorption of the X-ray beam by the filling material. Also, breaks oriented essentially parallel to the film, thin breaks, or those that otherwise have relatively little filler, may not appear on the X-radiograph. The limited sensitivity of the X-ray film is another factor.

Note that there does not appear to be any correlation between the results of X-radiography and the strength of flash effects seen: A filled break that does not produce a distinct white area on the X-ray film may display a pronounced flash effect under magnification, while a thick area of filling that is clearly visible on the X-radiograph may display only a weak flash effect or none at all.

Note, too, that artificial fillings are not the only substances found in diamonds that are opaque to X-rays. Some rarely encountered mineral inclusions, such as iron sulfides, also may appear white on an X-radiograph. Furthermore, iron sulfides may occur as thin-film inclusions that could closely resemble filled fractures on an X-radiograph. Therefore, the results of X-radiography can only be interpreted in conjunction with other, especially microscopic, evidence.

CHEMICAL ANALYSIS

Some introductory comments are necessary concerning the use of EDXRF spectroscopy in the chemical analysis of diamonds. Natural, untreated, near-colorless diamonds often contain small amounts of impurities such as iron, potassium, calcium, zinc, and copper (Field, 1979), which are not discussed below. The following results focus exclusively on heavy elements, which typically are not found in untreated diamonds. More details on the chemistry and other properties of diamond filling materials can be found in box C.

The Yehuda stones treated recently contain

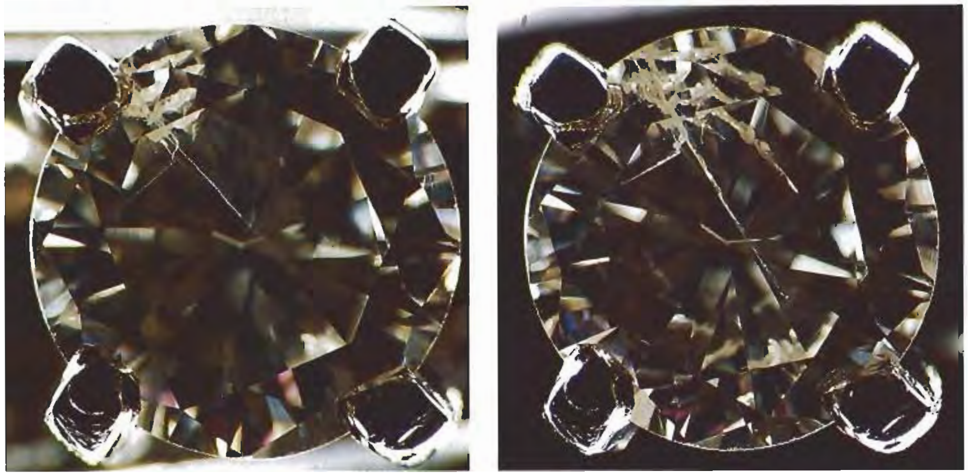


Figure 23. This 0.29-ct Koss-treated diamond had noticeable damage to the filler near the surface after steam cleaning for twenty minutes (before, left; after, right). Photomicrographs by Shane F. McClure.

both lead (Pb) and bismuth (Bi), which is consistent with the chemistry of the Yehuda diamonds treated earlier (Koivula et al., 1989). The early Koss-treated stones revealed Pb as their only heavy element, although the commercially available Koss diamonds revealed both Pb and bromine (Br). We found both Pb and Br in the Goldman Oved–treated diamonds as well. (Note that the chemistry of the Goldman Oved–treated stones was similar to that of a filled diamond from the Chromagem firm that was also analyzed by the authors.)

DURABILITY AND STABILITY OF THE FILLINGS

Over the past five years, concerns have repeatedly been voiced in the trade as to the durability and stability of filled diamonds. Treated diamonds with fillings that have been damaged by heat have been submitted to the GIA Gem Trade Laboratory for examination and damage reports (see, e.g., Hargett, 1992; Crowningshield, 1992). We have also learned that, while ultrasonic cleaning for a brief period may not damage at least some fillings, extended exposure to this process (and, by inference, numerous cleanings of short duration) may cause some shattering of, or other damage to, the filler (Crowningshield, 1992; Wakefield, 1993). Perhaps of greatest potential concern, independent research by Wakefield (1993) has shown that extended exposure to a short-wave ultraviolet lamp (and, by extension, to prolonged daylight exposure) can cause degradation of some fillers. This, in turn, has provoked a highly charged exchange (Koss, 1993, 1994a-d; Wakefield, 1994a, c-e; Yehuda, 1993, 1994a,b; Even-Zohar, 1994b).

For this study, we performed a series of durability and stability tests on diamonds filled by the Yehuda, Koss, and Goldman Oved firms. However, with the single exception noted below, only one stone from the current production of each diamond treater was used for each test. Therefore, we feel that the results of our tests are *representative,* but not *conclusive.* In other words, we do not guarantee that stones from any diamond treater will be either impervious or susceptible to a given circumstance.

Steam Cleaning. Twenty cumulative minutes of steam cleaning produced no noticeable change in the filler or the faceup appearance of the Yehuda-treated stone. The Koss-filled diamond showed some minor removal of filling material near the surface entry points after five minutes of steam cleaning. The damage continued throughout the testing procedure, with filling removed from areas deeper into the stone. Although relatively little material was removed, the damage did cause areas of the fractures at and just below the surface to become quite noticeable; at 10× magnification, they resembled deep scratches (figure 23).

The Goldman Oved–treated diamond, like many of the filled stones from this firm, had some areas of incomplete filling at the surface. After five minutes of steam exposure, there appeared to be an almost imperceptible change in the width of an unfilled area. After 10 minutes, however, there was a definite widening, with further widening noted at 15 minutes. After 20 minutes of steam exposure, this unfilled area was significantly wider than it was at the beginning of the test, with the damage having spread across the entire length of the fracture (figure 24).

It appears, then, that steam cleaning for even relatively brief cumulative time periods presents a potential durability problem.

Ultrasonic Cleaning. No change in the filler was noted in the Yehuda-treated diamond at five or 30 minutes. After 60 minutes total ultrasonic clean-

BOX C: More on the Fracture-Filling Process

The substances used for filling diamond breaks are high-refractive-index glasses related to those commercially used for glass adhesives ("solder glasses"; Nassau 1994), far-infrared optic fibers (1994 Koss promotional brochure), and other applications (Beck and Taylor, 1958). Such glasses contain large amounts of heavy elements. Solder glasses are commercially available through large glass-manufacturing companies such as Corning, Schott, and Pilkington. Glasses transmitting far in the infrared are generally not very stable physically and are produced only in small quantities (Dumbaugh, 1984). To be used as filling materials, the glasses must have an R.I. close to that of diamond in the visible range (i.e., approximately 2.4), be fairly liquid at relatively low temperatures (so that they can be easily introduced into the fractures), must not crystallize (devitrify) easily, and must be relatively free of coloration. Several of these considerations are discussed below, as they relate to diamond treatment.

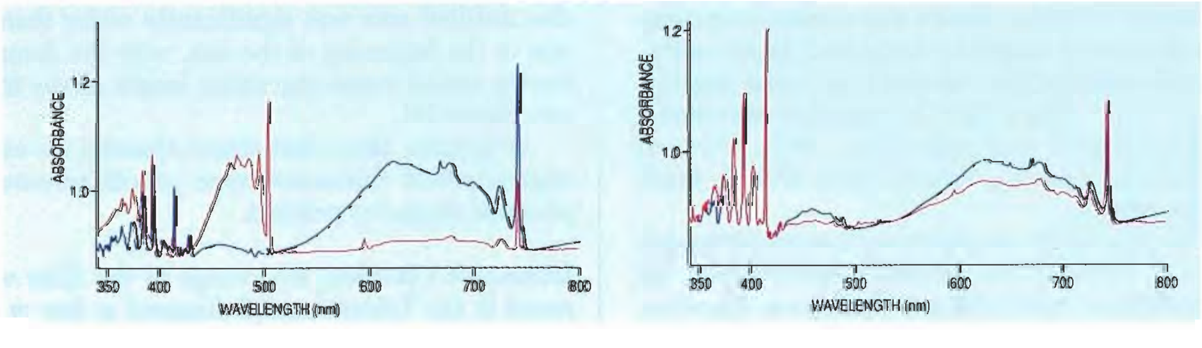
Chemical Composition. Solder glasses generally contain lead (Pb) and boron (B), sometimes with other elements. Infrared-transmitting glasses are oxides containing Pb and bismuth (Bi), as well as some additives to give the glass stability (Dumbaugh, 1984). Heavy elements (Pb or Bi) were found in the earlier Yehuda filling material, as well as possibly chlorine (Cl) and B (Koivula et al., 1989). Since then, further study has indicated that Cl is present only on or near the surface of the Yehuda fracture-filling material, but not in the bulk filling material itself. More recent commercial fracture-filling processes appear to be using similar types of materials, although with some variations in chemistry.

The following is a summary of the chemical elements found to date in the diamond fracture-filling materials currently available: for Yehuda—Pb, Bi, B, O; for Koss—Pb, Br, probably contains Cl or O, may contain B; for Goldman Oved—Pb, Br, probably contains Cl or O, may contain B. EDXRF analysis demonstrated that there is less bromine in the Koss glass than in the Goldman Oved filling material. Since these two glasses have similar optical properties, there must be another element to compensate for the relative lack of Br in the Koss glass. If it was a light element, especially at low concentration, it would not be detected by EDXRF. Candidates include oxygen or chlorine, or perhaps both. Boron is another likely glass-forming element that cannot be detected by EDXRF (Nassau, 1994).

High Refractive Index. Although we have been unable to measure the refractive index and dispersion of diamond fillings, the presence of flash-effect colors proves that, somewhere in the visible range, the R.I. of the filling glass matches that of diamond (2.435 at 486.1 nm, 2.410 at 656.3 nm; Field, 1979, p. 650). Pb and Bi in oxide glasses, as in those used for filling diamonds, are known to yield an R.I. that is considerably higher than those of normal commercial oxide glasses. Heavy-metal oxide glasses containing, among other things, PbO and Bi_2O_3 are reported to show R.I.'s in the range of 2.2 to 2.6 (Dumbaugh, 1986).

"Melting" Point and Temperature of Treatment. A glass has no melting point; it is already a liquid—albeit a very slow-flowing one—at room temperature. As it is heated, it reaches a temperature (the "softening temperature": K. Nassau, pers. comm., 1994) at which the glass begins to flow at a significant rate. The softening temperature places a lower limit on the temperature at which the fracture-filling process can be performed. Using a heating stage on a microscope, and observing the behavior of the filling in a diamond, one can estimate this temperature for fracture-filling glasses. Koss fillings show an approximate flow temperature of 370°C, and we first observed damage in the fill-

Figure C-1. Temperatures of treatment were estimated based on this comparison of the low-temperature ultraviolet-visible absorption spectra of two laboratory-irradiated green diamonds before (blue) and after (red) fracture filling: (left) a 0.84-ct round brilliant, and (right) a 0.76-ct round brilliant.



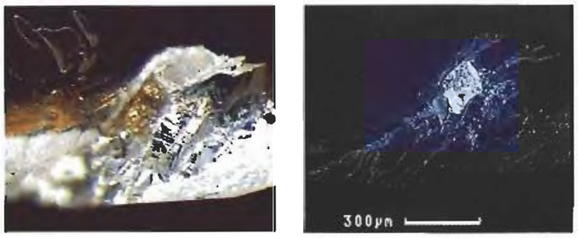


Figure C-2. A yellow mass is seen in the photo on the left, at the entrance of a filled fracture in a Yehuda-treated diamond (photomicrograph by John I. Koivula; magnified 20×). On the right, the same yellow mass is seen in a scanning electron micrograph; it has the same contrast and chemical composition as the filling material (the bar indicates the scale).

ing materials in a Koss-treated diamond in the temperature interval between 340° and 390°C (see the "Durability and Stability of the Fillings" section).

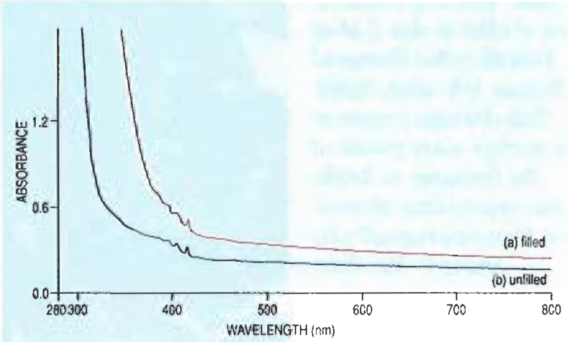
An indirect way to obtain information regarding treatment temperature is to observe changes in laboratory-irradiated green diamonds. Such diamonds are, in effect, annealed during the fracture-filling process; the behavior of various temperature-sensitive absorption features (such as GR1 at 741 nm) provides information on the temperature regime the treated diamond has undergone (see, e.g., Collins et al., 1986). Two such stones were submitted to this experiment, one filled by Koss (a 0.84-ct round brilliant), the other by Goldman Oved (a 0.76-ct round brilliant). The absorption spectra of these two diamonds before and after treatment are compared in figure C-1. On the basis of the decrease in intensity of the GR1 absorption, the intensities of the H3 (503 nm) and 595-nm features, and the presence or absence of the H1b absorption (4935 cm^{-1} in the near-infrared), the following approximate temperatures of treatment can be estimated: 600°C for the Koss process, and 500° to 550°C for the Goldman Oved process.

Coloration of the Filling Material. Because the apparent color grade of some fracture-filled diamonds drops after filling, at least some of the filling materials may themselves be colored. For instance, observations with the microscope indicated a yellow-to-brown color in the filling material in early Yehuda-treated diamonds (Koivula et al., 1989). A yellow mass found at the outcrop of a filled fracture in a Yehuda-treated diamond is shown in figure C-2, left. Scanning electron microscopy (figure C-2, right) and energy-dispersive X-ray spectrometry (SEM-EDS) analysis established that the chemistry of the yellow material was identical to the filling material. Therefore, the Yehuda filler is strongly colored. In general, oxide glasses that are suitable for fracture filling (i.e., with a high R.I. and a low softening temperature) contain large amounts of Pb or Bi, and are known to be colored yellow (Dumbaugh, 1978, 1986). The optical spectra of two representative glasses (a commercial solder glass obtained from Schott, and a lead borate glass made by Pilkington) showed UV-cutoff edges shifted toward the visible, which cause yellow color.

Optical absorption spectroscopy demonstrates that colored glass present in open fractures, even in small amounts, can decrease the apparent color grade of a diamond. Because the amount of glass present in a filled diamond is very small, we expect to see only subtle changes in the absorption spectrum of a filled diamond compared to its spectrum before filling. We were able to measure these changes in a Yehuda-treated diamond cut into a slice that contained a large filled fracture almost parallel to the sides of the slice. Absorption spectra were recorded for both the filled and unfilled regions (figure C-3). A second experiment was carried out by creating a diamond–solder glass (10 µm)–diamond "sandwich," with similar results. The filling material shifts the UV-cutoff by over 25 nm toward the longer wavelengths. The edge of this spectral feature extends into the visible range—up to approximately 450 nm—and therefore induces a weak absorption in the violet. This creates a pale yellow coloration and explains why some diamonds may have a slightly lower apparent color grade (i.e., are slightly more yellow) after fracture filling.

Infrared Absorption. Although solder glasses themselves show broad, weak absorptions in the mid-infrared range, at 500, 700, 900, and 1220 (strongest) cm^{-1}, in general there is too little filler present to be detected in nitrogen-bearing (i.e., most) diamonds, which also have absorptions in the mid-infrared. As we found previously (Koivula et al., 1989), infrared spectroscopy is not a useful technique for routine testing of fracture-filled diamonds.

Figure C-3. Ultraviolet-visible absorption spectra are shown for (a) a filled region and (b) an unfilled region of a laser-sawn and polished slice from a Yehuda-filled diamond. The absorption shifts (right) toward the visible, causing the yellow color (see text).



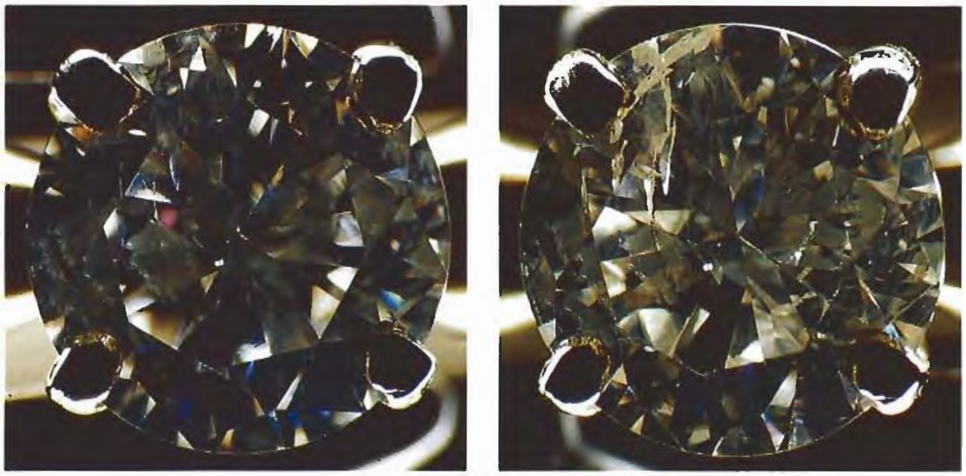


Figure 24. Obvious damage to the filler was also seen in this 0.36-ct Goldman Oved–filled diamond after a prolonged steam cleaning (before, left; after, right). Photomicrographs by Shane F. McClure.

ing, however, we noticed damage to the filler at the surface of one filled break—minute, but enough to make the fracture visible as a white line. After 90 minutes, the damage was significantly more apparent: At the entry points of all surface-reaching fractures, the filler was easily seen as thin, bright lines resembling scratches (figure 25). These damaged areas appeared about the same after two hours and 2 1/2 hours, with perhaps slightly more damage evident after three hours. (Note that although we did not observe any changes in the Yehuda-filled stones tested with ultrasonic cleaning in our 1989 study, we ran that test for only 30 minutes.)

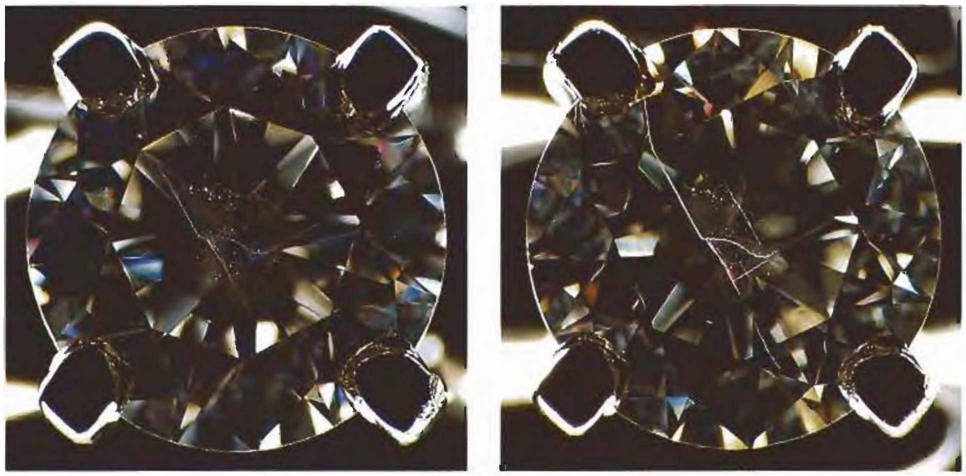
Neither the Koss- nor the Goldman Oved–treated diamonds showed any removal of, or damage to, the filler after three hours of cumulative exposure to ultrasonic cleaning, although the filling was removed (essentially, all at once) from a wide cavity on the surface of the Goldman Oved–treated stone.

Direct Heating. Another durability concern with filled diamonds is how such treated stones will react when exposed to the high temperatures employed in various jewelry repair procedures. The retipping tests caused major damage to the filled fractures in all three stones. The Yehuda-treated diamond showed a significant loss of filling material, with most of the remaining filler turning cloudy and containing many gas bubbles. The Koss- and Goldman Oved–treated (figure 26) diamonds lost even more filling material, although the remaining filler did not drop as much in transparency as it did in the Yehuda-treated stone.

In all three stones, the second phase of retipping—of the other two prongs on each ring—caused additional damage to the remaining filler.

In a separate test, furnace heating produced degradation in the fillings of all three sample stones at 390°C. In the Yehuda-treated stone, which was extensively fractured, the filling material became cloudy at that temperature, and the flash colors shifted and became less prominent (figure 27). No other change was noted until 600°C, at which point

Figure 25. Extended ultrasonic cleaning caused a loss of filler in this 0.34-ct Yehuda-filled diamond (before, left; after, right). This damage is seen at the surface entry points of the fractures as bright lines resembling scratches. Photomicrographs by Shane F. McClure.



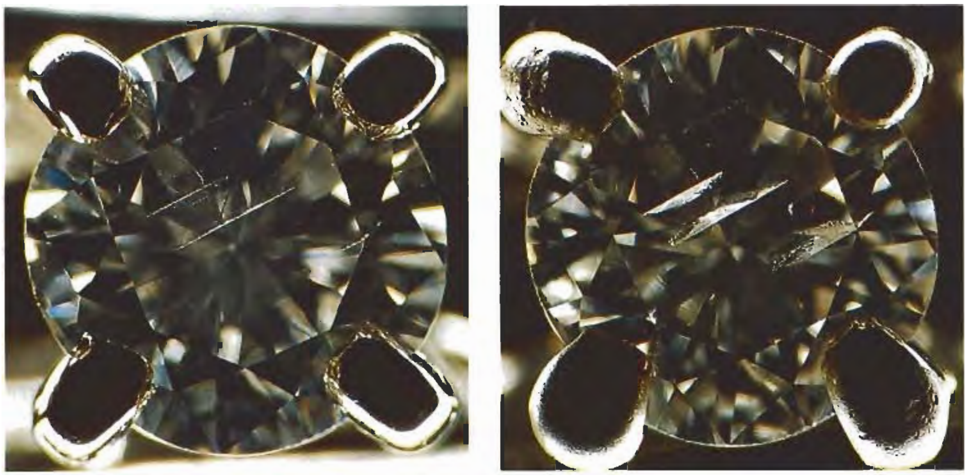
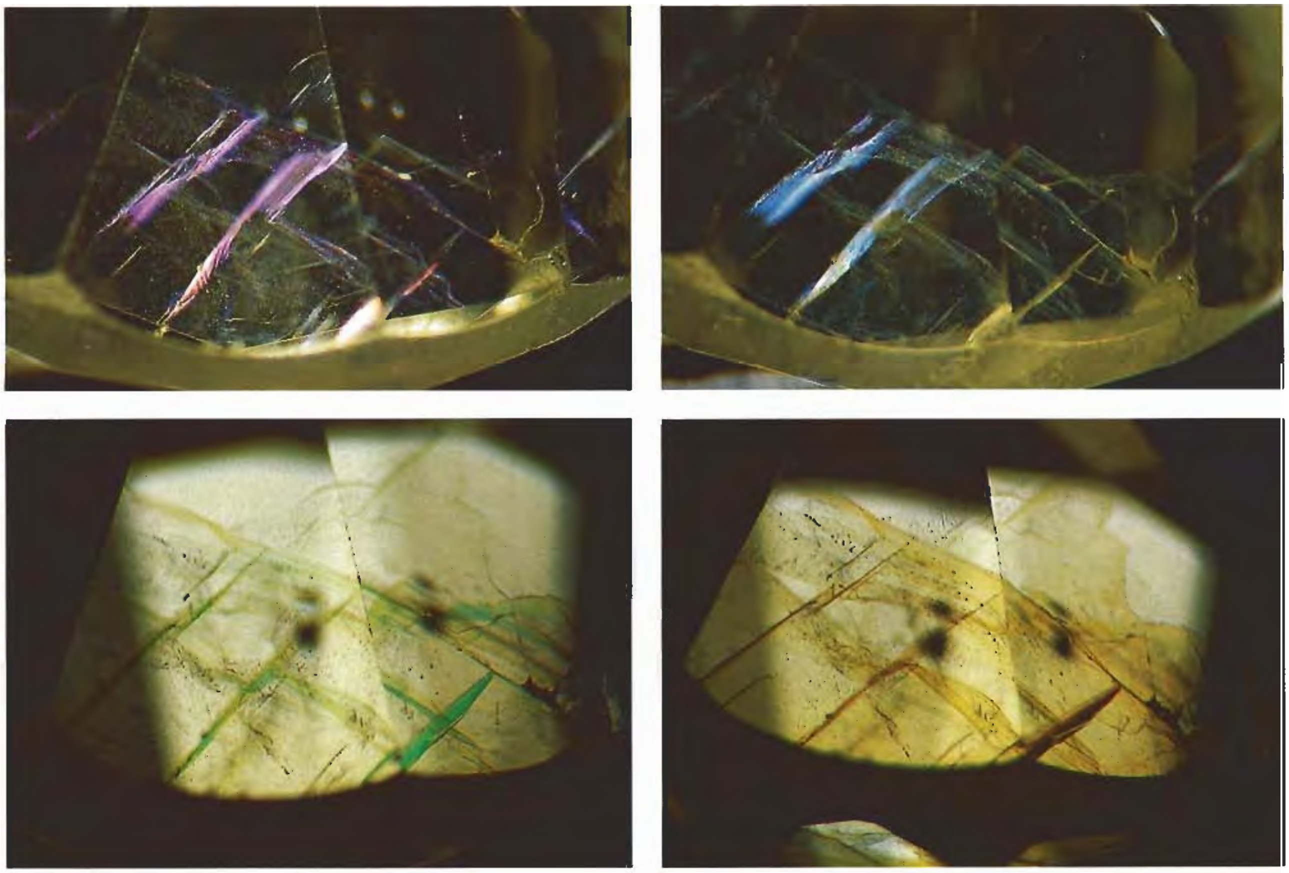


Figure 26. The vast majority of the filling material was removed from this mounted 0.19-ct Goldman Oved–treated diamond during the retipping of the prongs. Note the significant difference in appearance before (left) and after (right) the retipping procedure. Photomicrographs by Shane F. McClure.

we saw the first evidence of filler loss from the outermost edges of the fractures. In the Koss stone, we saw some loss of filler from the edges of the fractures after heating to 390°C (figure 28), with about half the filler gone after 45 minutes at 420° to 455°C. The Goldman Oved stone showed migration of the filler within the break into an apparently cellular structure at 340°C, loss of filler from the edges of fractures at 390°C (figure 29), and significant loss of filler at 455°C.

Figure 27. After this 0.36-ct Yehuda-treated diamond was heated to 390°C, the filler began to degrade and a distinct change in the flash colors was observed. In darkfield illumination before heating (top left), a pink flash is evident; after heating to 390°C (top right), the filler is cloudier and the flash color has changed to blue. The same diamond in brightfield illumination before heating (bottom left) shows a green flash color; after heating to 390°C (bottom right), the filler appears darker and the flash color is yellow. Photomicrographs by Shane F. McClure; magnified 30×.



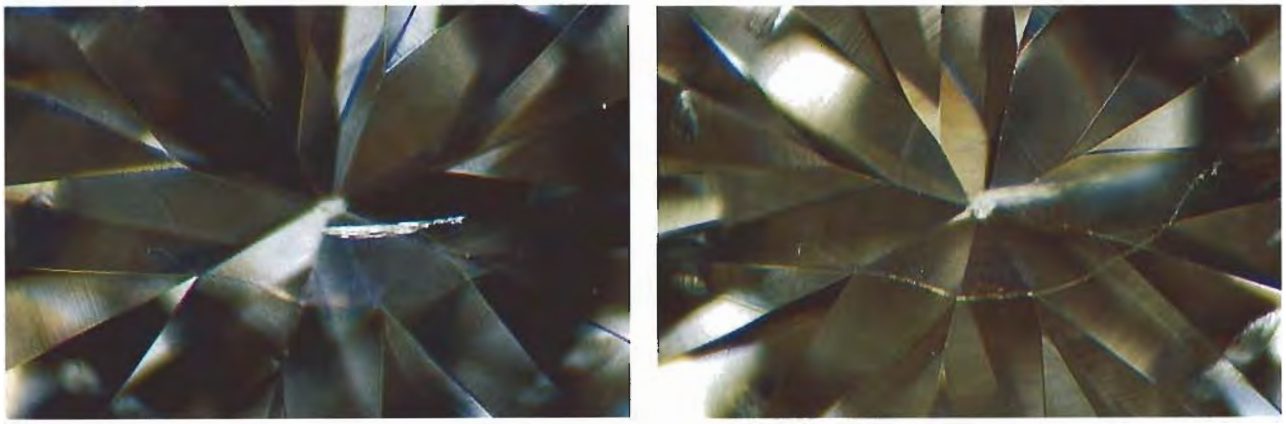


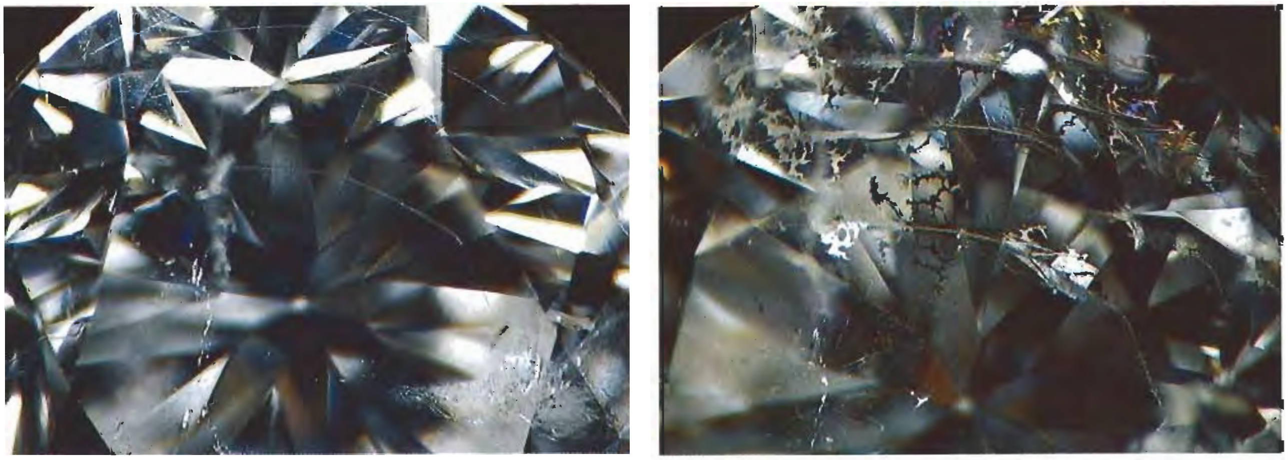
Figure 28. After heating to 390°C, this Koss-treated diamond showed a minor loss of filling material at the surface, apparent as a white line resembling a scratch (before heating, left; after, right). Photomicrographs by Shane F. McClure; magnified 33×.

Indirect Heating. Careful resizing (as when the jeweler is aware of the potential problems associated with fracture-filled diamonds) caused no visible damage to any of the three stones tested. Nor was any damage seen when resizing was performed with no special effort made to keep the diamonds from being heated. Note, however, that the results may differ depending on such factors as the karatage of the gold, thickness of the ring shank, and the length of time the filled areas are exposed to heat.

Repolishing. Repolishing produced different degrees of damage to the filler in all three test stones. Although the Yehuda-treated diamond lost only a small amount of filler from the treated breaks within a few tenths of a millimeter from the surface, almost all of the remaining filler became cloudy and more small gas bubbles had formed (figure 30). Substantial amounts of the filling material were removed from the Koss-treated diamond, resulting in large unfilled areas near the surface and some minor clouding but many gas bubbles (producing a fingerprint-like pattern, as in figure 31) appearing throughout the remaining filler. The Goldman Oved–filled diamond showed damage similar to that of the Koss-treated stone.

Laser Inscribing. Because of industry concerns about detection and disclosure, it has been suggested that all such stones be laser-inscribed with initials that disclose the treatment. One retailer (Blando, 1994) proposed "CL-E" (we assume for "clarity enhanced"); Daniel Koss has reportedly

Figure 29. A Goldman Oved–filled diamond showed extensive loss of filler after heating to 390°C. This damage was easily seen with a 10× loupe (before heating, left; after, right). Photomicrographs by Shane F. McClure; magnified 27×.



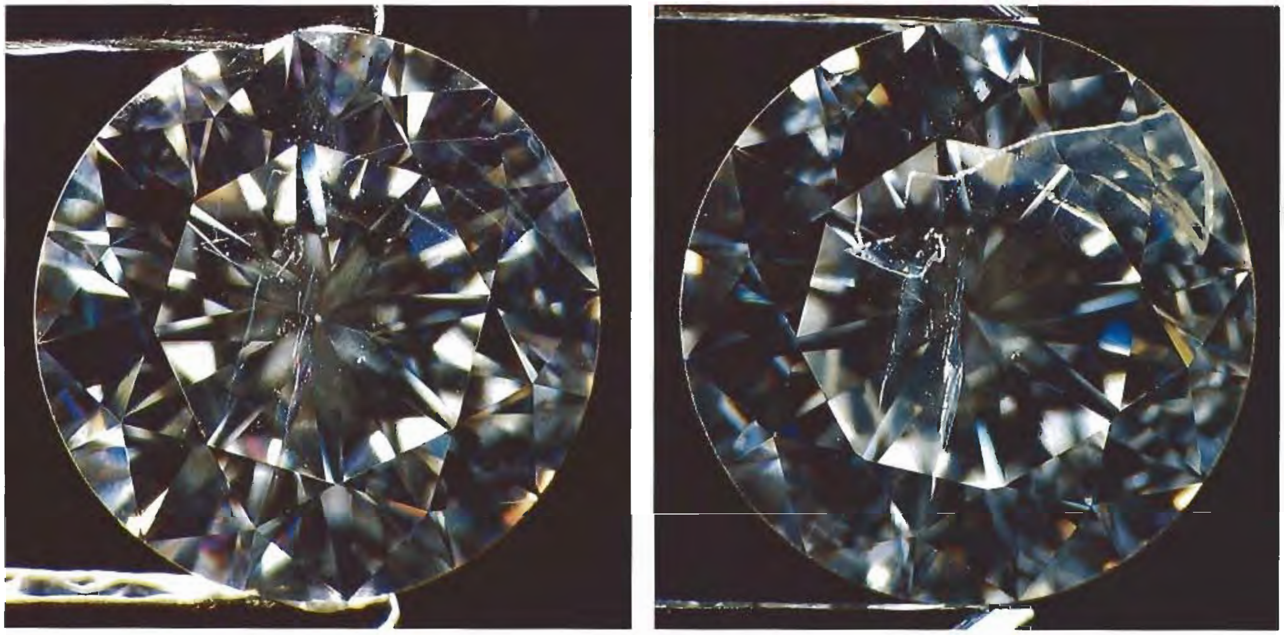
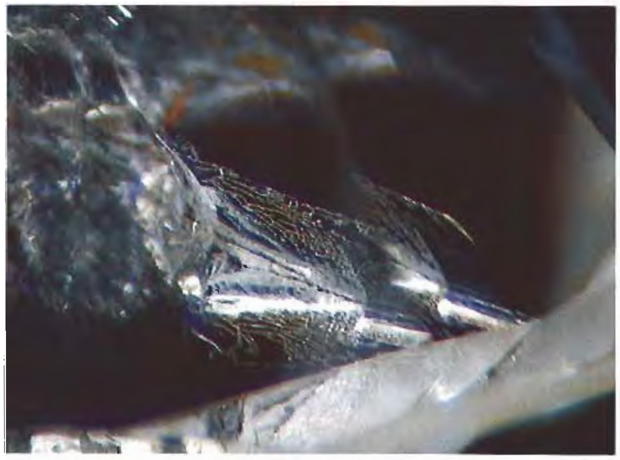


Figure 30. Repolishing the table facet of this 0.37-ct Yehuda-treated diamond caused almost all of the filling material to become cloudy, the formation of new gas bubbles, and removal of some of the material near the surface (before repolishing, left; after, right). Photomicrographs by Shane F. McClure.

pledged to laser inscribe "F.F." (fracture filled?) on the girdles of his stones (Federman, 1994). If such markings were supported broadly in the trade, a standard symbol (like a hallmark) might be adopted. Because the laser-inscription process generates high temperatures, however, this could pose its own durability problem.

Therefore, the authors laser-inscribed the GIA logo and identifying letter(s) on the girdle of one filled diamond from each of the three manufacturers. In each test, care was taken to inscribe an area of the girdle that was close to, but not intersected by, an entry point. Since many filled diamonds have more than one fracture that intersects the girdle, we chose a position approximately 45° from where the nearest fracture crossed the girdle. The diamonds were examined and photographed before and after laser inscription. We did not detect (with magnification) any deterioration in the filling in any of the stones.

Figure 31. Repolishing this 0.45-ct Koss-filled diamond removed substantial amounts of the filler, producing the fingerprint-like pattern seen here in the remaining filling material. Photomicrograph by Shane F. McClure; magnified 40×.



As with the other processes described here, however, the outcome may differ depending on the amount of the filling material or its proximity to the inscription.

Daylight Equivalency Testing. To simulate extended exposure to sunlight, the authors subjected filled diamonds to radiation in a solar simulator. No obvious changes were noted in the Yehuda-, Koss-, or Goldman Oved–treated diamonds after 200 hours (equivalent to only 340 hours of exposure to sunlight; see next section for results relating to a longer daylight-equivalent exposure).

Exposure to Ultraviolet Radiation. As noted above, Wakefield (1993) has reported that exposure to a short-wave ultraviolet lamp—which she equated to a longer daylight equivalency—can cause degradation of the filling material in Koss-treated dia-

Figure 32. Noticeable clouding of the filler in this large break in a 0.29-ct Koss-treated diamond was seen after 100 hours of exposure to long-wave ultraviolet radiation (before exposure, left; after, right). Photomicrograph by Shane F. McClure; magnified 37×.

monds. Some have questioned both the relevance of using a short-wave UV unit for the testing (something to which she has responded—see Wakefield, 1994e) and her correlation of the exposure to actual lighting conditions that might be encountered by filled stones (Koss, 1994d; Even-Zohar, 1994b). Wakefield subsequently (1994e) suggested that the damage to the filler from a short-wave UV unit she had documented was caused by the low levels of long-and medium-wavelength UV radiation, because most diamonds do not transmit short-wave UV.

Our testing with long-wave UV radiation showed no obvious changes to one Yehuda-treated diamond after 100 hours—and a second Yehuda-treated diamond after 200 hours—of exposure. However, we first noted minor discoloration of the filling material in one Koss-filled diamond after 60 hours (equivalent to 1,000 hours of daylight), with discoloration becoming visible table up after 100 hours, and further discoloration noted at 200 hours. A second Koss-treated stone showed discoloration and clouding of the filling (figure 32) after a single 100-hour exposure. One Goldman Oved–filled stone showed no apparent change after 100 hours' exposure, but obvious discoloration and clouding after 200 hours (figure 33). A second Goldman Oved–treated diamond showed no damage after 100 hours' exposure.

The presence of Br in the Koss and Goldman Oved fillers may explain their discoloration and clouding when exposed to long-wave UV radiation. Many compounds containing halogens such as Br and iodine are known to decompose spontaneously when exposed to strong sunlight (see, e.g., Turro 1978, pp. 568–569); an example well known to gemologists is the degradation of methylene iodide.

Low-Temperature Testing. Neither of the low-temperature tests had a noticeable effect on any of the three samples.

GIA GEM TRADE LABORATORY POLICY ON GRADING FILLED DIAMONDS

As stated by Koivula et al. (1989), the GIA Gem Trade Laboratory has an established policy of not issuing grading reports on diamonds determined to have been filled. This policy was adopted on the basis of two considerations: (1) the true—that is, untreated—color and clarity grades of such treated stones cannot be determined after filling (unless the filling material is completely removed); and (2) the treatment—like diamond coatings but unlike laser drilling—is not permanent. The implication of this second item is that, because of durability and stability concerns, even the *apparent* color and clarity grades of treated stones may change.

With respect to color, initial research showed that at least some filling treatments may lower the apparent grade due to the inherent body color of the filling material (Koivula et al., 1989). More recent research (Wakefield, 1993), and the results of this study, have indicated that some fillers may darken after exposure to ultraviolet radiation like that contained in sunlight.

With respect to apparent clarity, it has been shown that the filling may be damaged by extended ultrasonic cleaning (Crowningshield, 1992; this study). As Wakefield (1993) pointed out, the cumulative effect of repeated ultrasonic cleanings could have a similar effect. Acid boiling (Rapaport, 1987), repolishing (Crowningshield, 1992; this study), and jewelry repair procedures involving heat above 400°C (Koivula et al., 1989; Hargett, 1992; this study) may also adversely affect the filling material. All such damage makes the filled break more visi-

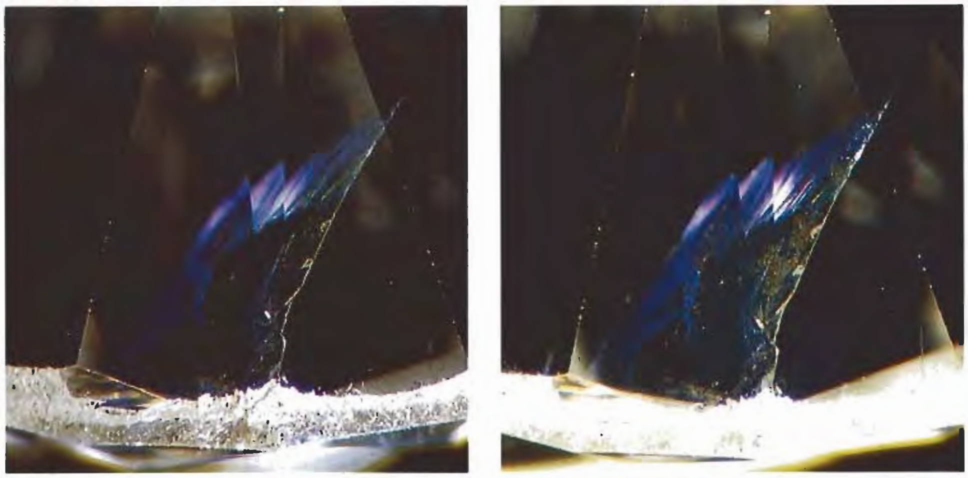


Figure 33. Obvious discoloration and clouding were seen in this filled break in a Goldman Oved–treated diamond after 200 hours' exposure to long-wave UV radiation (before exposure, left; after, right). Photomicrographs by Shane F. McClure; magnified 27×.

ble and, in general, lowers the apparent clarity grade.

An additional grading consideration relates to diamonds that are so heavily included that they fall outside the GIA clarity grading scale. Essentially, such stones are below I_3 in clarity and for GIA GTL purposes are classified as "rejection grade." Diamonds in this category include those that have so many inclusions or inclusions that are so large that the stone is no longer completely transparent. The GIA Gem Trade Laboratory does not issue grading reports on such low-clarity diamonds. Yet diamonds that fall in this "rejection grade" might be good candidates for fracture filling, and it would be inconsistent to grade filled stones that—in their unfilled state—would not be graded.

Therefore, the GIA Gem Trade Laboratory continues this policy of not grading fracture-filled diamonds. Any filled diamond that is submitted for quality analysis is issued an identification report stating the identity of the stone (i.e., diamond) and noting that a clarity-enhancing foreign material has been artificially introduced into surface-reaching features, which precludes quality analysis. As discussed earlier, this position has now gained formal support among diamond dealers.

TECHNIQUES TO IDENTIFY FRACTURE FILLING

At the time of our initial study, magnification with darkfield illumination was sufficient to detect fracture filling (Koivula et al., 1989). This lighting method is the standard for diamond clarity grading as well as for locating and interpreting inclusions in gem identification. More recently, however, we have encountered filled diamonds for which darkfield illumination is insufficient to detect conclusively the diagnostic features of this treatment. Following is a review of supplemental methods that have proved useful, as well as some precautions to keep in mind when examining diamonds for evidence of fracture filling.

Microscopic Techniques. *Fiber-Optic Illumination.* Through 1991, we saw distinctive flash effects in most fracture-filled diamonds we examined (Koivula et al., 1989; Koivula and Kammerling, 1990; DelRe, 1991). Filled breaks that lacked the flash effect included some with relatively thick fillings and some that were very small (see the example of bearded girdles in Koivula et al., 1989). Since 1991, GIA GTL gemologists have examined several fracture-filled diamonds in which the flash-effect colors were much less intense. We have found that, for such stones, the intense light from a pinpoint fiber-optic illuminator can make the flash effects significantly more noticeable, as well as reveal the extent of the filled breaks and any hairline fractures in the filling material (Kammerling and McClure, 1993).

Flash effects are often first noticed as reflections in facets around the stone (figure 34), rather than directly from the break itself. These can be extremely helpful with mounted stones, where viewing angles are restricted.

In some instances, flash effects can be detected in filled diamonds with intense fiber-optic illumination *without* magnification. To perform this test, place the stone table down on the end of a vertically positioned fiber-optic light wand and then rotate the stone: This can reveal flash effects from filled breaks in the pavilion that are parallel or nearly parallel to the girdle plane. However, even if a flash is seen using this test, the presence of filled breaks should be confirmed with examination under magnification.

Figure 34. In this 0.32-ct Yehuda-treated diamond, all of the flash effects visible are reflections of a single large filled break. The flash of the filled break itself is not seen at this viewing angle. Photo by Shane F. McClure.

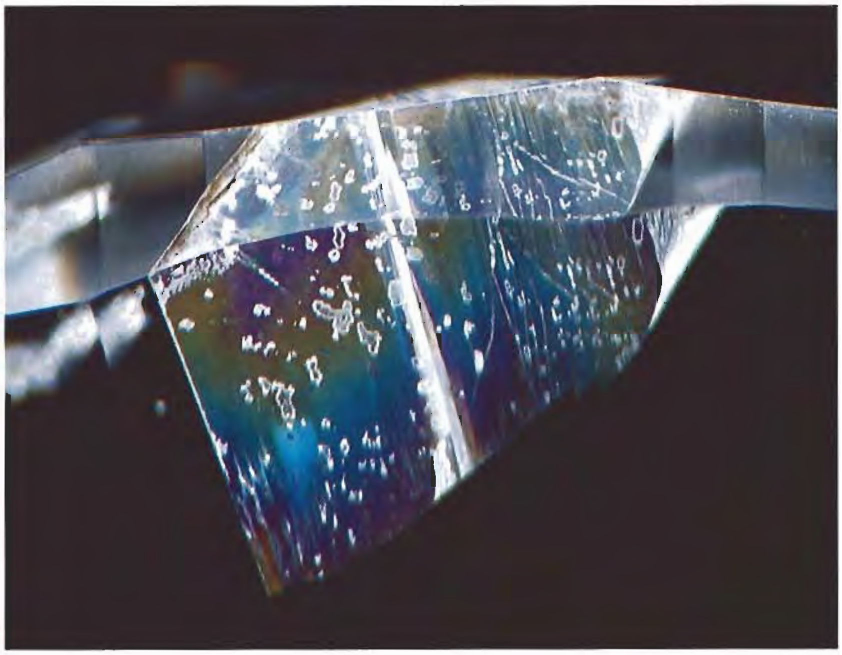
It is important to emphasize that failure to see a flash effect does not prove that the stone is untreated. Care must also be taken to make sure that dispersion or interference colors (figure 35) in unfilled fractures are not mistaken for a flash effect. (See also "Thin-Film Iridescence" under "Precautions," below.)

Partially Polarized Light. With a single polarizing filter placed between the microscope's objective and the diamond, light transmitted through a stone may sometimes reveal the outline of the filled areas (Kammerling and McClure, 1993).

Shadowing Technique. In this lighting technique, an opaque, black, nonreflecting light shield is inserted gradually into the transmitted light path between the gemstone and the light source (see Koivula, 1982). It has proved useful to the authors in detecting flow structures within the filling material of some treated stones. Generally, partial closing of the microscope's iris diaphragm is sufficient.

Application of Water. To perform this test, hold the diamond in question in a stoneholder on the microscope's stage with the fracture entry point facing up. While examining the stone, run a small brush (like that sometimes used by gemologists when clarity grading diamonds) that has been dipped in water across the entry point. If the water enters and fills the break—noted as a temporary lowering of the fracture's relief—then it can be concluded that the break is probably not filled (figure 36). Note, however, that failure of the water to enter the break

Figure 35. This unfilled fracture displays natural iridescent colors in a broad range of hues. (Note also the small, white areas within the fracture, which could be confused with the gas bubbles often seen in a filled break.) Photomicrograph by Shane F. McClure; magnified 33×.



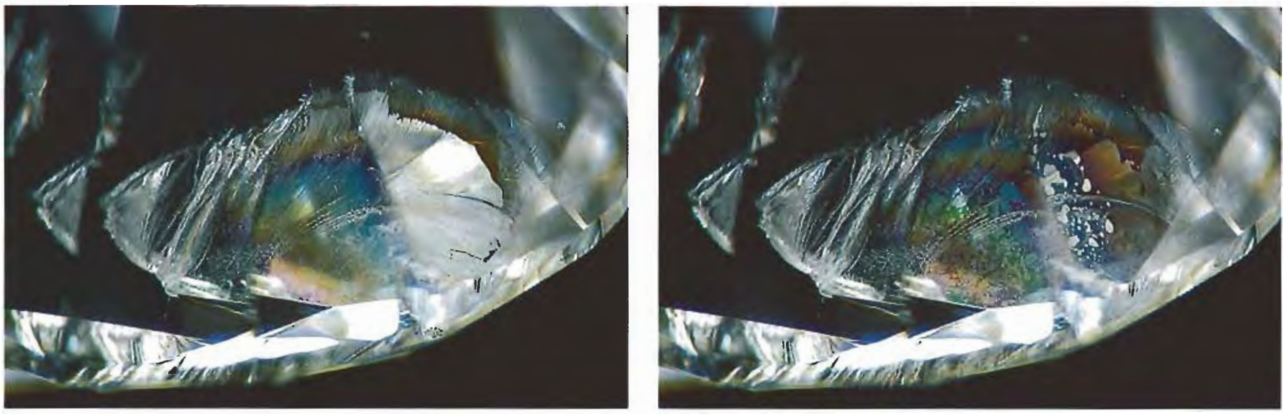


Figure 36. One method for determining whether a suspect fracture is filled is to see if water can be drawn into it. On the left is an unfilled fracture with natural iridescence. On the right is the same fracture after water was applied to its entry point at the diamond's surface; note the decrease in relief of the fracture, as well as the bubbles apparent in the water that was drawn into the break. With the microscope, one can actually see the bubbles move. Photomicrographs by Shane F. McClure; magnified 33×.

Figure 37. The interference spectrum can be seen by looking at a quartz wedge between crossed polarizers. The dark-gray color occurs where the interference film is the thinnest; colors vary to yellow, blue, red, yellow again, etc., and finally to repeated pinks and greens, as the film gets thicker. Compare this with the iridescent fracture in figure 35. Photomicrograph by John I. Koivula.

does not prove that the break *is* filled, as some unfilled breaks with very narrow surface openings will not accept the water.

Precautions. *Thin-film Iridescence.* As noted in Koivula et al. (1989), unfilled fractures can act as thin films, displaying rainbow-like interference colors that might be mistaken for flash effects (again, see figure 35). Like the flash effects in filled breaks, these iridescent effects can vary in the intensity of their colors; unlike flash effects, they should always show the same color sequence (figure 37; see also Fritsch and Rossman, 1988). The iridescence shown by unfilled breaks typically has a broad range of hues, although on occasion they may only display a few (figure 38). Flash effects often display a single color at most viewing angles, but some filled breaks can be positioned to show more than one color at a time.

One reliable feature that can be used to make the distinction is the *viewing angle.* Iridescent colors in unfilled breaks are usually seen best at a viewing angle roughly perpendicular to the plane of the break (again, see figures 35 and 36, and Koivula, 1980), whereas flash effects in filled breaks are usually detected when looking almost parallel (edge-on) to the break (figure 39). Another important distinction is the *texture* of the break: Unfilled breaks typically have a "feathery" appearance (figure 40) that we have not seen to date in filled breaks. Unfilled breaks also have much higher relief, the primary purpose of the filling being to lower the relief.

Another technique that may be helpful in separating iridescence from flash effects is illumination with polarized light. When a polarizer is placed

Figure 38. Occasionally, unfilled breaks exhibit iridescence in only one or two hues. Photomicrograph by Shane F. McClure; magnified 33×.

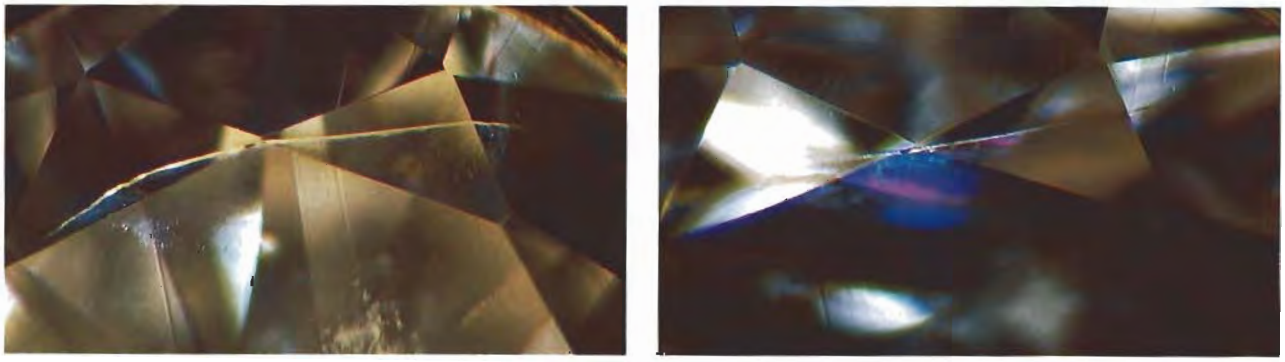
between the diamond and the observer, iridescent fracture colors will shift in position as the polarizer is rotated; flash colors, however, only turn darker and brighter, and they do not shift laterally with rotation of the polarizer.

Natural Colored Staining. Occasionally we come across surface-reaching breaks in untreated diamonds that contain an orangy brown staining of naturally occurring iron compounds (figure 41) which could be mistaken for an orange flash effect. The staining, however, should be visible throughout a broad range of viewing angles, whereas the similarly hued flash effect would typically be seen only within a very narrow range of viewing angles. In addition, a relatively thick staining may appear translucent to nearly opaque, whereas an orange flash effect would have no comparable reduction in apparent transparency. Also, a stained break should have higher relief than a filled break.

"Indirect" Surface-Reaching Breaks. It would seem obvious that a break must reach the surface of a diamond for it to be filled, and in most of the filled stones we examined, the fractures had direct surface-entry points. It is possible, however, for a break that is entirely internal to be filled by first laser drilling one or more narrow channels to it from the surface (figure 42; see also, e.g., Crowningshield, 1993). A thorough microscopic examination for possible fracture filling should take this possibility into consideration. A laser drill hole that appears to "go nowhere"—that is, that does not end at a void caused by a vaporized inclusion—should be considered especially suspect.

Body-Color Masking. The body color of a diamond can affect the ease with which flash effects are seen. In our experience, flash effects are relatively distinct when seen against the essentially colorless to very pale yellow body color of most diamonds; they may be even more obvious when the hue is complementary to the stone's body color, for example, a blue flash in a fancy yellow diamond. However, when the body color of a diamond and the flash

Figure 39. When the filled feather in this diamond is viewed perpendicular to its length (left), it is only visible at its entry point—as a white line on the surface of the crown—where it is not completely filled. Only after the stone is tilted so that the break is viewed nearly parallel to its length, can the flash colors be seen (right). Photomicrographs by Shane F. McClure; magnified 40×.



effect are of the same or a similar hue, a "masking effect" may result. Thus far, we have noticed this masking effect primarily with orange flash effects that are obscured in stones with deep yellow to brown body colors (although, as noted, the complementary flash effect should still be quite noticeable; see figure 43). A similar masking could be expected in pink stones with a purplish pink to purple flash effect.

Potentially Dangerous Use of Laser Light. In late 1993, a method for testing fracture-filled diamonds using a handheld laser pointer was suggested (Everhart, 1993a,e). The procedure calls for examining the stone in a darkened room, under low-power magnification, while illuminating it with the laser's intense red light. This will reportedly cause the entire area of a filled break to glow red, thereby clearly showing the extent of the filled area.

We strongly advise against using this technique. First, in experiments conducted by the authors using a 3.0-mw laser pointer, the results were ambiguous: Both filled and unfilled fractures reflected the laser light with no appreciable, consistent difference in their appearance. Second, laser pointing devices are labeled with clear warnings to avoid direct eye exposure. Diamond surfaces—and fractures within diamonds—are highly reflective, so the method could result in the intense laser light being reflected through the microscope's lenses and into the user's eyes. Because of this potential health hazard, as well as the ambiguous results, we recommend avoiding this method altogether.

Figure 41. Some untreated diamonds reveal an orange-brown staining in their fractures, which is actually a naturally occurring iron compound. Such staining should not be mistaken for a flash effect. Photomicrograph by John I. Koivula; magnified 35×.

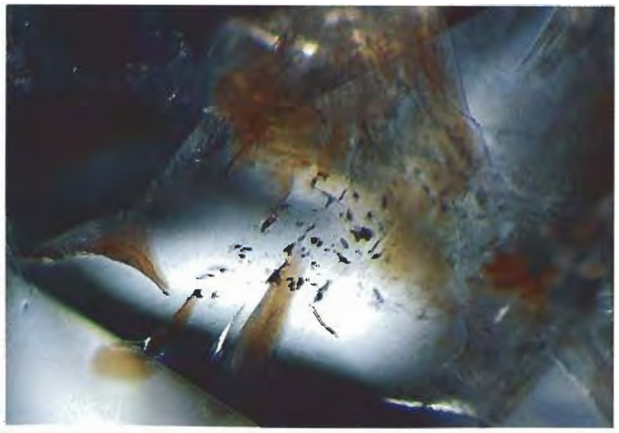


Figure 40. The high relief and feathery appearance typical of many unfilled breaks have not been noted in any of the fracture-filled diamonds examined by the authors. Photomicrograph by Shane F. McClure; magnified 33×.

Inadequacy of Loupe. The last and perhaps most important precaution has to do with the type of magnifier used. As noted by Koivula et al. (1989), a 10× loupe was adequate to detect diagnostic features of filling treatment in some of the earlier Yehuda-treated diamonds. We have since seen, however, that the identifying features can be very subtle, and other features, such as iridescent feathers, might be mistaken for filled fractures. Thus, evidence of fracture filling may be completely overlooked, or misidentified, if the stone is examined only with a low-power hand magnifier. Given this situation, *it is the authors' opinion that a 10× loupe cannot be relied on to detect characteristic features in all filled diamonds. Instead, a binocular gemological microscope with a range of lighting options should be used.*

CONCLUSION

The current investigation has confirmed that the fracture-filling processes of the three firms studied—Yehuda, Koss, and Goldman Oved—can effectively improve the faceup appearance of some diamonds. All three can improve the apparent clarity of a diamond by one or sometimes two grades. The

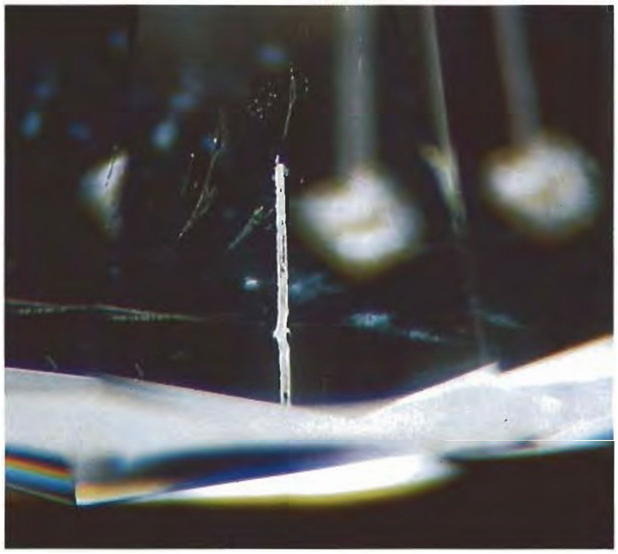


Figure 42. The laser drill hole in this diamond appears to end abruptly within the stone at no obvious feature. In reality, it terminates at a totally internal feather that was filled through the laser drill hole. Note the few minute gas bubbles in the filled break. Photomicrograph by Shane F. McClure; magnified 40×.

Yehuda treatment was found to lower apparent color grades in some but not all stones (Koivula et al., 1989; Koivula and Kammerling, 1990). In one group of Koss-treated diamonds (box A), the treatment lowered the apparent color grade of some stones, but the Goldman Oved samples showed no such effect.

Regardless of some of the claims made in the trade press, the fracture-filling treatments of *all three firms* can be detected using a binocular gemological microscope. While standard darkfield/brightfield illumination is often adequate for detecting the treatment, in some instances—especially with mounted stones—fiber-optic and other illumination techniques may be required. The most consistently encountered diagnostic microscopic features noted in all three products were as follows:

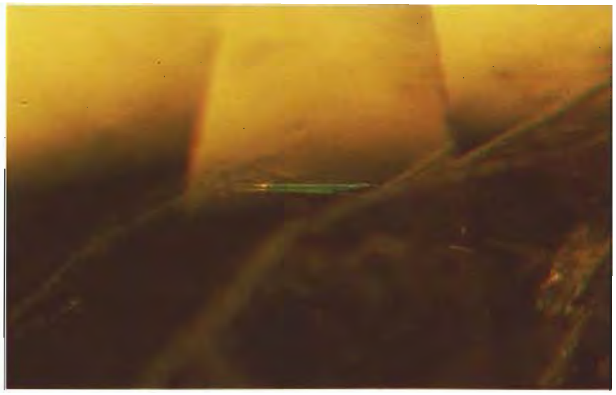
- Flash effects
- High-relief areas representing incomplete filling (trapped bubbles in the filling and/or thin, unfilled areas at surface entry points)
- Cloudy filled areas of reduced transparency that appear white

Other features noted with magnification in the products of one or more firms include a crackled texture or predominantly yellow color to the filler, as well as cloudy surface markings. Advanced laboratory tests that have proved useful in detecting the treatment are: X-radiography, which reveals the X-ray opacity of the filling material, as it typically contains one or more heavy elements; and EDXRF chemical analysis, which can detect trace amounts of heavy elements, especially lead (which was documented in the fillers of all three firms).

Although the suites of diagnostic features for filled stones from the three firms are not identical, there is significant overlap—both in the general types of features and in such specifics as the flash-effect colors. It also should be remembered that there are other firms that perform fracture filling of diamonds. It is reasonable to expect that their identifying features overlap those of the stones treated by Yehuda, Koss, and Goldman Oved. Thus, we conclude that *no individual gemological feature or suite of features will conclusively identify which firm treated a specific stone.*

The durability-testing phase of this study also provided useful information. In particular, prolonged exposure—or numerous short exposures—to commonly employed cleaning methods may damage the filling substances. Although such damage might be minor—as in the removal of a minute amount of filler at surface entry points—it could reveal treatment that had previously been unnoticed. For example, the appearance of a fine scratch on the surface where none had previously been

Figure 43. The orange flash from this filled fracture is almost completely masked by the yellow body color of the diamond. A small area of the complementary blue flash (seen here as green, because of the yellow body color) is visible in the center of the illustration. Photomicrograph by John I. Koivula; magnified 30×.



observed would be an unfortunate way of "disclosing" fracture filling to a customer. Jewelry repair procedures involving direct exposure to heat (as in retipping prongs) will damage and partially remove the filler from such treated diamonds. On a more positive note, we found that jewelry repair procedures involving *indirect* heating (as in sizing a ring) might not damage the fillings. Because exposure to long-wave UV radiation is comparable to exposure to sunlight (since natural sunlight contains a significant "UV-A" component), even prolonged exposure to daylight might have a negative effect on the appearance of fracture-filled diamonds. As with optical characteristics, the results of our durability testing do not substantiate some of the claims made in the trade press.

Because products from the various firms did not respond identically to all of the durability/stability tests—and in light of the highly publicized exchanges in the trade press concerning some of these products—it would not be surprising if these data were selectively used to help "substantiate" one product's alleged superiority over another. In this regard, there are some important considerations. First, the various durability tests in this study were, with one exception, performed on only one filled diamond from each of the three manufacturers. Therefore, *general conclusions cannot be drawn from the results of durability testing.* For example, the fact that one test diamond was not damaged by prolonged ultrasonic cleaning should not be misinterpreted to mean that all diamonds treated by that firm will necessarily be immune from such damage. Another diamond with larger or more extensive filled breaks—or one subjected to even longer cumulative cleaning times—might react differently.

Furthermore, while there may be some differences in the durability or stability of the products from the different firms, the "pedigree" of a filled diamond will probably not be known to the jeweler who takes it in for cleaning or repair. Thus, it may be best to proceed under the principle of "lowest common denominator," and not subject a filled diamond to any cleaning or repair procedure that has been shown to damage filled stones from any firm.

Because of these durability and stability concerns, it is evident that the apparent clarity and color grades of such treated stones can change over time. The GIA Gem Trade Laboratory therefore continues its policy of not grading diamonds that are found to have been fracture filled. Given the increasing numbers of fracture-filled diamonds, and the prospect that faceted synthetic diamonds will someday be commercially available, everyone in the gem, jewelry, and diamond industries should begin *now* to think of diamonds not only in terms of grading but also in terms of identification (as they currently do with colored stones).

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REFERENCES

Annual CIBJO Conference (1994). *Diamond Intelligence Briefs,* Vol. 10, Nos. 181–182, June 7, p. 1126.

Bates R. (1993a) Diamantaires' World Congress takes hard stance on disclosure. *National Jeweler,* Vol. 37, No. 14, July 16, pp. 1, 175.

Bates R. (1993b) Trade fractured over filled stones. *National Jeweler,* Vol. 37, No. 23, December 1, pp. 1, 55.

Bates R. (1994a) DMIA balks at trade use of "enhanced." *National Jeweler,* Vol. 38, No. 5, March 1, pp. 1, 86.

Bates R. (1994b) Helzberg's says no to clarity-enhanced. *National Jeweler,* Vol. 38, No. 2, January 16, p. 6.

Bates R. (1994c) CIBJO issues resolutions for treatment disclosure. *National Jeweler,* Vol. 38, No. 12, June 16, p. 4.

Beasley M. (1994) Helzberg Diamonds lays it on the line [letter to the editor]. *Jewelers' Circular-Keystone,* Vol. 165, No. 3, p. 25.

Beck W.R., Taylor N.W. (1958) High-index glass elements. *United States Patent No. 2,853,393,* September 23.

Blando G.A. (1994) Laser engrave enhanced stones? [letter to the editor]. *National Jeweler,* Vol. 38, No. 14, pp. 16, 18.

Bloss F.D. (1961) *An Introduction to the Methods of Optical Crystallography.* Holt, Rinehart, and Winston, New York.

Brown G. (1993) Value enhanced gems & gem materials—part 5. *Wahroongai News,* Vol. 26, No. 7, July, pp. 14–15.

Canadian Jeweller (1994) Advertisement of M.O.D. Diamonds Ltd. for Yehuda Treated Clarity Enhanced Diamonds. Vol. 115, No. 1, February, inside back cover.

Christiansen C. (1884, 1885) Untersuchungen über die optischen Eigenschaften von fein vertheilten Korpen. *Wiedemanns Annalen der Physik und Chemie (Neue Folge),* Vol. 23 (1884), pp. 298–306; Vol. 24 (1885), p. 439.

Clearly better, Doctor Diamond clarity enhanced diamonds (1994) *Jeweler's Circular-Keystone,* Vol. 165, No. 2, p. 60.

Collins A.T., Davies G., Woods G.S. (1986) Spectroscopic studies of the H1b and H1c absorption lines in irradiated, annealed type-Ia diamonds. *Journal of Physics C: Solid State Physics,* Vol. 19, pp. 3933–3944.

Crowningshield G.R. (1992) Gem trade lab notes: More on damage to fracture-filled diamonds—in cutting and cleaning. *Gems & Gemology,* Vol. 28, No. 3, p. 193.

Crowningshield G.R. (1993) Gem trade lab notes: Laser-assisted filling in diamond. *Gems & Gemology,* Vol. 29, No. 1, pp. 48–49.

DelRe N. (1991) Gem trade lab notes: Diamond, fracture filled. *Gems & Gemology,* Vol. 27, No. 2, p. 109.

Diamond leadership makes resolutions (1994) *Diamond Intelligence Briefs,* Vol. 10, No. 183, June 30, p. 1132.

Dodge N.B. (1948) The dark-field color immersion method. *American Mineralogist,* Vol. 33, pp. 541–549.

Dumbaugh W.H. (1978) Lead bismuthate glasses. *Physics and Chemistry of Glasses,* Vol. 19, No. 6, pp. 121–125.

Dumbaugh W.H. (1984) Oxide glasses with superior infrared transmission. In Society for Photooptical Instrumentation Engineers, Vol. 505, *Advances in Optical Materials,* Bellingham, WA, pp. 97–101.

Dumbaugh W.H. (1986) Heavy metal oxide glasses containing Bi_2O_3. *Physics and Chemistry of Glasses,* Vol. 27, No. 3, pp. 119–123.

Even-Zohar C. (1994a) Ban introduced on treated rough diamonds. *Mazal U'Bracha,* Vol. 10, No. 59, pp. 64–65.

Even-Zohar C. (1994b) Gemological research out of this world. *Mazal U'Bracha,* Vol. 10, No. 57, pp. 46–47, 50.

Everhart J. (1993a) Lasers: A new way of detecting fracture-filled diamonds? *Rapaport Diamond Report,* Vol. 16, No. 35, November 5, p. 9.

Everhart J. (1993b) Filled-diamond exposé rocks St. Louis. *Rapaport Diamond Report,* Vol. 16, No. 32, October 15, pp. 1, 5–9.

Everhart J. (1993c) Jewelry sales down in St. Louis in wake of filled-diamond exposé. *Rapaport Diamond Report,* Vol. 16, No. 35, November 5, pp. 9–10.

Everhart J. (1993d) St. Louis jeweler fined $50,000. *Rapaport Diamond Report,* Vol. 16, No. 38, December 3, pp. 1, 6–8.

Everhart J. (1993e) Gem labs see no advantage to laser technique. *Rapaport Diamond Report,* Vol. 16, No. 38, December 3, pp. 9–10.

Federman D. (1994) Fixing a hole. In "Israel's quick-change artists," *Modern Jeweler,* Vol. 93, No. 7, pp. 50–60.

Field J.E. (1979) *The Properties of Diamond.* Academic Press, London.

Five on Your Side, with Jody Davis (1993) KSDK [channel 5], St. Louis, MO, August 27, September 1, 9.

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

Hargett D. (1992) Gem trade lab notes: Diamond, heat-damaged filled diamond. *Gems & Gemology,* Vol. 28, No. 2, p. 123.

IJO takes stand against fracture-filled diamonds (1994) *Jewelers' Circular-Keystone,* Vol. 165, No. 9, p. 26.

Kammerling R.C., McClure S.F. (1993) Gem trade lab notes: Extensive, subtle fracture filling in diamond. *Gems & Gemology,* Vol. 29, No. 2, p. 123.

Koivula J.I. (1980) 'Thin films'—elusive beauty in the world of inclusions. *Gems & Gemology,* Vol. 16, No. 9, pp. 326–330.

Koivula J.I. (1982) Shadowing: A new method of image enhancement for gemological microscopy. *Gems & Gemology,* Vol. 18, No. 3, pp. 160–164.

Koivula J.I., Kammerling R.C., Fritsch E., Fryer C.W., Hargett D., Kane R.E. (1989) The characteristics and identification of filled diamonds. *Gems & Gemology,* Vol. 25, No. 2, pp. 68–83.

Koivula J.I., Kammerling R.C. (1990) Gem news: Filled diamond update. *Gems & Gemology,* Vol. 26, No. 1, pp. 103–105.

Koss D. (1993) Koss claims 'almost zero' flash effect in its treated diamonds [letter to the editor]. *Rapaport Diamond Report,* Vol. 16, No. 38, December 3, p. 2.

Koss D. (1994a) A 'sporting challenge' to Yehuda [letter to the editor]. *Rapaport Diamond Report,* Vol. 17, No. 5, February 4, p. 2.

Koss D. (1994b) 'Not-so-ancient test' [letter to the editor]. *Rapaport Diamond Report,* Vol. 17, No. 17, May 6, p. 37.

Koss D. (1994c) Filled diamond debate [letter to the editor]. *Jewelers' Circular-Keystone,* Vol. 165, No. 6, pp. 54, 56.

Koss D. (1994d) Math & aftermath [letter to the editor]. *Cornerstone,* Summer, pp. 1–2.

Koss to make fill more visible (1994) *Jewelers' Circular-Keystone,* Vol. 165, No. 8, p. 66.

Kusko J. (1993/94) Filled diamonds causing industry angst. *Jewellery World,* Vol. 13, No. 1, pp. 26–29.

Labs asked not to grade filled gems (1994). *Jewelers' Circular-Keystone,* Vol. 165, No. 2, pp. 64–65.

Levy H. (1993) Diamond fillings. *Gem and Jewellery News,* Vol. 3, No. 1, pp. 3–4.

Manufacturer places burden of fracture-filling on suppliers (1994). *The Diamond Registry,* Vol. 26, No. 8, p. 4.

Nassau K. (1994) On diamond-filling glasses and Nelson's speculations. *Journal of Gemmology,* Vol. 24, No. 3, pp. 183–184.

Nelson J.B. (1993) The glass filling of diamonds, part 1: An explanation of the colour flashes. *Journal of Gemmology,* Vol. 23, No. 8, pp. 461–472.

Nelson J.B. (1994) The glass filling of diamonds, part 2: A possible filling process. *Journal of Gemmology,* Vol. 24, No. 2, pp. 94–103.

A new stone is born, Genesis II [advertisement] (1994) *Jewelers' Circular-Keystone,* Vol. 165, No. 2, p. 48.

Oriel Corp. (1982) *Solar Simulator for Research and Industry* (rev. ed.). Oriel Corp., Stamford, CT.

Prime Time Live, with Diane Sawyer (1993) ABC television network, November 4.

Quam M. (1993) Jeweler beware! *Jewelers Inc.,* May, p. 6.

Rapaport M. (1987) Diamond treatment—buyers beware! *Rapaport Diamond Report,* Vol. 10, No. 32, September 4, p. 8.

Rapaport M. (1993) World Diamond Congress blasts diamond treatment. *Rapaport Diamond Report,* Vol. 16, No. 23, July 16, pp. 1, 3–4.

Roisen J. (1994) Appropriate terms for treated diamonds. *New York Diamonds,* No. 24, March, p. 10.

Rubin R. (1994) Dealers ask labs' cooperation. *National Jeweler,* Vol. 38, No. 1, January 1, pp. 1, 19.

Shapiro R. (1994) 'Truth in merchandising' for filled diamonds [letter to the editor]. *Rapaport Diamond Report,* Vol. 17, No. 5, February 4, p. 2.

Shor R. (1993) Filled diamonds: Are the tell-tale signs enough? *Jewelers' Circular-Keystone,* Vol. 164, No. 9, pp. 48–51.

Shor R. (1993/1994) Filled diamond case brings more disclosure calls. *Diamant,* No. 370, December-January, pp. 13–14.

Shor R. (1994) Fracture-filled diamond fight flares anew. *Jewelers' Circular-Keystone,* Vol. 165, No. 4, pp. 66–69.

Shuster W.G. (1994) IJO opens Antwerp office; opposes filled diamonds. *Jewelers' Circular-Keystone*, Vol. 165, No. 10, pp. 140, 142.

Turro N.J. (1978) *Modern Molecular Photochemistry*. Benjamin/Cummings Publishing, Menlo Park, CA.

Wakefield S. (1993) Fracture-filled diamonds: A ticking time bomb? *Cornerstone*, Autumn, pp. 1, 3–5.

Wakefield S. (1994a) Koss diamond treatment said to be 'unstable' [letter to the editor]. *Rapaport Diamond Report*, Vol. 17, No. 1, January 7, p. 2.

Wakefield S. (1994b) Koss' challenge 'not sporting.' *Rapaport Diamond Report*, Vol. 17, No. 6, March 4, p. 2.

Wakefield S. (1994c) Wakefield fires back. *Rapaport Diamond Report*, Vol. 17, No. 8, June 3, pp. 2, 37.

Wakefield S. (1994d) Filled diamond debate [letter to the editor]. *Jewelers' Circular-Keystone*, Vol. 165, No. 6, pp. 54, 56, 58.

Wakefield S. (1994e) Response from Sharon Wakefield [letter to the editor]. *Cornerstone*, Summer, pp. 2–4.

Windman J. (1994) Fracture filled diamonds from sale to repair take-in, a JVC warning. *News & Views Supplement*, February/March.

Yehuda diamonds offer great option for price- and size-conscious customers [advertisement] (1994). *Jewelers' Circular-Keystone*, Vol. 165, No. 3, p. 99.

Yehuda R. (1993) Yehuda responds to GIA article [letter to the editor]. *Rapaport Diamond Report*, Vol. 16, No. 32, October 15, p. 3.

Yehuda R. (1994a) Yehuda challenges Koss statements [letter to the editor]. *Rapaport Diamond Report*, Vol. 17, No. 1, January 7, p. 34.

Yehuda R. (1994b) Yehuda tells Koss: 'Go back to the lab' [letter to the editor]. *Rapaport Diamond Report*, Vol. 17, No. 7, April 8, p. 35.

COPPER AND TENORITE INCLUSIONS IN CUPRIAN-ELBAITE TOURMALINE FROM PARAÍBA, BRAZIL

By Franz Brandstätter and Gerhard Niedermayr

Inclusions of native copper and tenorite (CuO) were found in grayish green elbaite from São José da Batalha, Paraíba, Brazil. Native copper forms strongly dendritic platelets (about 100 μm long, 1 μm thick) oriented parallel to the c-axis of the host crystal in a trigonal arrangement. The much less abundant tenorite forms 20–30 μm platy grains. Electron microprobe analyses revealed that the tourmaline is cuprian elbaite (1 wt.% CuO), with significant contents of iron (2.7–3.1 wt.% FeO) and manganese (0.9–1.4 wt.% MnO). The CuO content of tourmaline around the native copper decreases toward these inclusions up to a factor of two. No such decrease in CuO was observed for the tenorite inclusions.

In 1989, unusually intense blue and green tourmalines appeared on the international market (figure 1). They reportedly came from a locality called Mina da Batalha, close to the village of São José da Batalha, in Paraíba State, Brazil (see, e.g., Koivula and Kammerling, 1989). Subsequent research revealed that the vivid yellowish green to blue-green colors of these tourmalines are mainly due to their copper (Cu) content (Fritsch et al., 1990; Rossman et al., 1991). Although the Cu concentration reported in these tourmalines (0.4–2.4 wt.% CuO) is among the highest ever analyzed in nominally Cu-free silicates, no information was available regarding the source of the Cu responsible for the unusual colors.

In September 1992, Mr. F. Janousek, a mineral collector from Vienna, showed us several pieces of tourmaline that he had selected in Brazil a couple of months previously from a lot of more than 100 similar-appearing tourmaline crystals and fragments. The miner from whom he purchased the material said that it came from Paraíba. All of the tourmalines contained numerous metallic yellow specks (similar to those seen on the table of the Paraíba tourmaline in figure 2). He gave us three representative pieces of this material and asked us to determine the nature of these unusual-appearing inclusions.

ABOUT THE AUTHOR

Both authors are mineralogists in the Museum of Natural History in Vienna (Naturhistorisches Museum Wien), Mineralogisch-Petrographische Abteilung, Burgring 7, A-1014 Vienna, Austria. Dr. Brandstätter specializes in mineral analysis by scanning electron microscopy and electron microprobe techniques; Dr. Niedermayr is curator of the mineral collection and head of the Staatliches Edelsteininstitut (State Gemological Institute).

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Figure 1. The striking blues and greens of these elbaite tourmalines from Paraíba, Brazil, are caused by the presence of copper in their structure. Stones (largest, upper right, is 26.63 ct) courtesy of Michael Scott; photo © Harold & Erica Van Pelt.

PREVIOUS WORK

Bank et al. (1990) and Fritsch et al. (1990) provided brief comments on the regional geology and mining history of the Paraíba tourmalines, together with detailed reports about their mineralogical and gemological properties. Microprobe analyses proved the tourmalines to be elbaites, with MnO and CuO contents up to 3.0 and 2.4 wt.%, respectively. In these reports, no explanation was given for the source of the unusually high Cu content of these elbaites. Fritsch et al. (1990) mentioned typical inclusions for gem tourmalines: three-phase, liquid (in veils or "fingerprint" patterns), thin growth tubes parallel to the c-axis, and some doubly refractive crystals. Also mentioned and illustrated were "numerous yellowish specks" that local miners had assumed to be gold (see figure 11 on p. 197 of that article). X-ray fluorescence analyses cited by the authors revealed the presence of Mn, Fe, Cu, Zn, and Bi, as well as some S; this implies that these metallic inclusions could be composed of a sulfide with a certain Fe content. In a short item in the Fall 1992 issue of *Gems & Gemology*, Koivula et al. reported the appearance of such inclusions near the surface of a cut Paraíba tourmaline and suggested that they might be the product of epigenetic exsolution. They pointed to the fact that "microchemical testing with nitric acid, done on a crystal with exposed inclusions, indicated the presence of copper." Brandstätter and Niedermayr (1993) proved these inclusions to be native copper.

Henn and Bank (1990), Fritsch et al. (1990), and Rossman et al. (1991) investigated the origin of color in the cuprian elbaites. According to their findings, the incorporation of Cu^{2+} into the tourmaline structure is the main cause for the exceptional hues. Some modification of the elbaite colors to violet-blue and violet hues is ascribed to increasing absorption from Mn^{3+}.

MATERIALS AND METHODS

All analytic results mentioned here were obtained from Mr. Janousek's three tourmaline specimens, which he said were representative of the tourmaline lot he had seen in Brazil. All of the samples were grayish green: a 1-cm-long crystal fragment weighing 0.7 ct, a 0.9-ct cabochon, and a 1-cm-long terminated crystal that weighed 10 ct. The crystal showed the striated prism faces typical of tourmaline and the pyramid $\{10\bar{1}1\}$ only. At the irregular base of this crystal, white platy albite was intergrown with the gem host.

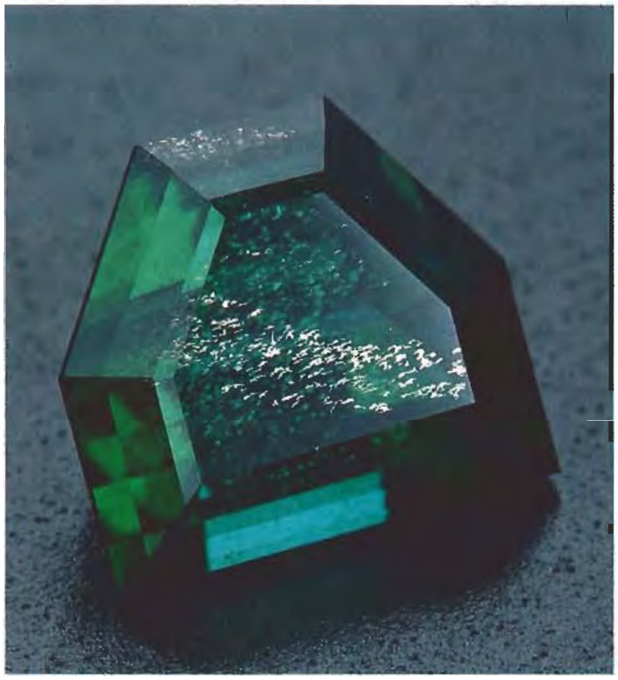

Figure 2. On this 2.41-ct faceted Paraíba tourmaline, the yellow platelets are seen near the surface, running across the table facet. Photo by Maha DeMaggio.

As a first step, the flattened crystal fragment was cut parallel to the c-axis and polished on one side. As a second step, the same crystal was cut perpendicular to the c-axis and a polished thin section was made.

Specific gravity was determined on all three specimens by the hydrostatic method; optical properties, using a standard gemological refractometer; and pleochroism, with a calcite dichroscope. Chemical composition was determined on two of these specimens (the cut crystal fragment and the cabochon). Qualitative chemical analysis and investigation of morphology and orientation of the inclusions on the polished tourmaline surface (cut parallel to the c-axis) were carried out on a JEOL JSM-6400 scanning electron microscope equipped with a KEVEX energy-dispersive system (SEM-EDS). Then five randomly located spots were selected on both specimens for quantitative chemical analysis with an ARL-SEMQ electron microprobe. To reduce sample decomposition, we analyzed the spots with a defocused beam (area 100 μm^2) at 15kV, 20nA. The analyses were corrected by standard procedures using natural and synthetic standards.

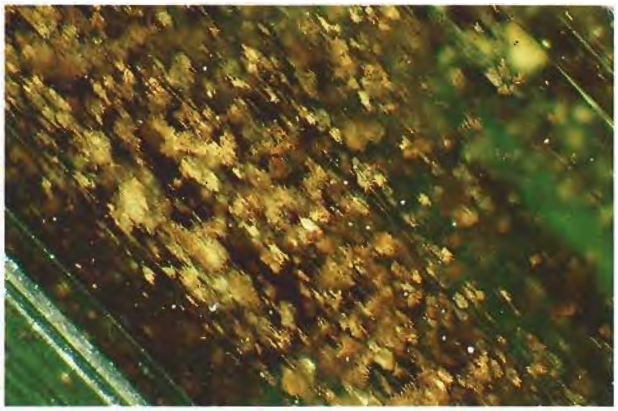

Figure 3. With magnification, numerous specks of a yellow metallic mineral were evident in the Paraíba tourmalines examined. Photo by Gerhard Niedermayr; field of view, 1.5 cm.

RESULTS

Optical Properties. The gemological properties (refractive indices, birefringence, and specific gravity) of these three samples are consistent with those reported by Fritsch et al. (1990) for two—one yellowish green, the other greenish gray—Paraíba tourmalines of similar color. All three samples were grayish green color and with typical pleochroism (ε = yellowish green, ω = grayish green). Refractive indices were measured as follows: $\varepsilon = 1.622$–1.624, $\omega = 1.642$–1.644, with a birefringence of 0.020; uniaxial negative. Specific gravity was 2.99.

Inclusions. When examined with magnification, all three specimens exhibited the standard suite of fluid, three-phase, and crystalline (e.g., tourmaline) inclusions typical for elbaite tourmalines. In addition, however, we noted platelets of a yellow material with a metallic luster (figure 3). In transmitted light, the yellow metallic inclusions turned out to be numerous minute, strongly skeletal, branching platelets on the average 100 µm long and only 1 µm thick (figure 4). They were reminiscent of the typical branching growth characteristic of native copper. With the microscope and reflected light (at a magnification of about 120×), we observed a few irregularly scattered grains that had a different reflectance behavior in the polished tourmaline sample that was cut parallel and perpendicular to the c-axis.

Chemical Analyses. As can be seen from table 1, there are some differences in the contents of CuO (1.01 and 1.02 wt.%) and FeO (2.71 and 3.10 wt.%)

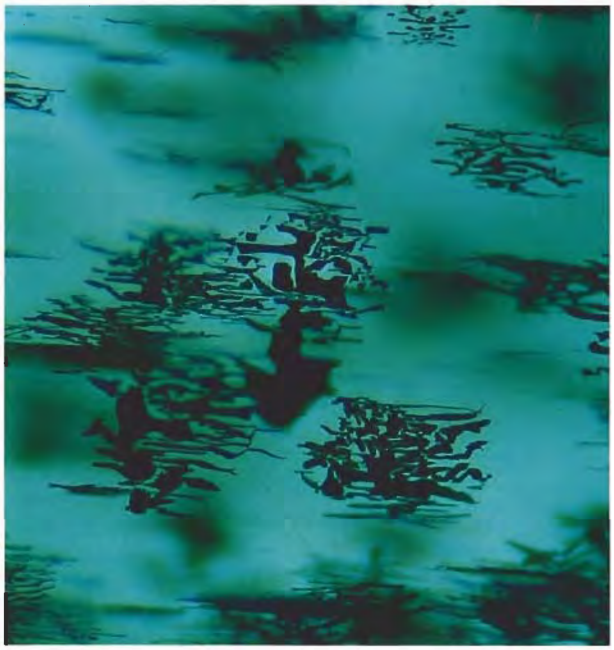

Figure 4. At higher magnification, the "gold"-colored specks reveal a dendritic form that is typical for native copper. Photo by Gerhard Niedermayr; field of view, 600 µm.

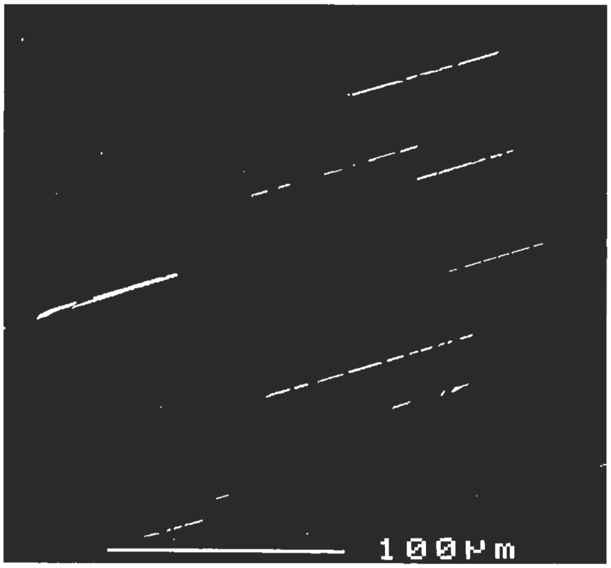

Figure 5. Note in this backscattered electron image of native copper (white) in cuprian elbaite (gray) from Paraíba that the copper inclusions are oriented parallel to the c-axis of the tourmaline. "Dashed lamellae" indicate the dendritic morphology of these platelets.

in the two specimens we analyzed as compared to the two specimens of similar color for which microprobe analyses were reported by Fritsch et al. (1990). Although the CuO content of our samples is within the total range (0.37–2.38 wt.%) for Paraíba elbaites of different colors given in that article, the FeO content is significantly higher (maximum FeO of 0.34 wt.%).

SEM analysis of the dendritic platelets proved that they are indeed native copper. The SEM investigations of one specimen revealed that the platelets are oriented parallel to the c-axis of the tourmaline (figure 5). In the thin section cut perpendicular to the c-axis, the arrangement of the copper platelets revealed the trigonal symmetry of tourmaline (figure 6). In addition, we subsequently identified (by SEM-EDS, confirmed by microprobe) the grains seen at high magnification as tenorite (CuO). As seen on the scanning electron micrograph, the tenorite grains (figure 7) commonly form subhedral platy crystals measuring 20–30 µm. In contrast to the copper platelets, the tenorite inclusions apparently do not show an oriented intergrowth with the host crystal.

Electron microprobe traverses perpendicular to the copper platelets and to the c-axis of the host tourmaline (figure 8) indicated that the CuO content of the tourmaline examined decreases—from 1.2 wt.% (maximum) to about 0.6 wt.% (minimum content)—in the direction toward the inclusions. We did not observe a corresponding variation in the CuO content of the tourmaline around tenorite inclusions.

TABLE 1. Electron microprobe analyses (in wt.%) of four elbaite tourmalines from Paraiba, Brazil.[a]

	Sample No.[b]			
Oxide	1a	1b	2	3
SiO_2	36.6	36.8	37.27	37.29
TiO_2	0.17	0.14	0.10	0.07
B_2O_3	n.d.	n.d.	10.94	10.94
Al_2O_3	40.2	38.2	39.04	38.73
Cr_2O_3	< 0.02	< 0.02	< 0.02	< 0.02
FeO	2.71	3.10	0.22	0.12
MnO	1.42	0.92	1.47	2.99
CuO	1.01	1.02	0.37	0.49
MgO	0.49	0.52	0.54	0.30
CaO	0.25	0.34	0.46	0.45
Li_2O	n.d.	n.d.	1.62	1.62
Na_2O	2.22	2.29	2.27	2.36
K_2O	0.03	0.04	0.03	0.02
H_2O	n.d.	n.d.	3.13	3.13

[a] *For description of equipment and analytical technique, see the "Materials and Methods" section.*

[b] *Samples 1a and 1b are the average of five single analyses on two of the grayish green tourmalines examined for this article. Sample 2 is a yellowish green elbaite (GIA no. R50) and sample 3 is a greenish gray elbaite (GIA no. R378), as reported in Fritsch et al. (1990). Total Fe and Mn are given as FeO and MnO, respectively. Li_2O, B_2O_3, and H_2O were not determined (n.d.) for samples 1a and 1b, and were calculated on an assumed stoichiometry for samples 2 and 3.*

DISCUSSION AND CONCLUSION

The existence of inclusions of native copper and tenorite, together with the determination of a high Cu content, in some Paraíba tourmalines indicates that these elbaites formed under unusual conditions for a granitic pegmatite environment.

Because to date there have been no comprehensive reports on the local geology, one can only speculate about the origin of the Cu enrichment. For example, pegmatitic fluids could have been enriched in Cu as a result of the interaction with pre-existing Cu-bearing mineralization or by the accumulation of Cu in an earlier magmatic stage of the pegmatite's evolution. Typically, however, granitic rocks have very little Cu, and Cu is not known generally to accumulate in pegmatitic melts (see, e.g., Wedepohl, 1974).

Irrespective of the process that caused the Cu enrichment, from our observations it seems most likely that the native copper (and tenorite?) inclusions were formed in an early stage of cooling after crystallization of the tourmalines had begun. The assumption of syngenetic precipitation of native copper during growth of these tourmalines does not agree with the observation of unoriented, scattered copper platelets in triangular arrangement (again, see figure 6). It is also possible, however, to interpret the tenorite inclusions as remnants of pre-existing Cu mineralization. This hypothesis is supported by our findings that—in contrast to the chemical changes observed in conjunction with the inclusions of native copper—there was no systematic change in the CuO content of the host tourmaline in relation to the tenorite inclusions. However, we cannot exclude with certainty the possibility that because of the small size of the tenorite inclusions, any chemical change around them is below the detection limit of the microprobe.

Figure 6. In this thin section of Paraíba tourmaline cut perpendicular to the c-axis, the arrangement of copper inclusions clearly reveals the trigonal symmetry of the host crystal. Photo by Gerhard Niedermayr; field of view, 600 µm.

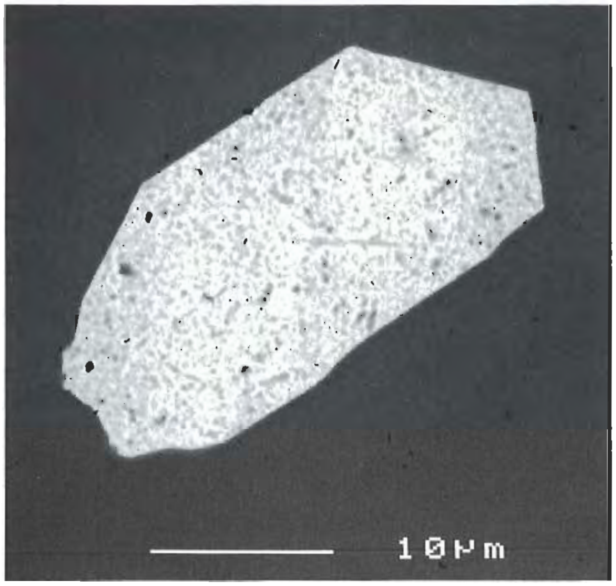

Figure 7. Subhedral tenorite (light gray) can be seen in this backscattered electron image of cuprian elbaite (dark gray) from Paraíba, Brazil.

The trigonal arrangement of the copper platelets indicates exsolution from the cuprian tourmaline. This had been suggested earlier by Koivula et al. (1992), who interpreted these inclusions as epigenetic exsolution, but did not explicitly state that they might actually be copper platelets. Similar types of growth features have been observed in ruby and sapphire: rutile needles and silk, formed by exsolution, that exhibit an epitaxial relationship to the host corundum. Gübelin and Koivula (1986) described diskettes of copper formed by solid-solution exsolution in labradorite feldspar ("sunstone") from Oregon. A more extensive investigation of this interesting material has since been made by Johnston et al. (1991).

In a compilation of native-element inclusions in minerals, Koivula (1991) mentioned copper inclusions in analcime, apophyllite, datolite, labradorite, natrolite, orthoclase, prehnite, quartz, calcite, and gypsum. To our knowledge, none of

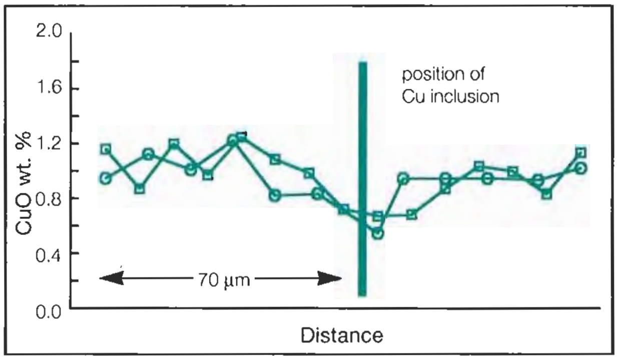

Figure 8. From this plot of CuO content in a Paraíba tourmaline (two electron microprobe traverses) as it relates to distance from native copper inclusions, it is evident that the CuO content of the host tourmaline decreases as the beam gets closer to the inclusions.

these mineral species contains Cu in its crystal lattice. Thus, for the minerals Koivula described, it is most likely that native copper precipitated syngenetically on earlier faces of the growing crystals of these minerals. The Paraíba tourmalines differ in that Cu^{2+} is incorporated into the tourmaline structure to a certain extent (e.g., Rossman et al., 1991). As described earlier, the copper platelets are aligned parallel to c but are otherwise scattered throughout the host crystal in an irregular manner. Therefore, we assume that these platelets are more likely a product of epigenetic exsolution than of epitactic overgrowth.

In any case, tourmaline must be added to the list of silicates where inclusions of native copper have been detected.

REFERENCES

Bank H., Henn U., Bank F.H., Platen H.v., Hofmeister W. (1990) Leuchtendblaue Cu-führende Turmaline aus Paraíba, Brasilien. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 39, No. 1, pp. 3–11.

Brandstätter F., Niedermayr G. (1993) Einschlüsse von gediegen Kupfer in Cu-Elbait von São José da Batalha in Paraíba, Brasilien. *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 42, No. 1, pp. 37–41.

Fritsch E., Shigley J.E., Rossman G.R., Mercer M.E., Muhlmeister S.M., Moon M. (1990) Gem-quality cuprian-elbaite tourmalines from São José da Batalha, Paraíba, Brazil. *Gems & Gemology*, Vol. 26, No. 3, pp. 189-205.

Gübelin E.J., Koivula J.I. (1986) *Photoatlas of Inclusions in Gemstones.* ABC Edition, Zürich.

Henn U., Bank H. (1990) On the colour and pleochroism of Cu-bearing green and blue tourmalines from Paraíba, Brazil. *Neues Jahrbuch für Mineralogie, Monatshefte.* No. 6, pp. 280–288.

Johnston C.L., Gunter M.E., Knowles C.R. (1991) Sunstone labradorite from the Ponderosa Mine, Oregon. *Gems & Gemology*, Vol. 27, No. 4, pp. 220–233.

Koivula J.I. (1991) Native element inclusions. *Lapidary Journal*, Vol. 44, No. 11, pp. 48–61.

Koivula J.I., Kammerling R.C. (1989) Gem news: Unusual tourmalines from Brazil. *Gems & Gemology*, Vol. 25, No. 3, pp. 181–182.

Koivula J.I., Kammerling R.C., Fritsch E. (1992) Gem news: Tourmaline with distinctive inclusions. *Gems & Gemology*, Vol. 28, No. 3, pp. 204–205.

Rossman G.R., Fritsch E., Shigley J.E. (1991) Origin of color in cuprian elbaite from São José da Batalha, Paraíba, Brazil. *American Mineralogist*, Vol. 76, Nos. 9/10, pp. 1479–1484.

Wedepohl K.H. (1974) Copper. In K. H. Wedepohl, Ed., *Handbook of Geochemistry*, Vol. II-2, Chap. 29, Springer Verlag, Berlin.

GEM TRADE LAB NOTES

CERAMIC Statue

Occasionally, carvings or statues come into the lab that we suspect are created from manufactured materials, but the difficulty may come in trying to prove this. A case in point occurred last May, when the West Coast lab was asked to identify an opaque, artistically stained "carving" of a seated man with a dragon (figure 1). Several clues led us to suspect that it was fashioned from a material that was not of natural origin.

For example, the "carving" had a half-inch (approximately 1 cm) hole in its base. This would serve no obvious purpose in a rock carving, but it would enable gases to escape from a ceramic during firing. Also, certain scratches on the statue showed parallel striations that were difficult to explain unless they had occurred while the material was still soft (i.e., before firing). The object was cracked in several places, and some of the cracks were filled with a material that burned when touched with the thermal reaction tester (hot point). The dragon's snout had been replaced with what appeared to be the same filling material. The balance of the cracks were empty. None showed any of the vein-filling minerals (e.g., quartz, calcite) that might be expected in a rock.

To confirm our suspicions, we took a minute amount of powder from two spots on the statue's surface for X-ray diffraction analysis. Long exposures to the X-ray beam produced patterns that contained 15 faint lines. These were subsequently identified as matching lines in the patterns of mullite ($Al_6Si_2O_{13}$), kalsilite ($KAlSiO_4$), and possibly gehlenite ($Ca_2Al_2SiO_7$). We believe the patterns were faint because most of the material had become amorphous after firing, with only a small amount of mullite and kalsilite formed. Energy-dispersive X-ray fluorescence spectroscopy (EDXRF) detected Al, Si, Ca, K, and a trace of Fe, which was in agreement with these identifications.

Figure 1. This 40-mm-high "carving" proved to be a ceramic product.

Mullite, kalsilite, and gehlenite are rare minerals that occur in unusual geologic environments. In particular, mullite occurs only in metamorphic rocks, and kalsilite occurs only in alkali basalts; they do not occur together. However, all three minerals are known to occur in ceramics; in fact, mullite was originally discovered in firebricks and porcelains. Thus, the unusual mix of minerals conclusively proved that this statue was a fired, but unglazed ceramic.

MLJ, Dino De Ghionno, and Patricia Maddison

Large "Knot" in CITRINE

As gemologists, we usually think of inclusions as minute internal features seen only with magnification. For most gem materials, the presence of eye-visible inclusions is considered to detract from the value. In other instances, however, eye-visible inclusions are desirable and are even included in the gemstone's name. Examples of the latter include acicular rutile crystals in rutilated quartz, tourmaline needles in tourmalinated quartz, and dendritic manganese oxide precipitates in dendritic and moss agates. Still a third category, however, is the presence of an unusual eye-visible inclusion in an otherwise transparent gem material that gives that gem a distinctive appearance.

The West Coast lab received for identification a sizable (229.09 ct, measuring 40.40 × 28.31 × 21.60 mm) faceted stone that appeared to have been cut specifically to display a large included crystal in the center of its table (figure 2), with the inclusion's well-formed first-order prism termination pointing toward the pavilion. Using standard gem-testing techniques, we identified the transparent, light brownish yellow, modified rectangular step cut as natural citrine quartz.

Using similar testing methods, we determined that the large inclu-

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

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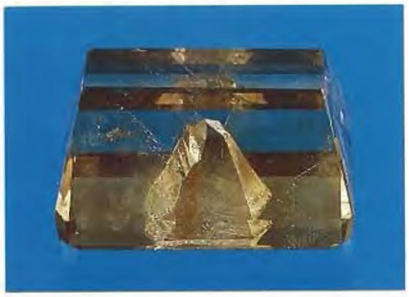


Figure 2. This 229.09-ct citrine was apparently cut to prominently display a large quartz inclusion.

sion was also quartz. Polariscope testing showed that the crystallographic orientation of the inclusion was different from that of the host. With diamonds, the term *knot* is used to describe an included diamond crystal that is oriented differently from the host diamond. By this definition, the inclusion in this citrine could be thought of as a quartz "knot." *RCK and KH*

DIAMOND

Americium-Treated Green Diamond

A 0.43-ct yellowish green, Old European–cut diamond submitted to the East Coast laboratory for an origin-of-color report revealed uneven color that was a challenge to interpret. The stone had two naturals at the girdle, but neither area was green. Instead, shallow, pale green blotches (which did not photograph well because they were very subtle) were visible on the table and the lower half of the pavilion. We saw them best by using diffused light with the stone immersed in methylene iodide. The visible spectrum, obtained with a Pye-Unicam SP8-400 spectrophotometer, showed a broad GR1 absorption band at 741 nm; this is typical of "surface-skin" green coloration, whether produced by natural irradiation or by laboratory treatment.

However, the pattern of green spots on polished facets of this stone indicated treatment with radioactive salts. Such treatment usually leaves some residual radioactivity in the diamond, but this stone showed no radioactivity above background levels when checked with a handheld Geiger counter. To determine if there was radioactivity below the detection limits of this type of meter, we sent the stone to the West Coast laboratory for radiation testing. A three-hour scan for gamma rays revealed a small, but significant, peak from americium-241 (^{241}Am), an artificial radionuclide, thus proving that the color of this diamond was due to treatment. The amount of radioactivity present corresponded to 0.09 nCi/g of ^{241}Am. (Analysis of another americium-treated diamond was described by C. E. Ashbaugh III in the article "Gamma-Ray Spectroscopy to Measure Radioactivity in Gemstones," *Gems & Gemology*, Summer 1992, pp. 104–111.)

Possession and sale of ^{241}Am, which has a half-life of 432.7 years, is regulated in the U.S. by the Nuclear Regulatory Commission. Because ^{241}Am is readily oxidized, can be inhaled, and is also an alpha emitter (alpha particles transmit their energy to human tissue with high efficiency), the NRC limit for permissible ^{241}Am exposure is very low. This diamond, although too low in radioactivity to register on a Geiger counter, may not be legally sold or distributed in the United States until the 50th century (see the letter by W. W. Hanneman regarding such regulations, on page 80 of the Summer 1993 *Gems & Gemology*.)

The abraded facet junctions on the crown, together with its old-fashioned cut, indicated that this stone was faceted long before americium was first made in the late 1940s or early 1950s. The reader is cautioned that a diamond may be treated at any time to alter its color, so indications that a fashioned diamond is old do not guarantee that the color is of natural origin. *IR and MLJ*

Unusual Triangular Inclusion in a Diamond

A 3.31-ct marquise-shaped brilliant-cut diamond submitted to the West Coast laboratory for full grading revealed an unusual inclusion. In addition to a white "cloud" that had been reached by a laser drill hole (in itself not unusual), there was a curious dark, flat, triangular inclusion that had no connection to either the white cloud, the laser drill hole, or the surface of the stone (figure 3).

Just as interesting as the inclusion itself (which was presumably graphite) was the question of what caused it. Three possibilities came to mind:

1. Triangular surface features (trigons) occur as shallow, flat-bottomed depressions or shallow pyramidal pits. Perhaps this is a growth phantom, a trigon that was filled with the dark material before diamond growth continued around it.
2. Stacking faults in diamond can cause flat triangular (or truncated triangular) patches of hexagonal-

Figure 3. This triangular inclusion in a diamond appears to be filled with graphite. The laser drill hole seen here actually goes to the cloud behind the inclusion, not to the inclusion itself. Magnified 45×.

structure diamond (lonsdaleite), which is usually only detected by X-ray tomography (see, e.g., J. E. Field, ed., *Properties of Natural and Synthetic Diamonds*, Academic Press, London, 1992, pp. 217 and 218). This may have been an inclusion of lonsdaleite that, because it is less stable than (isometric) diamond, later reverted to graphite.

3. It may have been an inclusion of some other shape on which the faces altered to a negative-crystal macle, although the sharp triangular points make this unlikely. However, trigons have been seen in crystal inclusions in diamond (E. J. Gübelin and J. I. Koivula, *Photoatlas of Inclusions in Gemstones*, ABC Edition, Zurich, 1986, p. 95), and in diamond (Gem Trade Lab Notes, *Gems & Gemology*, Spring 1990, p. 95).

Because the triangular shape does not appear to be equilateral, the reverted-lonsdaleite explanation is probably the most plausible.

MLJ

Figure 4. This 47.31-ct cut-cornered, faceted triangle is a rock composed primarily of white grossular garnet and green diopside.

GROSSULAR-DIOPSIDE Rock

Various rough and cut samples of a handsome, mottled white-and-green rock (represented to be massive grossular garnet) were recently seen in the West Coast GIA Gem Trade Laboratory. All polished pieces of this material, like that in figure 4, show variations in luster. A spot refractive index of 1.74 was obtained on one piece.

Four separate materials could be seen through the microscope: high-luster, opaque round green grains; a lower-luster, semi-translucent white material that in most cases made up the bulk of the rock; a high-luster, translucent gray-to-brown material (usually occurring as veins); and a low-luster, semi-translucent white vein material. X-ray powder diffraction analyses proved these to be, respectively: diopside, grossular garnet, idocrase, and clinochlore (a member of the chlorite group). White grossular was the most common mineral by volume in most of the samples we examined, although at least one massive piece was predominantly idocrase; we also saw a brownish yellow-green semi-transparent idocrase cabochon.

The combination of grossular with diopside and idocrase is typical for calcium-rich veins (called rodingites) that are found in metamorphosed ocean sediments. This may be the origin of this material, and some of the rough we examined shows slickensides (striations caused by slippage along a fault plane).

Miners of this material informed us that it comes from northern Washington State. Core drilling indicates that the grossular-rich layer in the deposit is as much as 35 feet (about 11 m) thick. Blocks weighing up to almost 50 kg have been cut on site from this layer.

MLJ

Iron-Rich HORNBLENDE

A necklace of highly polished, 10-mm opaque black beads (figure 5) was purchased in Tucson, Arizona, as black jadeite that had been mined in that state. Our client was skeptical because of the appearance (e.g., quality of the polish) of the beads and the rarity of black jadeite (most commercial black jade is nephrite).

Figure 5. Although these 10-mm opaque black beads were purchased as jadeite from Arizona, extensive testing revealed that they are actually ferrohornblende.

Although the gem name *jade* is properly used for either jadeite or nephrite, they are two wholly unrelated minerals that sometimes occur in similar colors. Jadeite is a single mineral within the pyroxene group, while nephrite is a solid-solution series between two closely related minerals of the amphibole group. What these jades have in common is toughness, but even this property is arrived at in different ways. Jadeite grains grow into interlocking aggregates, while nephrite forms compact, fibrous, matted aggregates.

Initial testing in the East Coast laboratory of one bead removed from the necklace gave results that could be mistaken for jadeite. The "spot" refractive index reading appeared to be midway between 1.60 and 1.70; the specific gravity was found to be 3.36. Still, the evenness of the polish just did not match the rather dimpled or uneven surface usually seen on jadeite. Although most minerals in both the pyroxene and amphibole groups have R.I.'s between 1.6 and 1.7, have S.G.'s between 3.0 and 3.9, and occur in the same range of colors as jade, no other mineral in either group exhibits jade's toughness. To identify this material conclusively, we sent the bead to the West Coast laboratory for X-ray diffraction analysis.

The results indicated *ferrohornblende,* an iron-rich member of the amphibole group. Being amphibole, this material is certainly not jadeite; being ferrohornblende rather than nephrite, it cannot properly be called jade at all. As the amphibole group contains 60 separately recognized mineral species, finding a more exact designation than ferrohornblende most probably would require (destructive) petrographic testing. Although a well-known and pleasing name may aid the marketing of an opaque black material, gem names become devalued when they are misapplied.

GRC, MLJ, and IR

Figure 6. The jadeite jade beads of this necklace have such high diaphaneity that the stringing material is clearly visible through even the largest (9-mm) bead.

JADEITE JADE

Exceptionally Translucent Necklace

One pleasure of working in the laboratory is seeing gem materials that are exceptional examples of their species or variety. This past spring, the West Coast lab was asked to identify a double strand of 117 intensely colored green beads (figure 6), which ranged from about 9.06 to 3.77 mm in diameter. Standard gemological testing proved them to be jadeite jade, visible-light spectroscopy revealed that they were of natural color, and infrared spectroscopy showed that they were not polymer impregnated.

The fineness of the aggregate and the resulting high degree of diaphaneity were such that individual strands of the stringing cord could be clearly seen through even the largest bead. *RCK*

Jadeite Jade with Impregnating Substance in Drill Hole

Bleached and polymer-impregnated jadeite jade is one of the most difficult detection challenges to confront the gem industry in the 1990s. As explained in the Fall 1992 *Gems & Gemology* article by E. Fritsch et al. (pp. 176–187), infrared spectroscopy is one of the few advanced testing methods that can detect this treatment in all cases. Although the instrumentation needed for such testing is not readily available to most gemologists, the above-referenced article did point out some tests that can be performed with standard gemological equipment. In particular, examination of the piece with magnification may reveal concentrations of the impregnating substance in irregularities, such as fractures or cavities, on otherwise smooth surfaces, or in recessed areas on carved jadeite that has been so treated.

The West Coast laboratory recently found another place where such concentrations might occur, when we examined a graduated necklace of mottled green and white beads that ranged from approximately 9.50 to 5.90 mm in diameter. Standard gemological testing identified the material as jadeite jade, and the spectra seen with a desk-model spectroscope confirmed that the green color was natural. However, microscopic examination revealed the presence of a colorless polymer layer in the drill holes of most of the beads (figure 7). Infrared spectroscopy confirmed that the material had been polymer impregnated.

Figure 7. Residue of the polymer material with which this jadeite bead was impregnated is evident in its drill hole. Magnified 28×.

Although the polymer in the drill holes provided very useful evidence that the beads had been polymer impregnated, such visual proof is—in our experience—very unusual. Only once before did we see similar evidence in jadeite beads that were later determined by infrared testing to be impregnated. *RCK*

PEARLS

"Banded" Natural Pearl, of Natural Color

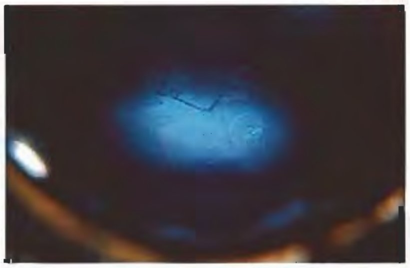
A very unusual pearl ring was examined last summer in the West Coast laboratory. Handcrafted of 18k matte gold, the ring was custom designed to highlight a rather distinctive pearl, which measured about 11 × 13 mm. The pearl was mounted such that it could be rotated to show on top either solid black (as in figure 8) or the distinctive banding (seen on the side in figure 8).

Our client asked us to determine if the barrel-shaped pearl, which was reportedly from the Gulf of Cali-

Figure 8. Different aspects of this unusual natural black pearl (11 × 13 mm) can be viewed by rotating it in its setting.

fornia, might be an assemblage because of the peculiar "banded" appearance. Visual examination showed no indication of assemblage. The "banding" consisted of nacreous layers that were alternately light and dark gray. The top and bottom layers appeared almost black with a very high luster and strong overtones of green and blue. When exposed to long-wave ultraviolet radiation, the dark areas fluoresced a very strong red, similar to the fluorescence seen in other black pearls from the Gulf of California. The X-radiograph showed a large dark central core, proving that the pearl was indeed natural and not cut from the shell or an assemblage. We cannot imagine what might have caused such an unusual growth pattern in this pearl. *KH*

Figure 9. The decrepitation of the nacre and resulting iridescence seen here often occurs on the surface of pearls that have been stained with a metallic compound. Magnified 18×.



Cultured Pearl, Treated Color

The treated-color black cultured pearl seen in the East Coast lab and discussed here was one of a strand of 30, which were graduated in diameter from 16.35 to 11.45 mm. On the developed X-ray film, a white ring was seen around the nucleus of the pearl, proving that the pearl had been treated with a metallic compound (which is opaque to X-rays). EDXRF analysis, which revealed a silver signature typical of the metallic compounds often used to stain pearls, confirmed the treatment.

Visual examination with magnification also provided indications of treatment. Specifically, as illustrated in figure 9, we noted the damage to the nacre layers caused by the treatment process. The iridescence seen in this figure is a side effect of this breakdown of the surface. Another indicator, while atypical, relates to the peculiar hammered or "dimpled" surface seen on many natural pearls and on some thickly nacred cultured pearls (see, e.g., the natural-color cultured pearl in figure 15, p. 128, of the Summer 1993 Lab Notes section). Typically, when a pearl is treated with some type of silver salts, the entire surface absorbs some of the dye; we have observed that, in general, even such dimpled areas take on the artificial color when treated. In this treated-color cultured pearl, we saw a white area in the center of the dimple (figure 10), where the stain apparently did not penetrate.

TM

Figure 10. The coloring agent did not affect the center of this dimple on the treated-color black cultured pearl shown in figure 9. Magnified 30×.

Figure 11. This 16.40-ct sapphire appears to be blue throughout.

SAPPHIRE, Natural Color with Unusual Fluorescence

When staff at the GIA Gem Trade Laboratory first encountered heat-treated blue sapphires in the late 1970s, many of the stones we examined fluoresced a weak, dull green (often in patches) to short-wave ultraviolet radiation, similar to the fluorescence seen in synthetic blue sapphire. Today we see far fewer heat-treated sapphires with this green fluorescence. This may be due to advances in the techniques and equipment used in heat treatment. Alternatively, it could be because most of the early treated sapphires appeared to be of the Sri Lanka geuda (milky white) type, whereas heat-treated stones seen more recently are from many different localities.

A 16.40-ct emerald-cut stone that we examined in the East Coast lab (figure 11) appeared a nice, relatively even color when viewed face up. When we looked at it from the side, however, we saw that it was predominantly colorless, with only a thin, dark layer of blue at the table (figure 12). Although some areas fluoresced orange to long-wave UV, as is

Figure 12. A side view of the stone in figure 11 reveals that the color is confined to a thin layer under the table. Magnified 10×.

common in blue sapphires from Sri Lanka, part of the table fluoresced a chalky green (figure 13) to short-wave UV. This led to our initial belief that the stone may have been heat treated.

When we examined the stone with magnification, however, we saw a number of what appeared to be pristine included crystals (figure 14); none showed the stress fractures that would be expected in a heat-treated stone. We then cooled the stone cryogenically and looked at it again under the microscope: Most of the "crystals" were actually negative crystals with two-phase inclusions (see, e.g., figure 15). As the stone warmed in the heat generated by the light of the microscope, the gas bubbles disappeared, indicating that the two phases were liquid and gaseous carbon dioxide. Because these inclusions formed under high pressure and were still under great pressure within the stone, they would have literally blown up if heated to as little as 270°C (see, e.g., J. I. Koivula's article "Carbon Dioxide Fluid Inclusions as Proof of Natural-Colored Corundum," *Gems & Gemology*, Fall 1986, pp. 152–155). Thus, the presence of these inclusions proved that this stone was never heated anywhere near the 1500°C necessary to produce the blue color artificially. Yet we have no explanation for the chalky green fluorescence.

GRC

Figure 13. The sapphire in figures 11 and 12 displays a chalky green fluorescence that has been considered indicative of heat treatment.

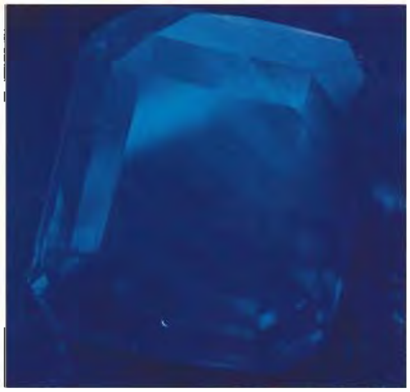


Figure 14. Seen magnified 63× at normal room temperature, these "crystal" inclusions in the blue sapphire shown in figures 11–13 lack stress fractures, which is key evidence that the stone had not been heat treated.

SYNTHETIC SAPPHIRE, Color-Zoned

Most flame-fusion synthetic corundums identified by the GIA Gem Trade Laboratory are rather evenly colored. In general, the overall color in those that display curved striae—for example, synthetic ruby and vanadium-doped color-change synthetic sapphire—is very uniform. Those that exhibit curved color banding (e.g., synthetic blue sapphire and synthetic sapphire in the yellow-to-orange color range) typically have a uniform distribution of the color bands throughout the piece.

A 7.03-ct, modified-oval mixed cut examined at the West Coast lab was an exception to the above. The gemological properties were consistent with corundum. Face up, it appeared to be a uniform yellowish orange. However, when examined from the side, most of the body color—all but a small orange area along the keel line—appeared pink. Only by using a blue color-contrast filter with diffuse transmitted light could we see that the zone along the keel consisted of very weak, diffused, curved orange bands. This curved banding, as well as scattered clouds of minute gas bubbles, proved that it was a synthetic sapphire. *RCK*

SERPENTINE and FORSTERITE Rock

Although most gem materials consist essentially of one mineral species or gem variety, there are important exceptions among the ornamental gems. Examples include lapis lazuli (a rock consisting of lazurite, calcite, and pyrite), unakite (an epidote-rich granite), and chrome zoisite with ruby inclusions.

Still another example was provided by the opaque, mottled brown-and-white carving of a horse (figure 16) submitted to the West Coast lab.

Figure 15. When the same sapphire was cooled cryogenically and reexamined at 63× magnification, it became clear that the "crystals" are actually negative crystals with two-phase CO_2 inclusions.

Figure 16. This 46-mm-long carving was identified as a rock consisting of serpentine and forsterite.

Standard testing revealed an indistinct spot R.I. of 1.55 and an S.G. of 2.45. There was no apparent difference in texture between the brown and white areas.

Subsequently, we took three X-ray diffraction patterns. Two patterns (one each in the brown and white regions) were identified as a mixture of forsterite and serpentine. The third pattern, in the white area, was identified as pure forsterite.

Although alteration can occur between serpentine and forsterite in either direction (see the section on olivine in Deer, Howie, and Zussman's *Introduction to the Rock-Forming Minerals* [Longman Group, London, 1974, pp. 1–8]), the color pattern more closely resembled serpentine altering to forsterite by dehydration. However, the question of which was the original material could only be answered conclusively with destructive testing. On the basis of the X-ray diffraction analyses, we concluded that this material is a rock consisting of serpentine and forsterite (a member of the olivine group). *RCK and MLJ*

Detecting Impregnated TURQUOISE

A great many substances have been used to treat turquoise, including waxes, oils, and plastics. Furthermore, the detection of impregnation in turquoise can sometimes be difficult, often requiring advanced testing techniques. See, for example, related entries in the Fall 1984 and Summer 1986 Gem Trade Lab Notes, and the Spring 1987, Summer 1992, and Summer 1993 Gem News sections.

The West Coast lab last spring had to perform such testing on a semi-translucent to opaque piece of partially polished blue rough that contained significant amounts of a brown and white matrix. Standard gemological testing proved that the blue gem material was turquoise. However, microscopic examination revealed a colorless, transparent substance on much of the stone's surface. Using a commonly employed technique (see, e.g., Lind et al., "The Identification of Turquoise by Infrared Spectroscopy and X-ray Powder Diffraction," *Gems & Gemology*, Fall 1983, pp. 164–168), we submitted a small scraping of the coating to infrared spectroscopy. Comparison with reference spectra showed that the colorless substance was a polymer. The same procedure was then performed on a potassium bromide pellet containing scrapings taken from areas on the turquoise where we did not see any evidence of a polymer. Infrared spectroscopy revealed the polymer in these areas, too. On the basis of these results, we identified the stone as impregnated natural turquoise. *RCK*

PHOTO CREDITS

Nicholas DelRe supplied the pictures used in figures 5 and 9–15. Figures 1, 4, and 16 were taken by Maha DeMaggio. The photomicrograph in figure 3 is by John I. Koivula. Shane F. McClure provided figures 2, 6, and 7. Figure 8 is © GIA and Tino Hammid

GEM NEWS

JOHN I. KOIVULA, ROBERT C. KAMMERLING, AND EMMANUEL FRITSCH, EDITORS
MARY L. JOHNSON AND DINO G. DEGHIONNO, CONTRIBUTORS

DIAMONDS

Update on Botswana diamond mining. De Beers reported almost 15.9 million carats of diamonds produced here in 1993, down from 17.5 million carats in 1992 because of renegotiated agreements between Botswana and the CSO. Most of this production came from Debswana mines, including Jwaneng (8.5 million carats), Orapa (almost 5.2 million carats), and Letlhakane (nearly 1 million carats). Onshore mining at Mining Area No. 1—Auchas, Elizabeth Bay, and Bogenfels—produced 774,000 carats, with an additional 62,000 carats from contractors and 302,000 carats from De Beers Marine. Debswana production is expected to increase with the current expansion at Jwaneng and possible expansion at Orapa (a feasibility study is in progress). Botswana Diamondfields has been evaluating kimberlite pipes in their Mopipi block by sampling soils. Minerals identified include peridotitic garnets, ilmenite, and chrome diopside. (*Minerals Today,* April 1994, p. 20; and *Mining Journal,* May 27, 1994, p. 385; July 24, 1994, p. 76)

West African diamond mining. In **Ghana,** Consolidated Diamonds plans to double output to 40,000 carats per month at the Akwatia diamond mine. In **Guinea,** Aredor reportedly has suspended all diamond and gold production because of increased security problems; majority shareholder Bridge Oil has transferred its share in Aredor-Guinea S.A. to the government of Guinea. Aredor's production had fallen from 204,000 carats in 1986 to 91,000 carats in 1991. In **Sierra Leone,** 1993 diamond production mainly came from small-scale mining. Government troops have reoccupied the diamond-rich Kono and Eastern Kenema districts, but the mining infrastructure there will have to be rebuilt. Given the falling ore grades and technical problems, it may be more productive for the Sierra Leone government to concentrate on new high-grade kimberlite pipes that have been found in National Diamond Mining Company's Yengema and Tongo lease areas. (*Mining Journal,* April 29, 1994, pp. 314–315; May 13, 1994, p. 351; May 27, 1994, p. 384; June 10, 1994, p. 427)

Diamond mining in Namibia. De Beers reported 302,754 carats from off-shore production (using two ships) in 1993, up from 29,195 carats in 1990. Regional Resources plans to develop an alluvial diamond mine at its Purros claims in Kunene Province, along a former channel of the Hoarusib River. This project is limited by water access, concerns about tourism, and local tribal interests. The Namibian government has invited bids for 46 three-year, exclusive diamond-prospecting licenses along a 1,380-km^2 stretch of the north bank of the Orange River. The alluvial diamond deposits are similar to those at the nearby open-pit mine at Auchas. Because of ecological concerns, no dredging will be allowed in the Orange River itself. (*Mining Journal,* June 10, 1994, pp. 425–426; June 17, 1994, p. 440; August 5, 1994, p. 97; and *De Beers Consolidated Mines 106th Annual Report and De Beers Centenary AG 4th Annual Report,* as of December 31, 1993)

South African diamond mining. De Beers reported production of 9.8 million carats from South African mines in 1993 as follows: nearly 5 million carats from the Venetia mine; over 2.0 million carats from the Finsch mine; almost 1.6 million carats from the Premier mine; and 0.6 million, 0.5 million, and 0.14 million carats, respectively, from the Namaqualand, Kimberley, and Koffiefontein mines. For all these mines, the ore grade has improved slightly from 1992; production seems to be limited by CSO demand.

Regional Resources intends to start pilot open-pit mining at its diamond pipe at Postmasburg in the northern Cape province. Grades are said to be 12 carats per 100 metric tons of ore.

Canadian Overseas has expanded its marine properties along the Namaqualand coast, just south of the estuary of the Olifants River. Diamond recoveries in its new claim 13b average 193 carats (at 0.81 ct per diamond) per metric ton of recovered gravel.

Diamond Field Resources has acquired the Loxton Dal and Frank Smith mines in the Kimberley area. They plan to expand annual processing from the current 204,000 metric tons to 504,000 metric tons of ore. Ore grades were not given, but they run 0.18 ct per metric ton for De Beers mines in the Kimberley region. (*De Beers Consolidated Mines 106th Annual Report and De Beers Centenary AG 4th Annual Report,* as of December 31, 1993; *Mining Journal,* May 13, 1994, p. 349; June 10, 1994, pp. 424–425; *Mining Magazine,* March 1994, p. 178)

Figure 1. It appears that this unusual 0.39-ct heart-shaped natural diamond crystal was formed by selective etching along a surface-reaching crack. Courtesy of Trillion Diamond Co.; photo by Maha DeMaggio.

Update on Australian diamond mining. *Quarterly Notes 94* from the Department of Mineral Resources, New South Wales, Australia, details a new model for diamond formation, which could explain the source for the alluvial diamonds in New South Wales. Because no lamproites or kimberlites have been found in connection with these stones, some Australian geologists think that the diamonds may have formed by rapid subduction of carbon-rich marine sediments and were subsequently brought to the surface by nephelinites or alkali basalts. (*Mining Journal,* March 18, 1994, p. 190)

The Australian Diamond Exploration Venture has begun exploration in the Batten Trough area of the Northern Territory. At least three sources of diamonds are already known in the region: the Excalibur pipe, the Merlin loam anomaly, and the newly discovered Ector pipe. Diamonds from pipes in the Batten area are larger than those from Argyle—17 stones per carat versus 30 per carat for Argyle. (*Mining Journal,* April 29, 1994, p. 309)

The Argyle joint venture is completing a major upgrade of the processing plant and vehicle fleet at the Argyle open pit in the Kimberley region, Western Australia. This upgrade is intended to increase the annual output of diamond ore from the current 6 million tons to 8 million tons. The current ore horizon has a grade of 6 carats per ton, but this grade is expected to decline to 4 carats per ton. In 1993, Argyle produced about 40 million carats (almost seven tons) of diamonds. Only 5% of Argyle's diamond production is gem quality, and less than 0.001% of the total number are "pinks." Drilling has confirmed that diamonds continue to be found in the lamproite pipe to 550 m below the top of the ore body. (*Mining Journal,* March 25, 1994, p. 223)

Additional diamond projects in Western Australia include the BHP-Stockdale joint venture at Forrest River, a number of pipes in the Ellendale area, and the Aries kimberlite pipe at Phillips Range, where Triad Minerals is planning to begin bulk sampling. (*Mining Journal,* April 8, 1994, p. 255)

Update on diamond production in the former USSR. For the first time since reaching their agreement with De Beers, Almazy Rossii-Sakha (ARS) sold its entire quota of diamonds in 1993, and $600 million worth of diamonds were sold in the first half of 1994. Profits are expected to be used to upgrade production at the Jubileynaya pipe. (Another pipe, the Udachnaya, produces 8 million carats per year, about 85% of the total Russian production.) However, where these "profits" will come from is not exactly clear. ARS declared a debt of 279 billion rubles at its June 1994 stockholder meeting and has petitioned the Yakutia government to reduce taxes, according to the August 18, 1994, *Diamond Intelligence Briefs.* ARS President Semyon Zelberg said that the company has paid 53.7% of its earnings into local and republic taxes, but tax rates for mineral developers are currently 73%. ARS would like the government to accept the lower rate of taxation, forgiving the rest. Yakutia has agreed only to waive ARS's fines resulting from late payment of taxes.

In an effort to attract private investment, Russian officials have released previously classified details concerning 10 potential mining sites in Russia. These include Karelia, the White Sea shelf, the Kola Peninsula, and the Arkangelsk, Perm, Voronezh, Pakov, and Leningrad regions. Among the companies involved in prospecting are Ashton Mining and De Beers Marine.

In other developments, the Russian Federation is proposing stronger central control over gold mining, while autonomous regions are pushing for legislation that would let them directly control gold and diamonds mined within their borders. The smuggling of diamonds from Russia may become a major problem, negatively affecting the price stability of rough diamonds on the world market. Russian Prime Minister Viktor Chernomyrdin has appointed a committee to combat this problem, and the CSO reduced the level of June, July, and August sights to compensate for "leakage" of Russian diamonds onto the international market. (*Diamond Intelligence Briefs,* August 18, 1994; *Mining Journal,* May 27, 1994, p. 387; July 22, 1994, pp. 57–58)

Unusual diamond crystal. Although nearly all gem-quality diamond crystals are destined to become fashioned gems, an occasional rough crystal is so unusual and attractive that it should not be faceted. Marvin Finker, president of Trillion Diamond, New York, has a fondness for these crystals—and the experience to know when one is special (see Gem News, Summer 1991, p. 118). Once again, he has loaned Gem News editors such a crystal to examine, this one a 0.39-ct heart shape (figure 1).

Preliminary examination of the crystal suggested that its shape might be the result of twinning. With magnification, however, we saw that the lobes of the "heart" were apparently formed by selective etching along a surface-reaching crack that had once existed between them. In a search through the diamond literature, including the *Atlas der Krystallformen* by Victor Goldschmidt (reprinted by the Rochester Academy of Science, Rochester, NY, 1986), we could not find any diamond crystal of similar shape. However, the main portion of the crystal—without the etched groove between the lobes of the "heart"—appeared to be a curved-faced diamond crystal known as a tetrahedroid (Yu. L. Orlov, *Mineralogy of the Diamond*, John Wiley & Sons, New York, 1977, p. 76).

COLORED STONES

"Caymanite" from the Grand Cayman Islands, Caribbean. Gerald Kirkconnell from Kirk Freeport Plaza in the Cayman Islands (British West Indies) sent us samples of, and jewelry made with, a banded rock called "Caymanite" (figure 2). Reportedly dolomite, he said that it is found only in the Cayman Islands, on the eastern end of Grand Cayman and in Cayman Brac. The bands vary in color and in hardness (6 to 7). The darker orangy brown layers are microcrystalline, while the lighter, "cream" color layers are cryptocrystalline. The lighter layers fluoresce orangy yellow to long-wave UV radiation, with a stronger emission to short-wave UV, whereas the darker layers have a much weaker fluorescence or none at all. We recorded an R.I. (measured on one sample by the spot method) of approximately 1.6 and a specific gravity (measured by the hydrostatic method, average of three tests) of 2.63. X-ray diffraction analysis of a scraping from one area produced a pattern that matched the pattern for dolomite.

Figure 2. The cabochons in these rings and the beads in the necklace have been fashioned from a dolomite found in the Cayman Islands that is called "Caymanite." Courtesy of G. Kirkconnell; photo by R. Weldon.

Figure 3. The yellowish green chrysoprase chalcedony from which these beetles were carved was formed in the brown serpentine and iron oxide matrix. Total specimen size is 6.0 x 4.2 x 2.76 cm; each beetle is approximately 15 mm long. Photo by Maha DeMaggio.

Chrysoprase chalcedony matrix carving. Darryl Roder, of the Gembank Group, Hong Kong, recently donated to GIA a carving that consists of two chrysoprase chalcedony beetles on brown matrix (figure 3), fashioned from material found in the Yerilla District in Western Australia. This specimen gave us the opportunity to examine the Yerilla matrix material, which has been described as jasperized ironstone by R. W. Jones ("The Greening of Australia," *Lapidary Journal*, February 1994, pp. 71–79).

The yellowish green color and refractive index (1.54 by the spot method) of the two beetles are typical of Yerilla chrysoprase chalcedony. The legs of the beetles gradually fade into the brown matrix at their extremities. The matrix as a whole is patchy, ranging from a medium

Figure 4. This 0.89-ct faceted demantoid garnet and the rough specimen are from Hermosillo, Sonora, Mexico. Courtesy of Neal Dwire; photo © GIA and Tino Hammid.

brown glassy to waxy material, to a light-brown earthy material with off-white veins. X-ray diffraction analysis of the matrix material revealed quartz (chalcedony or jasper) and a member of the serpentine mineral group, probably antigorite. The brown color is due to amorphous-to-poorly crystalline iron oxides, which are not obvious in the X-ray diffraction pattern.

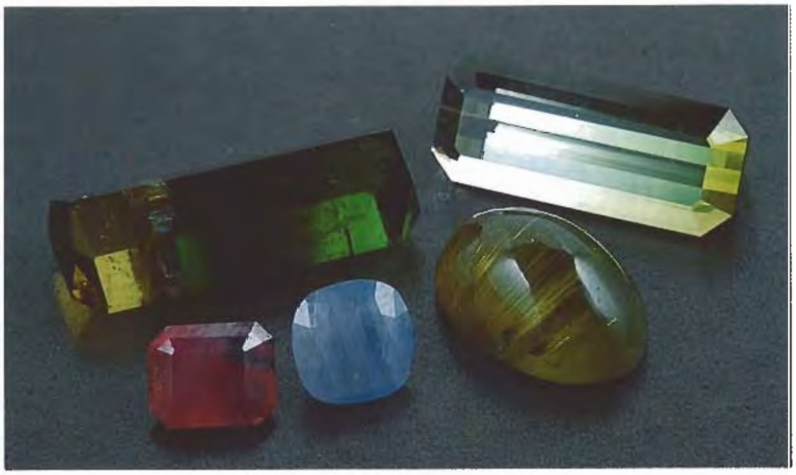
Demantoid garnet from Mexico. The Fall 1987 and Summer 1988 Gem News sections reported on the unusual iridescent andradite garnets being recovered in the state of Sonora, Mexico. Earlier this year, Neal Dwire of Rainbow Garnet, Tucson, Arizona, informed one of the editors (JIK) that he was mining the material from a locality near the city of Hermosillo in Sonora.

Mr. Dwire subsequently loaned the editors several specimens, both rough and cut, for examination. We examined in detail a yellowish green cluster of euhedral crystals (23.83 × 15.57 × 7.75 mm) and a transparent, 0.89-ct round brilliant that was cut from similar-appearing material (figure 4).

The color of these two andradites would classify them as the demantoid variety. On the basis of energy-dispersive X-ray fluorescence (EDXRF) analysis performed by Sam Muhlmeister of GIA Research, we concluded that the faceted stone was a very pure andradite, with no chromium and only a small trace of manganese. UV-visible absorption spectroscopy proved that the color is due to the presence of Fe^{3+} alone. In a presentation at Tucson this past February, GIA researchers, collaborating with Dr. George Rossman of the California Institute of Technology, had noted that some demantoid garnets from Russia do not show any chromium absorption either and also lack the iron-titanium charge transfer that gives Italian andradites ("topazolites") their yellower color.

Mr. Dwire informed us that the amount of both the transparent green and the iridescent varieties of andradite from this mining area appears to be limited.

Figure 5. These gems were recently acquired in Nepal. From the top, clockwise from left: 7.82-ct bicolored tourmaline from Manang; 5.63-ct bicolored and 4.71-ct cat's-eye tourmaline from the Hyakule mine; a blue sapphire from Gauri Shankar and a ruby from Ganesh Himal, approximately 2 ct each. Courtesy of Mark H. Smith; photo by Maha DeMaggio.



News from Nepal. In the Fall 1993 Gem News section, Gemologist Mark H. Smith of Bangkok provided information on the availability of various gem materials in Nepal. On his recent return from another buying trip to that country, he reported that gem-quality yellow to slightly greenish yellow tourmalines—from a deposit just east of the town of Manang, northeast of Annapurna, in the Marsyangdi River valley—continue to be readily available. The largest crystal he saw measured 15 × 2.5 cm; it was yellow with a thin layer of black to dark green on the single flat termination; he saw faceted yellow tourmalines as large as 149 ct. Dark green gems were being cut from the terminations, as were some green to yellowish green bicolors (figure 5). According to Mr. Smith, tourmalines of a dark green color similar to that seen on the terminations of these predominantly yellow stones are being recovered from deposits in the mountains north of Gorka, between Pokhara and Kathmandu.

A few gems were also available from the Hyakule mine on the Arun River, in eastern Nepal, which is the most famous gem locality in the country. Mr. Smith reported that the tourmalines said to be from the Hyakule mine were light green, orangy pink, or bicolored; some showed chatoyancy when cut *en cabochon* (again, see figure 5).

A few rubies and blue sapphires were also seen (figure 5). The rubies, reportedly from Ganesh Himal, were translucent and contained distinct blue color zones. The sapphires, reportedly from Gauri Shankar (a mountain on the Nepal-Tibet border, northeast of Kathmandu), were

*Figure 6. In general, the properties of these four horse conch (*Pleuroploca gigantea*) "pearls" were similar to those of such "pearls" from other conchs. The large brown specimen at the top right is 27.47 mm on its longest dimension. Photo by Robert Weldon.*

barrel-shaped opaque-to-translucent crystals that produced light grayish blue fashioned gems. Mr. Smith saw aquamarine, danburite, and hambergite as well.

Horse conch "pearls." Ever since we described the properties of conch "pearls" from *Strombus gigas* in the Winter 1987 issue of *Gems & Gemology*, we have been aware of the existence of similar-appearing "pearls" from the horse conch (*Pleuroploca gigantea*) but have not been able to obtain good examples for comparison. Susan Hendrickson from Seattle, Washington, and Stefan Hemmerle, from Hemmerle Juweliere in Munich, Germany, recently loaned us some typical and some spectacular examples of this very rare gem (figure 6). These "pearls" (placed in quotation marks here to indicate that they are nonnacreous) were said by reputable fishermen to come from the horse conch. Their exact geographic origin was not disclosed.

Mr. Hemmerle let us examine a 111.76-ct dark brown, football-shaped horse conch "pearl," 27.47 mm in its longest dimension. Ms. Hendrickson loaned us two typical brown specimens, as well as an exceptional 22.01-ct medium orange, round "pearl." On all examples, we measured (by the spot method) an R.I. of about 1.65, consistent with what we reported for conch "pearls," with a typical although weak "carbonate blink." Specific gravity (measured by the hydrostatic method) was 2.77 on the largest sample, and 2.85 on the round one. On the surfaces of all of the "pearls," we observed some small patches of lighter color, as well as a different flame structure from that reported for *Strombus gigas* "pearls." Many small "bursts" of fibrous, reflecting crystals, forming minute depressions where they reach the surface (figure 7), are relatively evenly distributed. They are flame-like in appearance, but smaller than those in *Strombus*. They show a whitish sheen in one orientation, and appear almost transparent when the "pearl" is rotated 180°. The UV fluorescence is weak and spotty, with a stronger response to short-wave than long-wave UV. The fluorescence color is yellow to orange, with lighter brown spots and small, hairline "fractures" seen on the surface fluorescing brightest.

X-radiography of the largest specimen revealed a concentric structure typical of natural pearls. EDXRF spectroscopy of the two largest "pearls" demonstrated the presence of calcium as a major component (as expected), with a strontium impurity (common in natural and cultured pearls).

Notable round black cultured pearl. A 19-mm undrilled black cultured pearl (see figure 8) recovered from this year's harvest in the Marutea lagoon is the largest such cultured pearl ever examined by the GIA Gem Trade Laboratory staff in New York.

Marutea is one of the French Polynesian islands in the Gambier archipelago, which lies more than a thousand miles southeast of Tahiti. According to Mr. Salvador Assael, of Assael International, because of the specific environment and conditions (especially the abundant food supply) found in this lagoon, the *Pinctada margaritifera* in which the pearls are cultivated grow to 23–24 cm, significantly larger than those grown in most other atolls in the area (typically no more than 20–21 cm). The larger mollusk can produce larger pearls, although it is very rare to encounter round black pearls over 18 mm in diameter.

This cultured pearl exhibited the typical dull orange-

Figure 7. Details of the flame structure are clearly visible on the largest horse conch "pearl" shown in figure 6. Photomicrograph by John I. Koivula; magnified 30×.

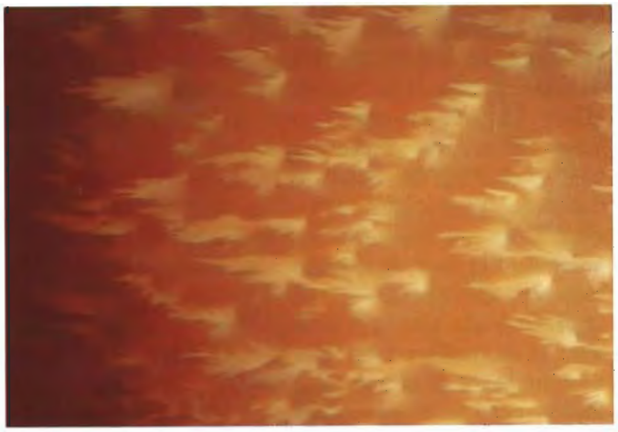


Figure 8. The 19-mm cultured black pearl that has been placed as the centerpiece of this graduated necklace layout was recovered from this year's harvest. A matched pair of 17-mm black cultured pearls flank the center position of the necklace. Courtesy of Assael International; photo by Nicholas DelRe.

brown reaction to long-wave UV radiation that corroborated its natural color.

Peridot from Pakistan. This decade has already seen two new sources—Ethiopia and Vietnam—added to the list of countries producing peridot (for more on these two localities, see respectively the Spring and Fall 1993 Gem News sections). In fall 1994, Bill Larson of Pala International, Fallbrook, California, brought to the editors' attention yet another new source of peridot: Pakistan. Subsequent communications with Laura Thompson, president of Shades of the Earth, Phoenix, Arizona, the firm marketing the material, provided the following information.

The locality, at an elevation of about 4,500 m (15,000 feet) above sea level, is in the far west of the Himalaya Mountains, not far from the Indus River. From the closest community, Basham Village, the deposit is reached by a seven-hour horse ride and two-day hike.

According to Mrs. Thompson, small crystals were first found in mid-1992, although good facet-grade material was only discovered in mid-1994, when actual mining began. The area is worked at any given time by anywhere from 200 to 2,000 villagers who hike in from as far away as 80 to 112 km (50–70 miles). There is no overall organization to this mining activity; Mrs. Thompson's firm purchases material from the various groups and individuals working the area. Because of the severe climate at the deposit's elevation, the area can only be mined from approximately late June to early October. Total production as of October 1994 was approximately 100 kg, the vast majority of which was only suitable for tumbling and/or cutting *en cabochon*. Only about 3 kg of facet-grade rough has been reported to date. However, because of the large size of the crystals, faceted stones are primarily in the 10- to 20-ct range, and stones as large as 100 ct will undoubtedly be cut in the future.

To date, the editors have examined only a few crystals (see figure 9). Gemological information will be provided as soon as we have had an opportunity to test faceted stones.

Yukon rhodonite. Rhodonite, one of the better-known ornamental gem materials, typically occurs in coarsely mottled patterns of varying shades of pink. Also common to this material are black "spots" and veins of manganese oxide. At Tucson this year, we saw some especially attractive material that had been fashioned into matching tablets (see, e.g., figure 10). The mottling in this material was unusually fine, somewhat reminiscent of jadeite; there were no dark inclusions. According to one dealer, the material came from in the Yukon region of Canada.

"Samotsvetov" Colored Stones Museum in Moscow. In August 1994, one of the Gem News editors (RCK) visited the Federal Museum of Colored Stones, "Samotsvetov," in Moscow. This small but impressive facility, operated under the direction of the Russian State Committee "Roskomnedra," is housed on the ground floor of a combined commercial and residential building in the center of the city.

The front section of the museum features an extensive display of fine-quality mineral specimens from virtually all regions of the former Soviet Union, with speci-

Figure 9. These peridot crystals, the largest of which is 45.3 mm × 24.3 mm × 34.5 mm, were recovered from a new locality in Pakistan, high in the Himalaya Mountains. Courtesy of Pala International; photo by Shane F. McClure.

mens grouped by geographic area. In addition to more traditional items, this section contains samples of fossilized mammoth ivory. The next section of the museum is a narrow corridor, along one side of which are pedestals with statuettes of traditional scenes from Russia or one of the other republics—for example, a Georgian peasant in native dress, and two women in a bath, drinking tea from a samovar (figure 11). All of these are constructed from various ornamental gem materials mined in Russia and the republics. There is also an exceptional writing table fashioned from wood and malachite.

The last section of the museum contains a series of wall cases, each of which contains examples of a single ornamental gem material, for example, charoite, lapis lazuli, nephrite, and rhodonite. One case is devoted to synthetic and imitation gem materials produced in Russia, including various colors of YAG, CZ, and hydrothermal synthetic quartz. A carved wooden map of the former Soviet Union graces one of the walls in this section and is inlaid with rough specimens placed to show their localities.

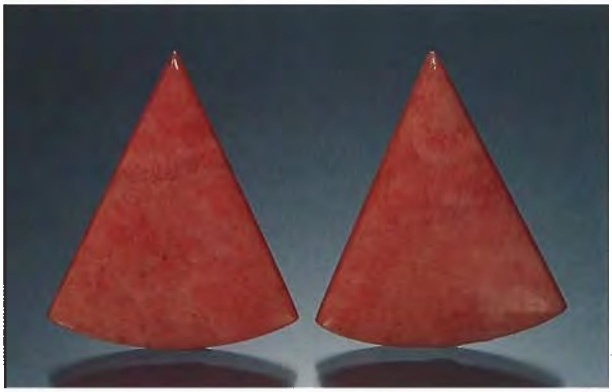
The museum also operates a foreign trade company, Exportsamotzvety, which markets mineral specimens and objects fashioned from ornamental gem materials.

Figure 11. This scene of two women in a bath, drinking tea from a samovar, is constructed of ornamental gem materials mined in the former Soviet Union. It is one of the many exceptional items on display in the "Samotsvetov" museum, Moscow. Photo by Robert C. Kammerling.

"Trapiche" purple-pink sapphire. Yianni Melas, of D. Swarowski and Co., Wattens, Austria, loaned us a very unusual, 3.38-ct sapphire crystal. This slightly rounded section of a tapered hexagonal prism shows inclusions preferentially located in planes running from the center of the stone to the edges of the prism faces—an appearance reminiscent of trapiche emerald. According to Mr. Melas, this is one of two such crystals he found in a parcel of sapphires from Vietnam. The gemological properties of this specimen are typical of corundum. The crystal fluoresced weak to moderate red to long-wave UV radiation, with a weaker reaction to short-wave UV. The small chromium content is evidenced by fluorescent chromium lines at about 670 nm—as well as a weak, sharp line at about 460 nm—in the spectroscope.

With magnification, we saw numerous needle-like inclusions that were all perpendicular to the prism faces when viewed along the optic axis. When viewed from the prism faces, they were no longer parallel, but rather within 20° of perpendicular to the optic axis. As mentioned earlier, they are preferentially located in or close to planes running from the center of the crystal to the prism edges. The exact nature of these inclusions is difficult to establish. They appear to be hollow. Some of those reaching the surface actually contain rust-color iron compounds. Others are fully included in the crystal, and therefore could not be the result of etching. X-ray diffraction analysis attempted on several such inclusions revealed only the typical pattern for corundum.

Figure 10. The Yukon region of Canada is the reported source of this finely textured rhodonite, total weight 21.89 ct. Courtesy of Judith Whitehead, San Francisco; photo by Robert Weldon.



Gem-inlaid shell jewelry. A revival of gemstone-inset shell jewelry was seen at the AGTA Tucson show this past February. The use of shell was popularized in the 1950s and early 1960s by the Duke of Verdura, a well-known Italian jeweler who decorated scallop shells, usually with rims of diamonds and insets of gold set with various types of cabochons (see, e.g., *Gems & Gemology*, Spring 1987, p. 14).

Sunil Tholia, of Universal Point, New York, selects gastropod shells from the Indo-Pacific region. He then adorns them with gemstones for use as cuff links, earrings and pins (figure 12). The obvious challenge of this process is drilling and insetting the shells without damaging them. Recently, a suite of these was sold at Christie's East in New York.

Figure 12. These gem-inlaid shells (largest, 6 × 2 cm) are used in producing such jewelry items as cuff links, earrings, and pins. Photo by Nicholas DelRe.

Tourmaline with atypical R.I. readings. Most gemologists consider the refractometer one of their most useful instruments. It enables the determination of several optical properties of a gem, including R.I., birefringence, optic character, and optic sign. In some instances, the information obtained on the refractometer may be so specific to a gem material (e.g., "the red flag effect" seen with a garnet-and-glass doublet) that it almost allows for identification with no further instrument tests.

Recently, Prof. A. A. Levinson of the University of Calgary, Alberta, Canada, showed the editors an 8.79-ct modified emerald-cut tourmaline that one of his students had encountered as a test stone. Not only did the stone show readings typical of tourmaline on the refractometer, but the stone's table facet displayed additional distinct shadow edges that appeared to "float" above (i.e., at numerical values higher than) the stone's true R.I. values (figure 13).

This unusual set of refractometer readings on tourmaline has been encountered by the editors in the past on rare occasions. Known as the "Kerez effect" or "satellite readings," they are believed to result from the stone having been subjected to overheating and/or thermal shock during polishing. Experiments have shown that the additional readings can be removed by careful repolishing of the stone. In our experience, such anomalous readings have only been encountered on very dark green tourmalines, as was the case with this specimen.

Gem production in the U.S. The total value of U.S. gem production in 1993 was $51.1 million for natural gems and $19.5 million for synthetic gems. The most important natural gem material in terms of value was freshwater pearls, which accounted for approximately $25 million in production from Tennessee. (Note, however, that shell inserts exported for cultured pearl production were even more important economically—$53 million for 1993, more than the *total* value for natural stones.) Natural-gem production from other states includes: $10.1 million for California (tourmaline, etc.); $4.5 million for Arizona (turquoise, peridot, petrified wood); $1.7 million for Oregon (labradorite sunstone, opal); $1.6 million for South Dakota (rose quartz); $1.4 million for Arkansas (quartz); $1.4 million for Utah; and $1.3 million for North Carolina, primarily from "fee-for-dig" areas. Montana also produced over $1 million in gemstones in 1993, mainly sapphires.

The production of synthetic gems—primarily synthetic emeralds, rubies, alexandrites, and sapphires, with imitation turquoise included in the figure as well—was concentrated in California. (*Mineral Industry Surveys, U.S. Bureau of Mines*, Annual Advance Supplement, June 1994)

Green cat's-eye zoisite. As noted in the article "Gem-Quality Green Zoisite" (N. Barot and E. Boehm, *Gems & Gemology*, Spring 1992), parallel growth tubes are a relatively common inclusion in both the green and blue-to-purple varieties of this gem species. If present in sufficient quantity and properly oriented in cutting, these inclusions will produce chatoyancy.

Recently, Mark H. Smith showed us a 6.83-ct oval cabochon of this material that displays a very distinct cat's-eye effect (figure 14). It struck us that in terms of both body color and the presence of large, eye-visible, tubular inclusions, the stone was very similar in appearance to some cat's-eye tourmalines. Furthermore, R.I. determinations on cabochons lacking flat polished bases are restricted to spot readings, and a careless spot reading on a green cat's-eye zoisite (about 1.69) could be misread as the 1.64 reading on a tourmaline. A similar situation exists with bright green cat's-eye diopsides, which typically give spot R.I. readings of about 1.68. Gemologists must keep in mind that zoisite, in addition to tourmaline and diopside, can occur as dark green cat's-eyes with a spot R.I. reading in the 1.6s.

Figure 13. Atypical "satellite readings" can be seen on the refractometer scale when the table facet of an unusual 8.79-ct tourmaline is tested. Photo by Maha DeMaggio.

Figure 14. Care should be taken not to mistake cat's-eye zoisite (like this 6.83-ct specimen) for other chatoyant green stones with R.I.'s in the 1.6s. Courtesy of Mark H. Smith; photo by Maha DeMaggio.

ENHANCEMENTS

Coated jadeite. A new treatment that involves coating jadeite with varnish to improve its color or appearance has been cited for some time (see, e.g., *Jewellery News Asia,* November 1990, pp. 1 and 90). However, we did not have a chance to examine such material until, on a recent visit to Taiwan, one of the editors (EF) was shown this peculiar form of treated jadeite by Ten S.-T. Wu, of IGI, Kaohsiung, and Peter Chiu, of Delight Jewelry, Taipei.

Mr. Ten showed us a large (117.99 ct, 24 mm in diameter) jadeite bead of grayish purple color that was coated with a layer of mottled green varnish. From a distance, it was a very convincing imitation of good-quality jade. On closer examination, however, it was evident that part of the coating had spalled off, showing the true color of the material. At 1.52 (spot reading), the R.I. was too low for jadeite; presumably, it was the R.I. of the coating. The specific gravity, 3.29, was slightly below normal for jadeite. The strong chalky blue fluorescence to long-wave UV radiation, with a weak reaction to short-wave UV, was also probably from the coating; the fluorescence of natural jadeite is normally spotty and yellowish white. The coating melted on contact when touched with a hot point.

Mr. Chiu loaned us a jadeite pipe that was similarly coated on its outside (but not inside) surface. In several areas, the coating had chipped away (figure 15). The R.I. was 1.54 on the coated areas and 1.66 (as expected for jadeite) on the uncoated areas. A moderate line at 437 nm in the handheld spectroscope further supported the identification of the bulk of the pipe as jadeite. Comparison by EDXRF of the chemistry of the pipe material with that of some well-documented jadeite samples confirmed the identification. Microscopic examination of the chipped areas in reflected light revealed that there were actually two layers of coating. The innermost layer is mottled green—apparently applied for color enhancement—whereas the outermost (top) layer seems to be colorless or of a uniform very light yellow color, probably a protective varnish (figure 15, inset). This double layering is actually more distinct in ultraviolet radiation, where both coatings fluoresce yellow-green with different intensities. The underlying jadeite is inert.

Infrared spectrometry showed a strong absorption around 2900 cm^{-1}, which is absent from the spectrum of natural jadeite. This absorption, similar to that recorded in some bleached and polymer-impregnated "B" jade, is typical of the presence of an organic polymer; it confirms that there is an organic coating on the jadeite piece. If one does not carefully examine such material, reference to the infrared spectrum alone might lead to the erroneous conclusion that this sample is actually "B" jade.

SYNTHETICS AND SIMULANTS

Synthetic phenakite from Russia. Graduate Gemologist Bill Vance, of Rough Times, San Diego, California, recently acquired a collection of 10 transparent blue-green crystals and crystal fragments of synthetic phenakite, a beryllium silicate, which were produced in Russia by the flux growth technique. He subsequently loaned one of these crystals (5.27 ct; 10.83 × 7.77 × 7.58 mm) to us for gemological examination. Because of its blocky shape, size, and transparency, it could provide a faceted stone of perhaps 2 ct or more. The optical and

Figure 15. Note where the coating has been chipped away from the surface of this approximately 8-cm-long jadeite pipe. As shown on the inset, there are actually two layers of coating, one with color and one presumably a protective varnish. Pipe courtesy of Peter Chiu; photo by Maha DeMaggio. Inset photomicrograph by John I. Koivula; magnified 30×.

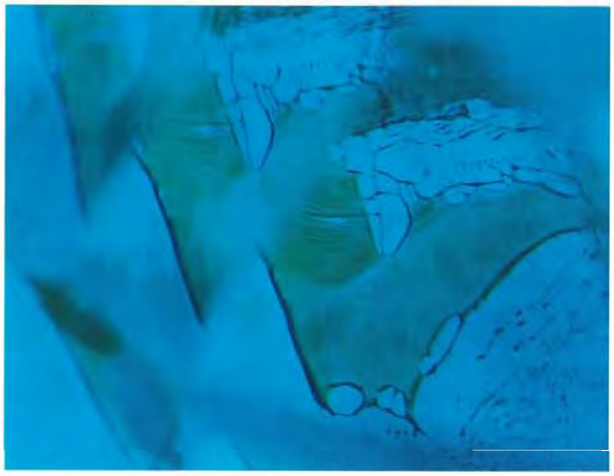


Figure 16. Primary flux inclusions form phantom structures in this synthetic phenakite manufactured in Russia. Photomicrograph by John I. Koivula; magnified 25×.

physical properties of the crystal matched those of phenakite. The dichroism observed through a calcite dichroscope was very distinct in a dark blue-green and a light bluish green. Aside from the distinctive color, which has not been observed in nature for the mineral phenakite, flux inclusions provided the most obvious clue to its synthetic origin. Magnification revealed fine networks and planar zones of primary flux inclusions that had apparently been trapped along growth steps and planes, forming phantom structures within their host (figure 16). These flux inclusions seemed to range from colorless (relative to body color of the phenakite itself) for very fine structures, to an obvious greenish brown in thicker areas. All 10 of these crystals will be faceted, and the largest—12.50 ct—is expected to yield a 5–6 ct stone.

New production facility inaugurated in Siberia. On August 3, 1994, a new synthetic-gemstone production facility was formally opened in Novosibirsk, Siberia. The new building, adjacent to the United Institute of Geology, Geophysics & Mineralogy (UIGGM), Siberian Branch of the Russian Academy of Sciences, is owned and operated by the firm Tairus, a joint venture between UIGGM and Pinky Trading Co., of Bangkok, Thailand. UIGGM brings to the joint venture personnel with expertise in crystal growth and related fields, as well as ongoing research in developing potential new products with jewelry applications. Pinky Trading, in turn, brings to bear its experience in the fashioning and marketing of gem materials, both natural and synthetic.

The primary focus of the new facility is the production of hydrothermal synthetic emeralds, Tairus's most important product. These—as well as smaller quantities of hydrothermal synthetic ruby—are produced in a large room with rows of metal containment "safes" (figure 17), each of which contains a hydrothermal autoclave housed in a raised concrete block. Control and monitoring equipment is located in an adjacent room. The new building also has facilities for the preparation of the seed-crystal wafers used to nucleate crystal growth; for growing synthetic emeralds and other synthetic beryls—at this stage on an experimental basis only—these seeds are currently being fashioned from natural golden beryl from the Ukraine. All of the equipment, including the autoclaves, control mechanisms, and even the saws for producing the seed plates, have been designed and manufactured by UIGGM.

Another building in the compound houses equipment used to produce synthetic oxide materials by a modified floating-zone technique known as horizontal growth. When one of the editors (RCK) visited the facility in early August, synthetic ruby and YAG in a variety of colors were being produced. Other products that have been grown by Tairus using this technique include synthetic alexandrite and a nonphenomenal green chrysoberyl.

INSTRUMENTATION

Russian equipment for diamond sorting and identification. On a visit to Moscow recently, one of the editors (RCK) visited the offices of Ginalmazzoloto, the State Central Research and Designing Institute of Precious Metals and Diamonds. In addition to carrying out research that focuses primarily on the properties of diamonds, the organization designs and manufactures equipment for use in the gem industry.

Most of the equipment produced is for sorting and processing rough diamonds. These include the AΦ-2, an instrument for analyzing the shape of rough and determining the parameters for fashioning round brilliants; the 9CA Diamond Analyser-Selector, for analyzing degree of strain; the ACΦγ-2 Diamond Selector, for automatically sorting diamonds based on nitrogen content; the 6CA Diamond Selector, for separating gem-quality from industrial-grade diamonds on the basis of color and transparency; and other automated equipment for sorting diamonds by weight, dimensions, color, and transparency.

The firm also designs and produces instruments for gem identification, including a diamond (thermal) probe for separating diamond from its simulants, a refractometer, a prism-type spectroscope, and a Chelsea-type filter. These and other items are available separately or may be purchased as components of a portable laboratory.

MISCELLANEOUS

Sinkankas book honored. *Gemology: An Annotated Bibliography* (Scarecrow Press, Metuchen, NJ), by *Gems & Gemology* Associate Editor Dr. John Sinkankas, received the coveted Geoscience Information Society (GIS)/Mary B. Ansari Best Reference Work Award for 1994. The award, given since 1988, was presented October 25 in Seattle, Washington. Marie Dvorzak, chairperson of the award committee, called the book a "wonderful contribution to the earth science literature . . . a valuable bibliographic resource for many years." (See *Gems & Gemology*, Winter 1993, p. 297, for Richard T. Liddicoat's review of *Gemology*.)

ANNOUNCEMENTS

Buccellati masterworks to be displayed. Fourteen masterworks from the private collection of Gianmaria Buccellati will be displayed at the Natural History Museum of Los Angeles County from November 5, 1994, to January 8, 1995. Based in Milan, Italy, the Buccellati company is best known for pieces designed in Italian Renaissance and French Rococo styles (see, e.g., the rock crystal chalice—which will be in the Los Angeles exhibit—on the cover of the Summer 1994 *Gems & Gemology*). The exhibit, the first stop of a world tour, will also include distinctive jewelry pieces created by the Buccellati company over the past 100 years, as well as tools, design drawings, and photographs that show their jewelry-making and goldsmithing techniques.

Dates set for February 1995 Tucson shows. The American Gem Trade Association (AGTA) GemFair will run from February 1 to 6 at the Tucson Convention Center. After that show leaves, the Tucson Gem & Mineral Society will take over the Convention Center for its show from February 9 to 12. At the Holiday Inn City Center from February 4–11 will be the Gem & Lapidary Dealers Association (GLDA) show. Other show venues include the: Pueblo Inn, Rodeway Inn, Howard Johnson Midtown, Discovery Inn, Desert Inn, Scottish Rite Temple, Day's Inn Convention Center and Congress Street Expo, Windmill at Phillip's Plaza, Best Western Executive Inn, La Quinta Inn, Holiday Inn Holidome, and Tucson Exposition Center. Times and dates of shows vary at each location. Consult the show guide, available at the different venues, for further information.

Education at the Tucson AGTA GemFair. The AGTA GemFair will feature a comprehensive gem-education program. Pre-show seminars—training your staff to sell colored stones, creating promotions and special events around colored gemstone jewelry, and the jeweler's quality advantage—will be offered on January 31, 1995. Other AGTA seminars, from February 2–5, include: sessions on jewelry business opportunities of the North America Free Trade Agreement, gemstone enhancements, and specific gemstones (for example, ruby and sapphire, tourmaline, emerald, and opal); and panel discussions about North American gem cutters and designing with color. For more information, contact Nancy Donaho of AGTA at (800) 972-1162 or (214) 742-4367.

In addition, GIA will offer technical training sessions, beginning with a diamond grading class, January 29–February 7. Also available will be seminars on topics such as detection of filled diamonds and treated rubies, sapphires, and emeralds; identifying challenging synthetics; advanced diamond clarity grading; and a gem identification challenge. For further information on GIA classes in Tucson, call (800) 421-7250, extension 292.

Figure 17. Each of the metal containment safes in the new Tairus joint-venture facility in Novosibirsk, Siberia, contains a hydrothermal autoclave. Most of the production is synthetic emerald, but there are also smaller quantities of synthetic ruby. Photo by Robert C. Kammerling.

***Gems & Gemology* invites you to visit us in Tucson.** *Gems & Gemology* Editor Alice Keller and Assistant Editor Irv Dierdorff will be staffing the *Gems & Gemology* booth in the galleria section (middle floor) of the Tucson Convention Center for the duration of the AGTA show, February 1–6. Drop by to ask questions, share information (and unusual stones), or just say hello. Many back issues will be available.

More GIA Tucson show news. Also in the galleria section of the Tucson Convention Center during the AGTA show with booths of their own will be the GIA: Bookstore, Alumni Association, Education, Advanced Retail Managements Systems, and GEM Instruments Corporation. The bookstore, GIA Education, and GEM Instruments also will have booths in the lobby at the GLDA show.

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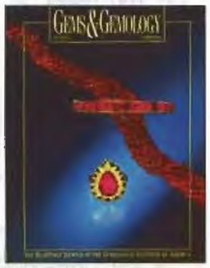
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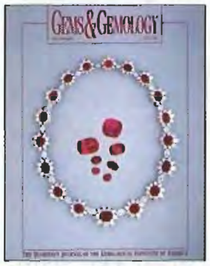
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1994 C♦H♦A♦L♦L♦E♦N♦G♦E WINNERS

For the eighth year, Gems & Gemology *readers from all over the world took our Spring Challenge, and once again they responded in record numbers to test their knowledge of recent developments in gemology. Many entrants score perfectly year after year, and we applaud their ongoing commitment to keeping up with information in this demanding field. We are proud to list the names of those who earned perfect scores in 1994. Congratulations!*

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Answers: (See pp. 58 and 59 of the Spring 1994 issue for the questions). (1) B, (2) A, (3) B, (4) A, (5) A, (6) A, (7) D, (8) D, (9) C, (10) B, (11) C, (12) A, (13) C, (14) A, (15) B, (16) D, (17) B, (18) A, (19) C, (20) D, (21) A, (22) B, (23) B, (24) D, (25) D.

BOOK Reviews

SUSAN B. JOHNSON AND JANA E. MIYAHIRA, EDITORS

DIAMONDS

*By Fred Ward, 64 pp. illus., publ. by Gem Book Publishers, Bethesda, MD, 1993. US$14.95**

This small book consists predominantly of very attractive color photographs and their captions. The remaining text (about one-third of the volume) is clearly and enthusiastically written at a "popular" level that presupposes no previous knowledge of diamonds or gemology. The text and the illustrations are very well coordinated.

The book, which would benefit from the addition of a preface, index, and references, is divided into six chapters: (1) History and Lore, (2) The Hunt for Treasure, (3) Romancing the Stone, (4) Jewels and Artifacts, (5) Synthetic and Industrial Diamonds, and (6) Buying and Caring for Diamonds. Most of the geologic information and diamond production statistics are found in chapter 2, The Hunt for Treasure. Discussion of the roles of De Beers and the CSO is found in chapter 3, Romancing the Stone. Selected famous diamonds (e.g., the Hope, the Koh-i-noor), and the rarity of stones of the best color and clarity, are discussed in Jewels and Artifacts.

This reviewer is aware that in a book of this limited size, the author must make difficult decisions as to what to include and what to leave out. Equally difficult is the requirement that the material be presented in simple, yet precise, language for what I assume to be a lay audience. Notwithstanding the style and substance chosen by the author, I believe that the book contains more technical errors, particularly those related to geologic concepts currently in the literature, than is acceptable. Some examples follow *(with the technical deficiencies italicized).*

Page 11—With respect to diamond deposits in Canada, the author states: "All indicators suggest large reserves both in primary kimberlite pipes *as well as in glacial deposits.*" Although isolated diamonds (some large) have been found in glacial deposits in the Great Lakes regions of Canada and the United States for over 100 years, there is no indication that large (or even minable) reserves will be found in these materials.

Page 15—"Although nearly 450 volcanoes have erupted more than 2,500 times in recorded history, *few have kimberlite. . . .*" In recorded history, there is no authenticated occurrence of kimberlite ever having erupted from a volcano.

Page 37—"The ones [diamonds] thus far studied indicate ages between *50 million and 3.5 billion years.*" The generally accepted ages for diamonds are between 990 million and about 3.3 billion years.

Page 46—The author states that: "*GIA estimates* current annual world diamond production at more than 100 million carats. But of those, only two to two and a half million carats produce faceted diamonds larger than one carat and in the desired D–H colors and flawless to SI_2 clarity grades." GIA does not estimate world diamond production; nor does it estimate the availability of stones in various sizes or color and clarity grades. The information appears to have originated in an article published in this journal (Vol. 28, No. 4, 1992, pp. 234–254) and was based on data from the U.S. Bureau of Mines and J.-F. Moyersoen.

There are other disappointing aspects of this book, most of which are related to what is *not* said. For example, even though the beauty, rarity, and value of fancy-colored diamonds are discussed in several places (e.g., pp. 22, 36–42), there is no mention of the fact that many colors can be produced in lower-valued (generally yellowish) diamonds by irradiation (and heat), and that such stones are readily available. Even more unfortunate, in my opinion, is the fact that the topics of enhancements (fracture filling and laser drilling) and simulants are not discussed. These timely and important topics should have been given at least passing mention in, for example, the chapter on buying diamonds.

The strengths of this book lie in the many very attractive color illustrations, the reasonable price, and the appeal of this general-interest type of presentation. Gemologists, jewelers, or anyone who has studied diamonds and routinely reads this journal may also appreciate this small volume, and especially the photography. However, they will probably be familiar with most of the material presented.

A. A. LEVINSON
University of Calgary
Calgary, Alberta, Canada

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

STREETER OF BOND STREET A VICTORIAN JEWELLER

*By Patrick Streeter, 174 pp., illus., publ. by Matching Press, Harlow, England, 1993. US$30.00**

Fifty years ago, when this reviewer first became infected with the gemological virus, he began to read any gem books he could find that were written in English—at the time, meager offerings compared to the list available today. Two books by London jeweler Edwin William Streeter, while considerably out of date, were read with particular eagerness: *Precious Stones and Gems* (1877) and *Great Diamonds of the World (1882).*

A leading Victorian jeweler, Edwin Streeter played a pivotal role in the exploitation of the Burma (now Myanmar) ruby mines and in opening up the pearl fisheries of Australia. He was also involved, though with substantially less success, in schemes involving South African diamonds, Montana sapphires, and Egyptian emeralds. Although sketchy outlines of Edwin Streeter's era and career can be found in earlier works, the current book—by his great-grandson—gives us insight into both Edwin Streeter the person and the Victorian jewelry industry.

Some of Streeter's misadventures are as exciting as his successes. Although Streeter's representative, Thomas Tobin, was in South Africa as early as 1871—before either Rhodes or Barnato had arrived—a seeming misunderstanding of the way the diamonds were deposited led to a sell-out and his early departure. Otherwise, Edwin Streeter and his associates would have become enormously wealthy men (he died in "genteel poverty" in 1923). The unsuccessful ventures in Montana and Egypt appear to have failed partly due to Streeter's perpetual optimism and fascination with mining projects. Yet perhaps success in life cannot be measured by material things. If this be so, Edwin Streeter was immensely successful for his time, as all nine of his children grew to adulthood.

Making use of original catalogs and family papers, Patrick Streeter also provides a window into jewelry making in the late Victorian period. Streeter's championing of strict stamping laws for precious metals—for most of his jewelry, he specified 18 1/2 k, with 16k solder so that when assayed an item never fell below 18k—helped formulate British stamping laws. Edwin Streeter was also an early advocate of machine-made jewelry, claiming that its use would lower the cost to the public without diminishing profits. Details of the machinery and processes used during this era, as well as objects fashioned, are reprinted from Part II of Streeter's *Hints to Purchasers of Jewellery*, 8th edition, 1867.

The author reproduces quite adequately many catalog illustrations, some in color, of jewelry as well as hollow- and flatware to provide an idea of designs and styles of the period. Edwin Streeter believed in the use of regularly distributed illustrated catalogs. Today, Streeter's catalogs are highly valued as a source for establishing the authenticity of jewelry purported to be from this period (in fact, the author has also published a reprint of the 1885 *Jewellery Catalog of Edwin Streeter*).

Although Edwin Streeter did not set the world on fire, his story is worthwhile reading for anyone interested in gems and jewelry.

G. ROBERT CROWNINGSHIELD
GIA Gem Trade Laboratory, New York

BEADS OF THE WORLD

*By Peter Francis, Jr., 142 pp., illus., publ. by Schiffer Publishing Ltd., Atglen, PA, 1994. US$19.95**

Mr. Francis' love for beads is apparent from the first paragraph to the last in *Beads of the World.* It is an excellent source of information for the novice bead collector, who will find the author's enthusiasm contagious and refreshing. His appreciation for beads draws the reader into the world of collecting, showing how these tiny objects are an art form not yet fully appreciated. In addition, the book is filled with wonderful color photographs that show different kinds of beads from all over the world.

Mr. Francis separates the book into three main sections. The first explains the global appeal of beads, their many special uses (both past and present), and basics of how to begin a collection. The second section discusses different materials from which beads are made, as well as simple approaches to help the collector identify those materials. Novice collectors should keep in mind that some of the suggested tests (i.e., hot point, chipping) can harm beads, and that alternate methods would be preferable.

But there is so much more to beads than just materials. Mr. Francis proceeds to devote most of his book to the origin and sources of beads. This includes taking the reader on a guided tour of the world's major bead centers, with an overview of each locality's history and distinctive manufacturing procedures.

The book ends with a price guide for the collector, which appears to be relatively accurate—at least for now. I am usually skeptical of such lists, because they so quickly become outdated, but this one is different. Instead of being all inclusive, it is correlated to the photos. This was an enjoyable twist: I found myself flipping to the rare beads, then back to the list to find out their retail value.

Although I enjoyed the book—especially all the color pictures and their explanations—I felt that Mr. Francis may have attempted to cram too broad a topic into too limited a format. The historical information was interesting, but it only seemed to scratch the surface; as a gemologist, I found his identification information somewhat meager, more appropriate for a hobbyist. However, the book was easy to read and I appreciated the author's enthusiasm and desire to help. I would certainly recommend it to a beginning bead collector.

SHELLEY C. TAYLOR
Huntsville, Ontario, Canada

GEMOLOGICAL ABSTRACTS

C. W. FRYER, EDITOR

COLORED STONES AND ORGANIC MATERIALS

Akoya pearl prices to rise. D. Catalano, *National Jeweler*, Vol. 38, No. 7, April 1, 1994, pp. 4, 80.

Annual raw-material auctions in Japan indicate that U.S. retail jewelers can expect an average 20% price increase for 7–8 mm Japanese Akoya cultured pearls. Kazuyoshi Watanabe, executive director of the Japan Pearl Exporters Association, said that an average 20% decrease in production, primarily in the 7–9 mm range, is partly to blame for the price increase. Colder-than-normal seawater temperatures during the summer, and continuing environmental problems, adversely affected the 1993 harvest. Meanwhile, consumer demand in Japan is growing stronger: Domestic consumption has risen from less than 40% of national production five years ago to more than 50% now. At the superior-quality "hama-age" auctions for the Ehime producers, average prices per piece were $60–$67 for 7-mm goods, slightly higher than the preceding year; and about $100 for 8 mm, $190 for 9 mm, and $376 for 10 mm—all considerably higher than the year before. However, prices for 6-mm pearls came in at about $37 per piece, down from last year. *MD*

The crystal chemistry of manganese-bearing elbaite. P. C. Burns, D. J. MacDonald, and F. C. Hawthorne, *Canadian Mineralogist*, Vol. 32, 1994, pp. 31–41.

Although most gemologists consider all members tourmaline—or use variety names such as rubellite, indicolite, etc.—the tourmaline group actually consists of at least 10 distinct mineral species. The most common gem tourmaline is elbaite. This paper examines eight yellow, green, brown, and colorless crystals of manganese-bearing elbaite in terms of chemical composition and crystal structure. It follows a previous work by the authors in which they examined tourmaline stoichiometry.

It is difficult to determine the composition of tourmaline-group minerals, because they contain so many different light elements at the same time: oxygen, boron (both not measurable by standard electron microprobe until recently), lithium, and hydrogen (the latter two still not measurable by standard electron microprobe). In this paper, the authors compare two methods for evaluating tourmaline composition: electron microprobe analysis

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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 his reviewers, and space limitations may require that we include only those articles that we feel will be of greatest interest to our readership.

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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.*

(coupled with previously tested assumptions about site-filling by various elements), and single-crystal X-ray diffraction and structure refinement (which determines the number of electrons per site—an "average" composition). They conclude that tourmaline compositions can be accurately determined using these methods: Boron fills its own site; fluorine and hydrogen sum to four atoms per formula unit; and lithium and oxygen can be calculated by stoichiometry if the oxidation states of atoms such as Fe and Mn are known. *MLJ*

extraLapis. No. 6, 1994.

This issue of *extraLapis* is entirely on tourmaline. It covers a broad variety of aspects, ranging from forgotten occurrences to brand-new finds, and including causes of color in, new varieties of, and technical uses for, tourmaline. Historical aspects are the main focus of several articles. These include Vorobyev's crystallographic description of 22 tourmalines from Sri Lanka with unusually complex crystal-form combinations (by F. Damaschun); a description of the once-famous tourmalines from Qârusulik, Greenland (by O. V. Petersen); the tourmaline production of Myanmar (Burma) (by R. E. Kane); the story of a (supposedly Burmese) 255-ct rubellite, now in the Kremlin (by M. Glas); and J. W. Goethe's observations on the "tourmalinic" (electric and magnetic) properties of tourmalines.

B. C. Cook describes the discovery and exploitation of the Mina da Batalha, Paraíba, Brazil (closed in 1993). A. Petrov describes the type locality for "ferridravite," near Villa Tunari, Alto Chapare, Bolivia, and explains why "ferridravite" now has become povondraite. J. Zang analyzes the composition and colors of color-zoned tourmalines from a new mine at Sanga-Sanga, Tanzania. In two additional articles, J. Zang also explains why apparently black schorl tourmalines in thin sections are not really black (nor are they always schorl!) and how the red stars in color-zoned Madagascar tourmalines develop. B. Wöhrmann tells the story of these Madagascar tourmalines and of the beautiful water-color paintings of longitudinal crystal sections in F. Benesch's impressive book *Der Turmalin: Eine Monographie* (Stuttgart, Germany, 1990).

J. I. Koivula gives a comprehensive description of typical inclusions in tourmaline. M. Glas discusses optical phenomena, such as halos and chatoyancy caused by hollow growth tubes. M. Glas and U. Althaus explain the use of tourmalines as parts of accelerometers in airplanes.

To complete the volume, this *extraLapis* contains not only a 20-page compilation of the most important and interesting tourmaline occurrences worldwide (extracted from Benesch, 1990, and updated), but also the most up-to-date mineralogical system of the tourmaline group (to be published in the upcoming—1995—edition of *Dana's Mineralogy*, by R. V. Gaines et al.). Excellent color photos lavishly illustrate this informative volume. *RT*

Fluorescent oil inclusions in quartz. A. de Goutière, *Journal of Gemmology*, Vol. 24, No. 2, 1994, pp. 84–86.

This short, well-illustrated note reports on the occurrence of petroleum-bearing inclusions in two quartz specimens from Herkimer, New York. In one, the "four-phase" inclusion consists of brine, petroleum, a gas (within the petroleum), and bitumen particles. In the other, a three-phase inclusion consists of petroleum, a gas bubble, and bitumen particles. *CMS*

An important peridot. G. Webb, *Australian Gemmologist*, Vol. 18, No. 6, 1993, pp. 191–193.

In August 1992, the Mineral Section of the Australian Museum purchased an exceptionally large—193.44 ct—faceted peridot said to be from Myanmar. Subsequent gemological examination of the stone revealed properties typical of peridot in general (R.I., 1.650–1.685; birefringence, 0.035; S.G., 3.34; absorption bands at 493, 473, and 453 nm). Microscopic features include a "lily pad" inclusion with a white opaque crystal butting against a black mineral grain in the center; faint brown, rectangular mica inclusions (considered by Dr. Gübelin to be diagnostic of this locality); and minute fissures with a high degree of strain in adjacent areas, as noted with polarized light.

After describing the stone's properties, the author provides from the literature a good, concise review of the Burmese peridot deposits. This is followed by a brief listing of large peridots held in other museums around the world. One macrophotograph and three photomicrographs accompany the report. *RCK*

Interstellar oxide grains from the Tieschitz ordinary chondrite. L. R. Nittler, C. M. O'D Alexander, X. Gao, R. M. Walker, and E. K. Zinner, *Nature*, Vol. 370, August 11, 1994, pp. 443–446.

We usually think of corundum and spinel as coming from two environments: basaltic lavas and metamorphic rocks, especially marbles. However, by virtue of their refractory natures (that is, very high melting temperatures), these minerals sometimes come from a more exotic source—direct precipitation from gases produced by nucleosynthesis (atomic fusion) in stars. Some mineral grains in chondrites (stony meteorites) are older than the Earth, formed from gases from other stars before our sun condensed.

In this paper, the authors describe the results of oxygen and aluminum isotopic studies of 20 corundum grains and one spinel grain from the meteorite Tieschitz. Twelve grains probably came from oxygen-rich red giant stars, five possibly came from massive mass-losing (Wolf-Rayet) stars, and four possibly came from low-mass red giant stars. However, don't expect to see interstellar rubies on the gem market soon: All the grains described in this study were between 0.5 and 2 mm, and were selected by examination of more than 6,000 refractory oxide grains. *MLJ*

Optical anisotropy of cuprite caused by polishing. E. Libowitzky, *Canadian Mineralogist*, Vol. 32, 1994, pp. 353-358.

Many materials that are structurally isotropic show anomalous birefringence; common gemological examples include garnets (birefringence sometimes due to lowered symmetry caused by structural water), spinel (birefringence due to strain), and diamond (birefringence also due to strain). The copper ore mineral cuprite, sometimes cut as a gemstone, can show pronounced anomalous birefringence caused by surface deformation when polished mechanically. The birefringence can be prevented by polishing cuprite using an alkaline silica solution instead of diamond paste. *MLJ*

DIAMONDS

Diamonds and their sources in the Venezuelan portion of the Guyana Shield. H. O. A. Meyer and M. E. McCallum, *Economic Geology*, Vol. 88, No. 5., 1993, pp. 989–998.

Venezuela has been a minor producer of diamonds since they were first discovered there in 1901. To date, all are from alluvial deposits in the Guyana Shield area south of the Orinoco River in the state of Bolívar. However, few detailed studies have been published on the geologic source and nature (quality, size) of these diamonds. This paper addresses this void, first by recognizing that there are actually two different geographic/geologic diamond sources in Venezuela, and second by comparing and contrasting these sources and the diamonds recovered from each.

The first region in Venezuela that produced diamonds is underlain by the Roraima Group of clastic sediments. Diamonds mined here originated in basal rocks of this group. However, the diamonds in these source rocks are alluvium from yet an older primary kimberlite or lamproite source(s) that has yet to be found. The second region, the Guaniamo district, is about 200–300 km west of the Roraima-associated deposits. Discovered in 1969, it now accounts for more than 75% of Venezuelan production. Several diamond-bearing kimberlites (1.73 billion years old, among the oldest known kimberlites in the world) have been discovered in the area. These are believed to be the primary source of the alluvial diamonds in the Guaniamo region.

There is a marked contrast between the two regions in the commercial value of the diamonds found there. For example, from 1950 to 1968, the recorded production of Venezuelan diamonds (all from Roraima-associated deposits) was 47% gem, 43% industrial, and 10% bort. In 1979, because of a large amount (at least 77%) of lower-quality diamonds from the Guaniamo region, total Venezuelan production averaged only 27% gem, with 43% industrial and 30% bort.

The abundance of bort in the Guaniamo deposits implies limited transport distance from a primary source rather than reworked alluvial deposits (as is the case with the Roraima deposits). On the basis of this and other characteristics of the diamonds produced in the two areas, the authors suggest that a common source of diamonds is unlikely. They further suggest that a much more detailed geologic survey of the Roraima rocks is necessary to determine the source of the diamonds found in that area. *AAL*

Fracture-filled diamonds: A ticking time bomb? S. Wakefield, *Mazal U'Bracha*, Vol. 10, No. 57, April 1994, pp. 40–43.

In an effort to test claims of the undetectability, stability, and durability of fracture-filled diamonds, Gemologist Sharon Wakefield purchased six Koss fracture-filled diamonds for testing. She says that all were identifiable via the "flash effect," contrary to the manufacturer's claims, and that the filler was extremely vulnerable to damage during prong retipping. All it took for "loss of filler" was a cumulative exposure of 60 seconds to the jeweler's torch. Bench jewelers, she said, "need to exercise great caution" because of this. The most interesting and unexpected environmental response was an "alarming" rapid filler degradation when exposed to a short-wave UV lamp. Ms. Wakefield observed a slight brown discoloration on a filled diamond after only 1.5 hours of exposure 10 mm from a four-watt short-wave UV lamp. After 2.5 hours, the filler continued to darken and actually receded from the surface. The filled diamonds also showed loss of filler after 4.5 hours of ultrasonic cleaning. The loss continued with increased exposure.

Fracture-filled diamonds "pose a clear and potentially elusive danger to the gemologist, appraiser, jeweler and, worst of all, the consumer," according to Ms. Wakefield. *AC*

Editor's note: See this issue's feature article for much more on filled diamonds, as well as the next abstract, on the article by C. Even-Zohar, which is a rebuttal to Ms. Wakefield's findings.

Gemological research out of this world. C. Even-Zohar, *Mazal U'Bracha*, Vol. 10, No. 57, April 1994, pp. 46–50.

Mazal U'Bracha Editor Chaim Even-Zohar disputes the findings of Sharon Wakefield's research paper, "Fracture Filled Diamonds: A Ticking Time Bomb?" (see previous abstract).

Mr. Zohar maintains that Ms. Wakefield's findings about the degradation of the filler in Koss-treated diamonds when exposed to UV radiation and ultrasonic cleaning are needlessly alarmist and based on flawed methodology. He maintains that the short-wave UV radiation to which Ms. Wakefield exposed the treated diamonds does not naturally occur between the surface of the earth and the ozone layer; rather, it occurs only in outer space (hence the title of this article). Also, Ms. Wakefield subjected her samples to 10 hours of ultrasonic cleaning when the normal maximum exposure is 10–15 minutes. Mr. Zohar claims that Ms. Wakefield's methodology was further flawed because she examined the product of only one manufacturer. *AC*

Helium isotope diffusion in natural diamonds. R. C. Wiens, D. Lal, W. Rison, and J. F. Wacker, *Geochimica et Cosmochimica Acta*, Vol. 58, No. 7, pp. 1747–1757.

Diamonds play an important role in understanding the processes operating in the Earth's mantle. During their formation in the mantle, diamonds incorporate various types of inclusions from which geologic, geophysical, and even cosmogenic interpretations can be made. Although gemologists are acquainted with the solid inclusions in diamonds and the interpretations that may be made from them (e.g., the depth and temperature at which diamonds form), they may not know that very small amounts of rare (noble) gases, such as helium, are also present and detectable by mass spectrometer. Valuable information can be obtained by studying these rare gases from the mantle, and the crystal structure of diamond—unlike other mantle minerals—is generally strong enough to contain these gases both under mantle (high temperature and high pressure) and surface conditions.

Helium occurs as two isotopes, ^{3}He and ^{4}He. Both are found in all diamonds, although they originate from different sources. The ^{3}He isotope is characteristic of the primordial mantle and is of cosmogenic origin (it is the most abundant He isotope in the present-day sun). It can also occur in alluvial diamonds as a secondary, "cosmogenic" component produced by cosmic-ray irradiation at the Earth's surface. The ^{4}He isotope is formed by the decay of radioactive elements, notably uranium and thorium, and thus its occurrence in diamonds may be explained by the presence of U or Th mineral inclusions (other sources are also possible). By measuring the relative amounts of each helium isotope, usually reported as the ratio ^{3}He/^{4}He, geologists can determine significant aspects of a diamond's history, This is because the source of the helium is a clue to the origin of the diamond and to aspects of the mantle conditions where the diamond formed (assuming that the analyzed helium isotopes are representative of diamond formation conditions and that the isotopes are not lost from the crystal lattice by diffusion or modified in any way by other processes).

Because of the great age of diamonds and the high temperatures to which they have been subjected in the mantle, it is necessary to know how heat affects helium retention. Various experiments by "step heating" diamonds up to 1900°C (diamonds in the Earth probably do not exceed 1400°) show, for example, that natural terrestrial diamonds with a high cosmogenic helium content retain much more ^{3}He than ^{4}He. As a result of this and many other experiments detailed in the article, the authors conclude that mantle helium is only one of several helium components in terrestrial diamonds, each of which may have different temperature-related release patterns. *AAL*

Mantle xenoliths from kimberlite near Kirkland Lake, Ontario. H. O. A. Meyer, M. A. Waldman, and B. L. Garwood, *Canadian Mineralogist*, Vol. 32, 1994, pp. 295–306.

In a sense, the incipient Canadian "diamond rush" began in the last century, when diamonds were found in some glacial outwash material south of the Great Lakes. The Kirkland Lake area in Ontario, one possible source for those diamonds, contains at least 10 kimberlites, including micaceous and hypabyssal kimberlites and tuffisitic kimberlitic breccias. This paper examines ultramafic xenoliths from a 156-million-year-old kimberlite breccia pipe, C-14.

C-14 xenoliths contain forsteritic olivine, enstatite-rich orthopyroxene, "emerald"-green clinopyroxene, pale pink-to-purple pyrope garnet, phlogopite, and chromite. On the basis of trace elements in olivine, pyroxene, and garnet, it was found that these xenoliths equilibrated in the temperature range 917°–1221°C and the pressure range 35.8–55.6 kbar, both of which are within the stability region of diamond. However, diamonds are not found in this kimberlite in economic quantities. The authors caution that even if pressure-temperature conditions favor diamond formation, later temperatures or oxidation states in the kimberlite magma can cause diamond resorption. *MLJ*

Petrology of a diamond and coesite-bearing metamorphic terrain: Dabie Shan, China. A. I. Okay, *European Journal of Mineralogy*, Vol. 5, No. 4, 1993, pp. 659–675.

Although the most significant primary occurrences of diamonds are in kimberlite and lamproite (igneous) rocks, diamonds are known in several other geologic environments, ranging from meteorites to ophiolites to metamorphic rocks. In all cases, the necessary geologic conditions for diamond crystallization (high pressure and high temperature) were present. To date, all non-kimberlitic/lamproitic primary occurrences have been economically insignificant, so little attention has been paid to them.

This paper describes the ultra-high-pressure, coesite-(high pressure form of quartz) and diamond-containing metamorphic rocks of the Dabie Shan complex, in central China. This metamorphic occurrence is also noneconomic, as the diamonds are very small (typically aggregates of 2–30 µm; cubic, cuboctahedral, and octahedral morphology) and only occur as inclusions in garnet. The diamond-bearing garnets occur within a specific eclogite zone. *AAL*

Superkimberlites: A geodynamic diamond window to the Earth's core. S. E. Haggerty, *Earth and Planetary Science Letters,* Vol. 122, No. 1–2, 1994, pp. 57–69.

Diamonds are among the deepest solid objects to reach the Earth's surface. Research has shown that most diamonds probably formed in the upper mantle at depths of 180–200 km. However, a few formed in the transition zone (at depths of 400–670 km), and some possibly even deeper, in the lower mantle (>670 km).

Kimberlites (and lamproites) transport diamonds to the surface. Therefore, these highly gas-charged (containing carbon dioxide, oxygen, nitrogen, etc.) volcanic magmas must have formed at even greater depths than their entrained diamonds. Kimberlites that form at the greatest depths (down to 2,900 km, the boundary between mantle and core) and eventually reach the surface are called "superkimberlites." The rare diamonds carried up from such depths have characteristic mineral inclusions—for example, SiC (moissanite), native iron, and many sulfide minerals—that are indicative of a highly reducing environment. These and other geochemical features of deep-mantle diamonds (as well as geochemical aspects of the superkimberlites themselves) provide a "window to the Earth's core." Some diamonds have recorded events in the core that date back to 3.3 billion years!

Kimberlites and superkimberlites are emplaced exclusively in the oldest (>1.7 billion years), most stable, and thickest (about 200 km) regions of the lithosphere. Surface locations of these rocks, the exceptional energy required for their emplacement from such great depths, geomagnetic reversals, plumes (localized bodies of volcanic rock rising into the crust from the mantle), and diamonds from all depths are integrated into a model which establishes some correlations among these factors. *AAL*

GEM LOCALITIES

Colored pectolites, so-called "larimar," from Sierra de Baoruco, Barahona Province, southern Dominican Republic. K. Bente, R. Thum, and J. Wannemacher, *Neues Jahrbuch für Mineralogie, Monatshefte,* No. 1, January 1991, pp. 14–22.

The authors describe the occurrence, paragenesis, outer appearance, physical properties (including X-ray powder diffraction data), and chemical composition (obtained by XRF and AAS analyses) of "larimar" pectolite—all of which are essentially the same as for pectolites from other localities. Heating experiments led to the conclusion that "larimar" was formed below 240°C (the maximum thermal color-stability temperature). The greenish tints that disappear at this temperature correlate with color centers, and the bluish tints are caused by vanadium. *RT*

Formation of the Muzo hydrothermal emerald deposit in Colombia. T. L. Ottaway, F. J. Wicks, L. T Bryndzia, T. K. Kyser, and E. T. C. Spooner, *Nature,* Vol. 369, June 16, 1994, pp. 552-554.

Most emeralds occur in association with igneous rocks, especially pegmatites. Important exceptions are the emerald deposits of Colombia, including the Muzo, Chivor, and Cosquez mines. The Muzo emeralds described here are found in a single horizon in the Villeta Formation, a thick sequence of dark-colored, Lower Cretaceous organic-rich shales and limestones. They occur in cavities within a network of thin calcite-albite-pyrite veins. Accessory minerals include quartz, barite, fluorite, and parisite, a rare-earth fluorocarbonate; the latter two minerals have been successfully used as indicators of emerald mineralization.

The emerald-containing veins surround highly altered regions in the host shale. These altered regions, known as *cenicero* (or ash) zones, are pale gray and contain calcite, albite, muscovite, pristine unweathered pyrite, doubly terminated quartz crystals, and elemental sulfur. Trapiche emeralds are found in the dark shale on the perimeter of the *cenicero.*

Fluid inclusions in Muzo emeralds are a (Na,K)Cl-saturated brine that contains gases (CO_2, CH_4, N_2) and minor amounts of Ca, Fe, Sn, Mg, Mn, and Ti complexes. Two different measurement techniques (salt composition and oxygen-, sulfur-, and carbon-isotope studies) give a consistent formation temperature for these inclusions (and thus the emeralds) of about 375°C at 1-km depth. The mineralizing brines probably formed from evaporites, or had previously reacted with them.

The authors propose the following model for emerald formation at Muzo. The dark shale included partially crystalline carbon-rich pyrobitumen (coal), which contained the reduced-sulfur species H_2S; the brines contained oxidized sulfur as the sulfate ion $(SO4)^{-2}$. These reacted with each other and with the reduced-carbon species in the hydrocarbons to form carbonate ions, elemental sulfur, and sulfide ions; the carbonate ions went on to form calcite, and the sulfide reacted with dissolved iron to form pyrite. These reactions converted the black shale to ash-gray *cenicero;* they also produced enough heat to continue the reaction until the reduced-carbon starting materials were depleted. The fluids that reacted with the *cenicero* zones—saturated with calcite, pyrite, and other phases—precipitated these minerals in veins at the *cenicero* margins; trace amounts of Be, Cr, and V from the organic material were deposited as constituents of late-forming emerald crystals. Beryl that had precipitated directly in the nearby shales formed trapiche emeralds.

Colombian emeralds owe much of their beauty to their low iron content, the result of pyrite formation having "gobbled up" all the available iron during emerald deposition. Emerald prospectors take note: The ash-gray *cenicero* zones in organic-rich shales should be good indicators of emerald pockets nearby. *MLJ*

Four hessonite occurrences in Orissa, India. J. Kanis and M. Redmann, *Journal of Gemmology,* Vol. 24, No. 2, 1994, pp. 75–83.

Discussed are four new localities for transparent and massive hessonite garnet in the Indian state of Orissa—Ghatpara, Dahikbala, Budhido, and Burubura. Physical, optical, and chemical data are listed, as are inclusions indigenous to each specific area's transparent material. Typically, Ghatpara hessonites contain many different types of mineral inclusions. Burubura hessonites tend to be fairly clean, with possible healing cracks containing two- or three-phase inclusions. Budhido material usually appears very oily, which can negatively affect a stone's transparency; these garnets also contain numerous corroded mineral inclusions. The hessonite samples from Dahikbala all showed long needle-like inclusions, in part parallel and often bent. In addition to several photomicrographs, the article presents color photos of the areas being mined, and a map of Orissa with mining sites marked. *JEC*

Gems around Australia: 8. H. Bracewell, *Australian Gemmologist,* Vol. 18, No. 6, 1993, pp. 193–194, 196.

Mrs. Bracewell continues to lead us on a personal tour of Australia's gemstone localities, beginning this segment with an amusing anecdote about getting lost on the way to Hillside Station in Western Australia, where she eventually visited the Curlew mine. This is an abandoned underground (shaft) emerald deposit of the mica-schist type, reached by descending an old iron ladder. While no specimens of interest were found in the mine itself (except for a snake, thankfully dead), time spent sorting through some tailings yielded opaque green beryl in matrix and one or two small emerald specimens. A local resident informed the author that there were other gem materials in the area, including green aventurine and agate, but no samples of these were collected.

The report includes three photographs and a map of the author's route in Western Australia. Unfortunately, the latter does not show the locality described in this installment. *RCK*

A high chromium corundum (ruby) inclusion in diamond from the São Luiz alluvial mine, Brazil. G. R. Watt, J. W. Harris, B. Harte, and S. R. Boyd, *Mineralogical Magazine,* Vol. 58, No. 3, 1994, pp. 488-491.

A highly chromian, red corundum inclusion (about 100 μm long) was found in a type-II diamond. Electron microprobe analyses gave these averages (in wt.%) for the corundum: SiO_2, 0.58; TiO_2, 0.10; Al_2O_3, 90.37; Cr_2O_3, 8.58; FeO, 0.28; MnO, 0.04; MgO, 0.40; CaO, 0.01; Na_2O, 0.01. The high Cr content of the São Luiz corundum inclusion, relative to corundum from eclogitic xenoliths, may reflect formation at sublithospheric depths, analogous to increased Cr partitioning in kyanite with pressure. *RAH*

An imperial chrysoprase from Yerilla. *Jewellery Review,* Vol. 6/93, No. 11, 1993.

Although first mentioned 2,000 years ago by the Roman scholar Pliny, chrysoprase localities remained rare and obscure until 1965, when a good-quality deposit was found on the East Coast of Australia. In 1991, on the other side of the continent, an "imperial" chrysoprase was found. This deposit at Yerilla, some 850 km from Perth, is owned and operated by the Gembank Group. It produces chrysoprase ranging from yellow green to deep "jade" green. *NDC*

India's invisible gem rush. V. Kuriyan, *Europa Star,* No. 199-4, 1993, pp. 67–70.

This article surveys the rapid development of gemstone mining in Orissa, India. Gems found there include aquamarine, chrysoberyl cat's-eye and alexandrite, iolite, rhodolite garnet, and ruby. At present, the government is making efforts to develop mining and establish a cutting industry. In the author's opinion, Orissa's future as a gemstone producer is promising. This article is part of a dossier covering various aspects of gems and gemology. *RT*

Spessartine aus Namibia. Th. Lind, H. Bank, and U. Henn, *Neues Jahrbuch für Mineralogie, Monatshefte,* No. 12, December 1993, pp. 569–576.

This article, in German, describes the attractive new orange gem-quality spessartine garnet—from a locality in Namibia—that has been marketed under the names "Hollandine" and, more recently, "Mandarin" garnet. Gemological examination has revealed that this material falls along the solid-solution series between spessartine and pyrope, with a spessartine content between 80% and 90%. It has a specific gravity of 4.09–4.15 and R.I.'s of 1.790–1.797. The absorption spectrum exhibits bands at 408, 421, 430, 457, 483, and 527 nm (due to Mn^{2+}, the coloring agent). *JES*

Two interesting "double star" sapphires. J. I. Koivula, R. C. Kammerling, and E. Fritsch, *Australian Gemmologist,* Vol. 18, No. 7, 1993, pp. 235–236.

The authors examined two bluish gray-to-grayish blue star sapphires, reportedly from Sri Lanka, that each has an unusual double star. The smaller (0.87 ct) stone had two distinct, adjacent six-sided stars, apparently sharing one arm (imagine two six-sided starfish holding hands). The stone was cut from two intergrown crystals oriented with their optic axes parallel to each other. The larger (38.56 ct) stone showed two overlapping six-sided stars, again with separate centers (imagine two off-center stars connected at the tips of all six rays), unlike 12-ray star corundum. This stone was polysynthetically twinned in microscopically thin layers (lamellae); one set of twin layers contained three orientations of needle-like inclusions, creating one star, while the other set contained needles in three slightly different orientations, creating the other star. Microscopic examination revealed that each set of lamellae only produced one star. *MLJ*

INSTRUMENTS AND TECHNIQUES

Carl Zeiss Citoval 2 Stereomicroscope. T. Linton, R. Beattie, and G. Brown, *Australian Gemmologist*, Vol. 18, No. 7, 1993, pp. 225–226.

This Instrument Evaluation Report begins with a discussion of the importance of a good microscope for gemologists and then describes the criteria used by the authors in their evaluation of the Carl Zeiss Citoval 2 Stereomicroscope. The vertical-format instrument provides continuous stereo-zoom magnification from 10× to 100× using standard 16× eyepieces. With this configuration, it has an operational field of view ranging from 20 mm at 10× to 2 mm at 100×, at a working distance of 107 mm. Depth of field is described as "adequate" for most gemological applications. The 45° inclined binocular eyepieces can be individually focused, and the mechanical construction of the microscope is said to be both simple and utilitarian—for example, a simple clamping screw attaches the microscope to its cast base. Incident illumination is provided by a tungsten-halogen lamp that is attached by an articulated arm to a ring below the zoom magnification changer. For transmitted (i.e., brightfield) illumination, a transmitted-light support base is attached to the microscope and the tungsten-halogen lamp is removed from its articulated arm and inserted into the base. An optional darkfield illuminator is also available.

The authors found the microscope's optics to be excellent in the 10×–75× range, with some problems encountered at higher magnifications. There was also some criticism of the illuminator's rheostat switching system. In final analysis, however, the instrument was felt to be an excellent value.

Abstractor's Note: Although I have not examined this instrument, I would have difficulty recommending any microscope for routine gemological applications that did not have an integral darkfield/brightfield system of illumination. For both diamond grading and initial microscopic examination of gems during identification, darkfield illumination is mandatory, not an option. In addition, a practical microscope system—including optics and illuminator(s)—should not require that a single clamp-on illuminator be removed and reinstalled each time a different method of illumination is needed. *RCK*

A device to facilitate the measurement of birefringence in gemstones. T. Farrimond, *Journal of Gemmology*, Vol. 24, No. 2, 1994, pp. 105–108.

Mr. Farrimond describes a simple device, which he calls a "twiddler rod," that can be added to any refractometer to help determine birefringence. The usual method involves using fingers to rotate a stone on the hemicylinder of a refractometer, which requires opening (or leaving open) the lid of the instrument, as well as repeatedly removing one's eyes from the scale to adjust the stone. The new device mounts through the refractometer lid and holds the stone in proper position on the hemicylinder so that the user can concentrate on the scale while rotating the stone. Instructions are given to make one's own "twiddler," or one can be ordered from the author for a nominal price. *CMS*

JEWELRY HISTORY

Common intrigue. P. Francis, Jr., *Lapidary Journal*, Vol. 47, No. 3, June 1993, pp. 41–44, 96, 98.

Peter Francis, Jr., director of the Center for Bead Research, investigates circumstances surrounding unusual beads of opalized wood that appeared on the antique bead market in the mid-1980s. He bases some of his information on a government report that was reportedly smuggled out of Myanmar. Provided is an overview of the geology, history, and ethnography involving these beads, a once-precious commodity. Although the topic is complex, the author clearly tells of the importance of these now-rare beads to the ancient Pyu and Chin societies. Mr. Francis also notes the occurrence of early gem treatment associated with the common-opal beads, as well as simulant materials used in the past and today. *JC-G*

The Retro revival. L. Hagan, *Jewelers' Circular-Keystone*, Vol. 165, No. 5, May 1994, pp. 86–98.

Jewelry trends are almost predictably cyclic in the way their popularity wanes for a time and then begins anew. Currently, jewelry characteristic of the late 1930s through the 1950s, also known as "Retro" jewelry, is in favor. In the first half of this "Heritage" article, Lael Hagan outlines the origins of the style, and briefly describes its expression in jewelry. Characterized by a bold sculptured-gold look, Retro jewelry typically incorporated diamonds, pale sapphires, rubies, amethysts, citrines, and aquamarines set in large brooches, double clips, bib necklaces, and cocktail rings. Generally the designs were based on floral, feminine themes or on mechanical, industrial motifs and were executed in yellow, white, and rose gold.

The second half of the article is devoted to an alphabetized list of the "major players in Retro jewelry design." This list—a real service to the jewelry community—gives salient facts about each jewelry company, including a brief history, its location during this period, signature designs or contributions to the style, and (when known) a verbal description of the maker's marks.

An extensive bibliography and a time line for the period conclude this useful article, which is abundantly illustrated with beautiful examples of Retro jewels.

EBM

Verdura rediscovers a "revolutionary." V. Becker, *Jewellery International,* Issue 15, 1993, pp. 17–18.

In this article, Vivienne Becker focuses on the revival of Parisian-style jewelry created by Suzanne Belperron, a little-known yet influential designer of the 1920s. Drawing from a vast archive of Ms. Belperron's designs, the house of Verdura has launched a very limited selection of her jewels, "both original pieces and modern recreations of original designs." Verdura maintains exclusive rights to use and distribute these items.

Ms. Becker provides the reader with as good a history as can be expected for the talented but somewhat mysterious Ms. Belperron. (Except for her 4,500 jewelry sketches and designs, she destroyed most of her personal papers before her death in 1983.) Ms. Becker writes of the importance of Ms. Belperron's contributions in the transitional phase of jewelry fashion between the Art Deco and Modernism periods, stating that the work and influence of the very talented Ms. Belperron has been "underestimated" until now. The article is accompanied by color illustrations of famous Belperron jewels. *JC-G*

JEWELRY RETAILING

French royal jewel doubles its estimate. *Retail Jeweller,* Vol. 31, No. 826, July 14, 1994, p. 9.

An elegant brooch—originally from the French Crown Jewels—sold for £62,000 (US$97,960) to London dealers SJ Phillips at Sotheby's sale of fine jewels held June 23, 1994. Based on a scroll-and-foliate design, the brooch was set with cushion-shaped diamonds and foiled rubies. It originally formed part of a ruby and diamond parure made for Marie-Therese, Duchess D'Angouleme (1778–1851), who was the daughter of King Louis XVI and Marie Antoinette. The top price paid at the sale (£84,000, or US$132,720) was for an early 19th-century diamond necklace, which also went to a London dealer. A rare gold, enamel, and gemstone pendant by Carlo Giuliano sold above estimate for £21,850 (US$34,523). *MD*

Saleroom report: Diamonds on top as season closes. V. Becker, *Retail Jeweller,* Vol. 31, No. 826, July 14, 1994, p. 9.

Christie's last jewelry sale of the season, on June 22, took in more than £3.6 (US$5.7) million, the third highest total for a London jewelry auction. More than 87% of the jewelry items offered were sold, including a rare, fancy light green 5.30-ct diamond that "raised more than $38,000 per carat." An "important" Edwardian diamond necklace sold for £150,000 (US$237,000). Sale prices of all the finest period pieces substantially exceeded their pre-sale estimates, proving the continuing demand for this type of jewelry. An 1830 diamond tiara, once property of the late Mary, Viscountess Rothermere, went for £43,333 (US$68,466). Christie's January-to-June jewelry results for this year were up 20% over the same period last year. *MD*

PRECIOUS METALS

A glimpse of life in the gold country. Excerpts from John Doble's journal and correspondence. *California Geology,* Vol. 47, pp. 104–117.

Accounts of California's gold rush are often heavily romanticized, so first-hand accounts—particularly diaries—can be fascinating in the ways that they demystify and corroborate our impressions of the past. This article consists of a set of excerpts from the letters and two years of diaries of John Doble, who arrived in Amador County, in the California gold country, in 1851, and went on to become a notable jurist in the region. The excerpts contain descriptions of:

- ❖ The ore and theories about gold formation [sic]—". . . some thinks it washed into the gulches out of the hills[,] others think it thrown at some time long since all over the country by Volcanic action & Others that it is a natural formation & has always been where we find it . . . ."
- ❖ How quickly claims were staked—"About 7-o-clock we seen men running in every direction. . . . The news had spread very rapidly and by noon at least 100 men were on the ground most of them sinking holes. . . ."
- ❖ The cost of supplies—sometimes high, sometimes very low—and the effects of weather, as well as flood, fire, and fever.

Social progress was extremely rapid: from tents in the wet clay and renting the use of a donkey to carry sluice-box components, to phrenological examinations and tickets to balls in under two years.

One is left with a strong impression of the personal costs and rewards of gold-rush mining. Five vintage photographs are included. *MLJ*

Metal news: Gold jewelry production dropped 7.1% in 1993. *National Jeweler,* Vol. 38, No. 14, July 16, 1994, pp. 47, 146.

Karat-gold jewelry fabrication fell 7.1% worldwide in 1993, to 2,751.1 tons, according to the Gold Field Mineral Services' annual survey of the gold market. Gold production was down in all major world markets except

Latin America and the United States, where fabrication grew 6% to 154 tons. Total European fabrication fell 4.9%, to 702.9 tons; Italy's production of gold dropped 4.3% to 485.1 tons. Far East output fell 10.7% to 704 tons. Manufacturers in China, Taiwan, Japan, Hong Kong, and Malaysia all recorded significant declines. In the Middle East, fabrication demand fell 6.2% to 521 tons. Saudi Arabia and Yemen recorded modest decreases, while Turkey showed strong growth. On the Indian subcontinent, gold jewelry manufacturing dropped 9.7% to 336.1 tons. African jewelry manufacturers registered a 25.9% drop in total fabrication last year, to 35.5 tons.

During 1993, however, the United States regained from China its position as the world's largest consumer of gold jewelry. U.S. manufacturers were helped by a recovery in U.S. spending and a weakening of Indian and Chinese demand. Canada chipped in with an 8.1% gain to 10.2 tons in 1993. In recent years, U.S. manufacturers have set up facilities in Latin America, or have shipped goods there for finishing, to take advantage of low labor costs. Such factors helped Latin America record an 8.1% increase in gold-jewelry production, to 64.8 tons last year. *MD*

SYNTHETICS AND SIMULANTS

Density-driven liquid-liquid phase separation in the system Al_2O_3-Y_2O_3. S. Aasland and P. F. McMillan, *Nature*, Vol. 369, June 23, 1994, pp. 633-636.

Yttrium aluminum garnet (YAG) is an important gem simulant, although its popularity has been somewhat eclipsed in recent years by that of cubic zirconia. YAG crystals are grown primarily by the Czochralski method, and flux-grown crystals do not reach large sizes (K. Nassau, *Gems Made by Man*, Chilton Book Co., Radnor, PA, 1980).

In the paper reviewed here, the authors discuss one reason for YAG's reluctance to crystallize from the melt: Oxygen atoms occur in several different environments in intermediate Al_2O_3-Y_2O_3 melts (nearest neighbors can be 4 Al, or 3 Al and 1 Y, or 2 Al and 2 Y), and in only one environment (2 Al and 2 Y nearest neighbors) in the garnet crystal structure. Because the melt viscosity gets too high for easy structural rearrangement at temperatures near the YAG melting temperature, two separate glasses of the same composition—but different density—can be formed by fast cooling from compositions slightly more aluminum-rich than that of YAG. *MLJ*

A girl's best friend. K. Leutwyler, *Scientific American*, Vol. 269, No. 6, December 1993, pp. 40, 44.

For 40 years, engineers have tried to exploit the hardness and thermal conductivity of diamond through the creation of synthetic diamond and diamond-like materials for commercial uses. However, it is difficult to synthesize high-quality diamond cheaply. Chemical vapor deposition is the least costly method of applying a synthetic diamond thin film, but it is irregular and the result is of dubious crystal structure.

In June 1993, a Pennsylvania State University group developed an inexpensive method of forming synthetic diamond films from a commercial polymer using a conventional oven. In July, Harvard chemists described the formation of a material purportedly harder than diamond, b-C_3N_4. These claims still need to be confirmed.

At Microelectronics and Computer Tech Corp. in Austin, Texas, it was discovered that synthetic diamond thin films emit a shower of electrons when subjected to a weak electric field. In both Japan and the U.S., diamond-like films are being tested for possible applications in the automobile industry, using these electrical properties and their ability to withstand corrosion. *NDC*

Twinning in Ramaura synthetic rubies. K. Schmetzer, C. P. Smith, G. Bosshart, and O. Medenbach, *Journal of Gemmology*, Vol. 24, No. 2, 1994, pp. 87–93.

Described are characteristics of five interpenetrant-twinned Ramaura synthetic ruby crystals, including crystal morphology not previously detailed in the literature. The Ramaura twins have a form that differs somewhat from that of other twinned synthetic rubies. "Laminated" twinning—a characteristic of natural rubies—was not observed in these Ramaura specimens and has not been encountered in other Ramaura material. The features described for the Ramaura samples are well illustrated with color macro- and micro-photographs. *CMS*

TREATMENTS

Colour treatment of common beryls. D. Robert, *Australian Gemmologist*, Vol. 18, No. 7, 1993, pp. 231–234.

Described is the author's development of a patented two-step process for the color enhancement of beryls to simulate other gem materials. The first step is to heat treat preformed material at approximately 800°C, which apparently results in the removal of some water from the beryl's structure and induces some porosity to permit dyeing. The stones are then immersed in dyes that have been dissolved in a mixture of alcohols. Final cutting and polishing follows treatment; details of the recommended fashioning steps are provided. An optional last step in the processing is wax surface treatment to improve apparent luster. Photographs illustrate simulants of turquoise, chrysocolla, coral, and rhodochrosite that have been produced by this method. *RCK*

Editor's note: A Gem News entry on this process appears in the Summer 1992 issue of Gems & Gemology.

Glass-filled rubies increasing [and sidebar: **Agreement on filling of corundum**]. *Jewellery News Asia,* No. 119, July 1994, pp. 66, 68, 70.

Laboratories in Asia are reporting an increase in the occurrence of glass fillings in rubies from Mong Hsu. One Thai lab said that up to 90% of Mong Hsu rubies tested showed this filling; a Hong Kong lab reported that 55% of Mong Hsu rubies tested were glass filled; still another lab—this one in Singapore—put their estimate at 70%.

According to Vichian Veerasaksri, secretary to the Thai Gem and Jewelry Traders Association, the "filling" is actually the result of heat treatment, done to remove the bluish tint typically present in Mong Hsu rubies. The rubies are heated with borax and silica. During heating, the silica melts and fills cracks and fissures in the rubies. Some of these cracks are deep enough that the glass cannot easily be removed by repolishing or soaking in hydrofluoric acid. (Removal of the filling does not seem to be a problem for the Gemmological Association of All Japan, Tokyo, however. Director Junko Junk Shida said that her lab removes it with the acid and then issues certificates that the rubies are natural, heat treated. Of 1,000 rubies from different locations tested there weekly, only about 2% are filled with glass or other foreign substances.)

Prevalence of the glass filling has apparently not decreased demand for the rubies, and some Asian labs have even agreed that if the filling can be seen at 10× magnification or below, reports will be issued stating, "For the treatment of corundum, cavities and fissures are often filled with colourless foreign substances. Evidence of this treatment has been found in this stone."

This article is accompanied by several photographs of rubies that contain the glass filling and by a half-page sidebar detailing the agreement between Asian labs regarding disclosure of the filling. *JM*

More on the antiquity of emerald oiling. K. Nassau, *Journal of Gemmology,* Vol. 24, No. 2, 1994, pp. 109–111.

Dr. Nassau adds to his previous claims regarding the historic origin of emerald oiling with this brief note. Three sources provided by two other researchers (Dr. John Sinkankas and Dr. Hedi Benaicha) reveal that, while the practice is not as ancient as is sometimes claimed, it has been in existence for at least 650 years. *CMS*

MISCELLANEOUS

The long way home. D. D'Arcy, *Art and Antiques,* Vol. 17, No. 4, April 1994, pp. 64–69.

Several celebrated cases in the last decade point to the trend discussed in this article: Art-rich countries worldwide are turning to international litigation to have indigenous works of art, including jewelry and metalwork, returned to their places of origin. As the result of these cases, cited in the text, countries are beginning to demand—and win back—objects that had been bought by some very respectable museums and collectors under sometimes questionable circumstances. The art-rich countries are starting to use leverage to achieve settlements in a number of these cases. For example, many important archeological digs take place in Egypt, most under the aegis of American colleges and universities. Suppose the government suspends an institution's digging privileges until some previously acquired work of art in that institution's collection is returned to Egypt?

More often than not, though, pilfering of antiquities seems to involve countries least able to afford expensive litigation. In Eastern Europe, following the fall of communism, organized crime is playing an increasingly significant role in offering antiquities from such countries as Hungary, Turkey, and the former East Germany to the highest bidder in the world community—without seeking prior approval from the country of origin.

Still, the heyday of the unscrupulous antiquity dealer/collector seems to have passed. There have been too many severe lessons for them "to turn a blind eye to questions of provenance." *JEC*

Minerals, mineralogy, and mineralogists: Past, present, and future. F. C. Hawthorne, *Canadian Mineralogist,* Vol. 31, 1993, pp. 253–296.

Several fundamental concepts used in gemology come from the field of mineralogy. Good examples include much of gemological nomenclature, certain methods of gem identification, and ideas on topics, such as crystal growth and the causes of color in some gemstones. Thus, an understanding of mineralogy's past and its possible future directions should be of interest to gemologists.

In this article, Dr. Frank Hawthorne, a mineralogy professor at the University of Manitoba and a recent past president of the Mineralogical Association of Canada, presents a condensed but thorough overview of mineralogy. Starting with the earliest key publications on minerals, he traces the major developments, first in the classification and then in the characterization of minerals. All major analytical techniques now used to study minerals are briefly reviewed. Future directions that research on minerals may take are highlighted. The author concludes with a plea for retaining classical mineralogical education and mineralogical research in a period of shrinking funding for both science and scientific education. *JES*

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Armstrong J.T. (1988) Accurate quantitative analysis of oxygen and nitrogen with a Si/W multilayer crystal. In D.E. Newbury, Ed., *Microbeam Analysis*—1988, San Francisco Press, San Francisco, CA, pp. 301–304.

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

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