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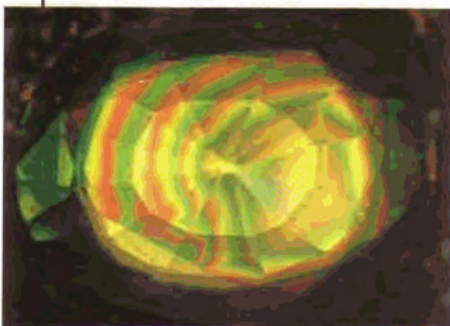


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ABOUT THE COVER: Emeralds are one of the most popular of all gemstones. New sources—and new treatments—are of great interest to the trade. The first article in this issue discusses and evaluates the increasingly popular synthetic resin Opticon as it compares to traditional "oils" in the treatment of emeralds to enhance apparent clarity. This issue also provides a report on emeralds that have recently emerged in commercial quantities from the historic Ural Mountains deposits. The emeralds on the cover are reportedly from another historic producer, Colombia. The necklace features a 74.03-ct cabochon emerald, the ring a 12.10-ct cabochon emerald, and the earrings two cabochon emeralds of 16.61 and 16.93 ct; the diamonds in this suite exceed 55 ct total weight. Jewelry courtesy of Fred Joaillier, Beverly Hills, California.

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INFORMATION AND COMMUNICATION: KEYS TO THE FUTURE

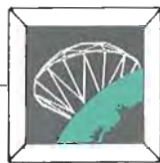
It's over! The Gemological Institute of America's 60th Anniversary celebration—the International Gemological Symposium—is now history. As one who had relatively little to do with its preparation, it looked to me to be a stunning success. From the opening reception by the pools of the beautiful Century Plaza Hotel, through the many sessions and social functions and, ultimately, at GIA's Open House, the lines of communication between the numerous segments of the industry have never been more open. The opportunities to discuss topics with the leaders of our diamond, colored stone, and jewelry industries were overwhelming. There have been many gatherings that have brought together some of the leading personalities in gemology, but, in my view, there has never been a meeting that did so to such an extent. In all, more than 1,800 people participated; 46 states and 47 countries were represented. As an information and communications vehicle, the International Gemological Symposium was an outstanding success and a worthy commemoration of GIA's 60 years of service.

The range of topics at Symposium—from localities to synthetics to treatments to jewelry history to marketing—was exceptional and complete. While at Symposium, one could go from a discussion of diamond mining in Africa to one on European jewelry, from pearl research to emerald synthesis, from gem carving to the Israeli diamond market. As editor-in-chief of *Gems & Gemology*, I like to think that Symposium was a macrocosm of what we do in this journal: provide you with a dependable source of information on diverse gemological subjects, each important in its own right.

It has been said before and was said often at Symposium, but bears repeating: As the world reaches a communications zenith with computers and modems, fax machines, satellites, and desktop publishing, gemological information will become more available at a quicker pace than ever in history. Yet, will it be more reliable? Through vehicles like *Gems & Gemology* and Symposium, I firmly believe that it will be. While it is important to get information to the public quickly, it is equally important to make sure that thorough research and analysis have been done before releasing any data. As innovations in gemology arrive faster and faster, it will be up to the print media to publish articles that take preliminary findings and rumors and turn them into fact—or dismiss them as fiction. In a world where global economic and political forces can change overnight and where the pressure to respond immediately to each supposed breakthrough is so great, we must be careful to evaluate new information carefully since every decision we make is capable of initiating drastic change.

The theme of the 1991 Symposium was FACING THE FUTURE. As a vehicle to provide critical information and foster improved channels of communication within the gem and jewelry community, Symposium represented an important step in facing the future with even greater pride and professionalism. GIA, including *Gems & Gemology*, will continue to promote the dissemination of accurate information to as broad a segment of the industry as possible. With both a strong information base and a solid communication corps, this industry cannot help but grow and prosper.

Richard T. Liddicoat
Editor-in-Chief, *Gems & Gemology*



FRACTURE FILLING OF EMERALDS

Opticon and Traditional "Oils"

By Robert C. Kammerling, John I. Koivula, Robert E. Kane, Patricia Maddison,
James E. Shigley, and Emmanuel Fritsch

The filling of surface-reaching breaks in emeralds is a relatively common practice, for which various kinds of oils and a natural resin have historically been used. Now, however, epoxy resins are replacing the more traditional fillers such as cedarwood oil and Canada balsam. The most widely known of these epoxy resins is sold under the brand name Opticon. The results of a broad study of various fracture-filling materials found that Opticon treatment (1) was, like the traditional materials, best detected using magnification with a variety of lighting techniques; and (2) although somewhat more durable than the traditional enhancements, was still altered in the course of routine jewelry cleaning and manufacturing processes. This article also examines the filling of surface pits with epoxies, the potential effectiveness of "dyed" Opticon, and the use of Opticon to fill the fractures in gem materials other than emerald.

ABOUT THE AUTHORS

Mr. Kammerling is director of technical development, Mr. Koivula is chief gemologist, Dr. Shigley is director of research, and Dr. Fritsch is research scientist, at the Gemological Institute of America, Santa Monica, California. Mr. Kane is manager of identification, and Ms. Maddison is senior staff gemologist, in the GIA Gem Trade Laboratory, Inc., Santa Monica. See end of article for acknowledgments.

This article expands on a presentation given at the International Gemological Symposium, held in Los Angeles, June 20–24, 1991.

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Although color enhancements have played a preeminent role in gemology in recent years, clarity enhancements are rapidly gaining in prominence. The filling of fractures in emeralds has been practiced for decades. During the 1980s, we also saw the introduction of "filled" surface pits and cavities in ruby, as well as the filling of surface-reaching separations in diamond (as reviewed in Kammerling et al., 1990).

Historically, the fractures in emeralds have been filled with a variety of oils (of which cedarwood oil is perhaps the best known) and the natural resin Canada balsam (see, e.g., Ringsrud, 1983). However, recent reports in the trade press have mentioned a more sophisticated fracture-filling procedure and the greater use of epoxy resins (Themelis and Federman, 1990; Themelis, 1990). What appears to be the most popular of these epoxy resins is marketed under the brand name Opticon. Still other reports make note of additional, proprietary fracture-filling treatments for emeralds. These include one being offered in Israel by the firm (Zvi Yehuda, Ltd.) that pioneered the filling of fractures and cleavages in diamond (see, e.g., Gilbertson, 1990; Lee, 1990; Yehuda, 1990); another being offered by CRI Laboratories of Grand Rapids, Michigan ("Emerald Clarity Enhancement Offered by U.S. Treatment Laboratory," 1990; "Emerald Treatment Services," 1990; Lee, 1990); and yet another being provided by the Kiregawa Gemological Laboratory in Japan (Y. Doi, pers. comm., 1991).

With this proliferation of processes and substances, concern has developed that filled fractures may have become even more difficult to detect. In addition, there is considerable question in the trade as to the durability of the different fillers and filling processes. For example, there is the perception that Opticon offers advantages over so-called traditional fillers because the breaks can be sealed at the surface. In other cases, as with the CRI and Yehuda emerald-filling services, claims to enhanced durability

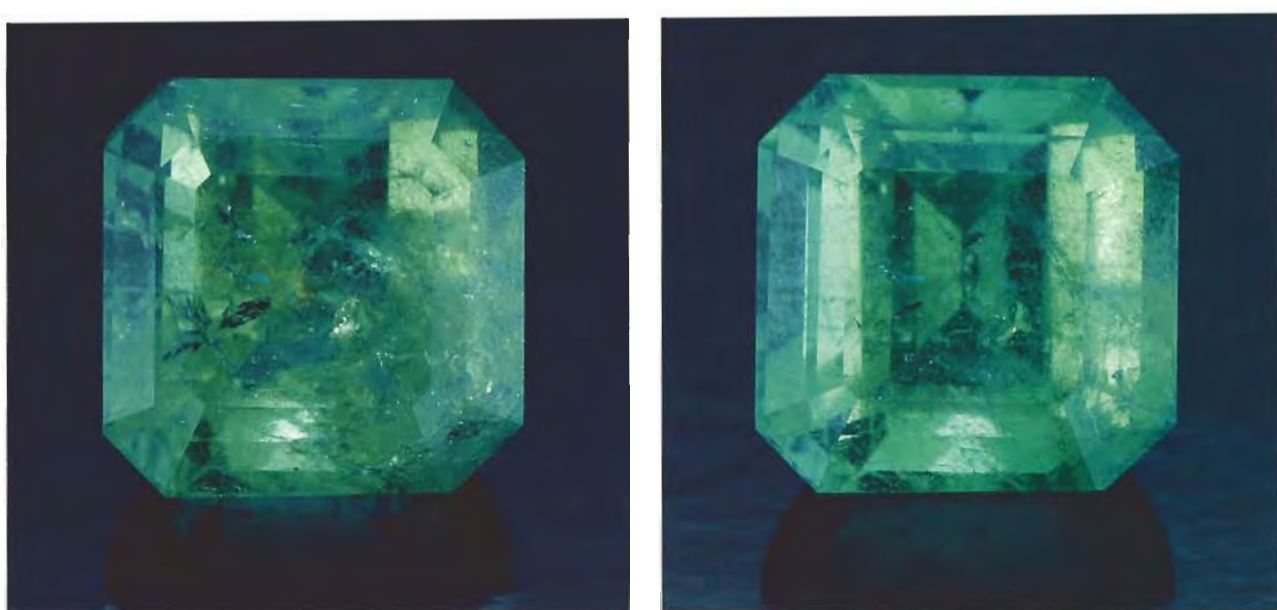


Figure 1. These two photos of a 5.74-ct emerald before (left) and after (right) Opticon treatment graphically illustrate how effective this fracture-filling treatment can be in improving apparent clarity. Photos © GIA and Tino Hammid.

have been made openly (see, e.g., Everhart, 1989; Gilbertson, 1990; Lee, 1990; Themelis and Federman, 1990; "U.S. Firm Offers New Emerald Treatment," 1990). Last, because of the various durability claims, jewelers and gemologists alike are trying to relate various features (e.g., "flash effects"; Kane, 1990) to specific processes.

This article, the first of two parts on the fracture filling of emeralds, will focus on stones treated with Opticon (figure 1) as they compare to those filled with the more "traditional" cedarwood oil and Canada balsam. Following descriptions of a commercial Opticon treatment procedure as practiced in Brazil and the identifying features of Opticon-treated stones, we will examine the relative durability of the filling materials when subjected to standard jewelry cleaning and manufacturing procedures. The second article in this series will describe the identifying features and durability of the Yehuda, CRI, and Kiregawa treatments.

THE OPTICON TREATMENT PROCESS

Opticon Resin No. 224, an epoxy resin marketed by Hughes Associates of Excelsior, Minnesota, is widely available commercially. The Opticon (plus hardening agent) kits used for this study were purchased at two Los Angeles-area lapidary supply shops (figure 2).

A number of dealers have told the authors that Opticon treatment is used on the majority of emeralds mined at Santa Terezinha in Goiás, Brazil (see, e.g., Koivula and Kammerling, 1989). Recently, one of the authors (PM) visited Stone World

in Teófilo Otoni, Minas Gerais, Brazil, a firm that purchases and cuts rough emeralds (predominantly from Santa Terezinha) and then markets them in Brazil, the U.S., and Europe. According to Mr. Sérgio Martins, president of Stone World, production averages 5,000–6,000 fashioned stones per month, approximately a third of which are relatively large and good quality. Most stones are in the 0.5- to 2.0-ct range, with about 10% in the 2.0- to 5.0-ct range.

After cutting, Stone World treats virtually all their emeralds with Opticon (figure 3). First, the

Figure 2. Opticon treatment kits are available at lapidary shops throughout the U.S. Photo by Robert Weldon.





Figure 3. Treatment at Stone World, in Teófilo Otoni, Brazil, begins immediately after cutting. The stones are first cleaned in weak hydrochloric acid, rinsed in water, and—as shown here—examined to make sure that any polishing compound or residual fillers (used on the rough) have been removed. Photo courtesy of Stone World.

fashioned stones are cleaned, that is, they are soaked in dilute hydrochloric acid and rinsed in water. Mr. Martins indicated that the acid used is quite weak and that some treaters simply use lemon juice. The stones are cleaned not only to remove polishing compound but also to remove any residue of Opticon that the miners may have applied to the rough.

Next, the cleaned stones are immersed in Opticon in small (50 ml), heat-resistant Pyrex beakers. As many as 200 small stones may be placed in a single beaker. The beakers are then placed (uncovered) in a small oven and brought to a low temperature that is maintained for 24 hours. Considerable experimentation was done by Stone World to find optimal temperatures; they did not reveal those temperatures for proprietary reasons. However, one dealer familiar with Opticon suggests 95°C (203°F; J. Crescenzi, pers. comm., 1991). This gentle heating reduces the viscosity of the filler and thus helps it penetrate the fractures.

After the stones are removed from the oven, they are left (still immersed in Opticon) to cool to room temperature. At this point, the emeralds are removed from the beakers and the hardening agent (or a mixture of Opticon and hardener; figure 4) is wiped across the entire surface of each stone. The

hardener is left on for 10 minutes; this “sets” the filler near the surface of the fractures, sealing the remainder of the still-liquid Opticon inside. According to Mr. Martins, the excess hardening agent must be wiped off at about 10 minutes; at 15 minutes, it is completely set and will require repolishing to remove. Thus, no more than 25–30 stones can be treated at one time with the hardener. After the hardening treatment, the stones are washed with a mild solution of water and baby shampoo and rinsed in water.

The stones are then carefully examined. Mr. Martins noted that approximately 15% must be recut at this point to repair surface damage that occurred during treatment. (Note: Although Mr. Martins did not elaborate on this damage, we observed minor chipping on the edges of some stones during our experimentation with Opticon treatment. This may be caused by the expansion of pre-existing fractures during heating.) After these stones are recut, they are cleaned again and then re-treated with Opticon.

The above describes only one method used to treat emeralds with Opticon; there appear to be countless variations. For example, Gemlab Inc. of Clearwater, Florida, reportedly uses vacuum pumps to evacuate the fractures prior to filling, high pressure to force the filler into the fractures, and a radio-frequency thermal-wave transmitter to heat the filler during the filling process (Themelis and Federman, 1990).

Figure 4. After Opticon treatment at Stone World, the emeralds are coated with a mixture of Opticon and hardener—here, being prepared—to seal the surface-reaching breaks. Photo courtesy of Stone World.



BOX A: USE OF GREEN-DYED OPTICON

Not all of the "oiling" of emeralds is carried out with essentially colorless filling substances. It is well known that green oils and dyes are also used, primarily on pale, low-quality beryls that might not be accepted as emeralds in their untreated state (see, e.g., Fryer, 1981; Nassau, 1984). From the standpoint of disclosure, such enhancement is generally considered dyeing rather than fracture filling.

Colored Opticon is now being used on emeralds as well. Themelis (1990) noted that any of the filling agents he described (which include Opticon) could be mixed with green organic dyes. Stone World has also experimented with the use of green-dyed Opticon. According to Stone World's Luiz Martins (pers. comm., 1991), however, there was a higher incidence of breakage during the treatment process when the colored Opticon was used—for which no explanation was offered—and they use only untinted Opticon in their commercial treatment. Dealers at the February 1991 Tucson show reported that colored Opticon was being used by some emerald treaters in Brazil (Koivula and Kammerling, 1991).

In an effort to determine the effectiveness and identifying features of green-dyed Opticon, the investigators made a number of attempts to mix Opticon with green coloring agents. These experiments met with limited success. In one, a small amount of Opticon was put in a test tube and a green coloring agent, marketed to color polyester casting resins, was added a drop at a time and mixed until a very dark green color was obtained. A near-colorless (very, very light blue) beryl that had been quench-crackled to produce numerous surface-reaching fractures was treated with the colored Opticon plus a hardener to seal the breaks. The resulting stone appears a light yellowish green face-up. Magnification combined with darkfield illumination revealed orangy yellow and blue dispersion flashes from the filled fractures, while diffused transmitted light revealed concentrations of light green color in the filled areas.

In two other experiments, Opticon was mixed



Figure A-1. The combination of Opticon treatment and green dye in a colorless quartz similar to the stone on the left produced a radical change (right). Photo by Maha Smith.

with powdered green dyes, one a commercial fabric dye and the other a substance marketed for dyeing gems. While both appeared to produce a dark green liquid Opticon, the quench-crackled colorless beryls and quartzes treated with these dyes remained essentially colorless, albeit nicely filled with essentially colorless Opticon. A commercial treater of emeralds who at one time had experimented with colored filling substances (T. Lee, pers. comm., 1991) indicated that the mixture of powdered dye and Opticon, rather than producing a solution, resulted in a fine suspension of dye particles in the Opticon. In the filling process, the dye was "filtered" out of the Opticon at the surface of the fractures, resulting in an essentially colorless filling.

The final experiment involved essentially colorless quartzes that had previously been quench-crackled and dyed green. The original transporting agent for the dye had since evaporated, leaving particles of green dye lining the walls of the fractures. These stones were then treated with undyed Opticon. The results (figure A-1) give an indication of the significant amount of color that might potentially be added to a stone with colored Opticon.

To document the appearance of stones before and after treatment, the authors developed their own treatment methods. Stones to be treated (all from the GIA reference gem collection) were first sent to CRI Laboratories in Grand Rapids, Michigan, for thorough cleaning to remove residue of previous fillings in the fractures. Tom Lee, president of CRI, indicated that they had found that the most effective cleaning method was to place the

stones in methylene chloride under a pressure of 50 p.s.i.

At GIA, the cleaned stones were placed in a heat-resistant glass beaker and heated for 10 to 20 minutes in an oven set at approximately 95°C (203°F). While the stones were heating, a small amount of Opticon was placed in a small Pyrex test tube fitted with a rubber stopper pierced by a glass tube. The test tube containing the liquid was

placed in a pan of water and heated on a gas range until the water started to boil; in a few minutes, the viscosity of the liquid was significantly reduced. The stones were then removed from the oven and placed in the preheated Opticon. After the stopper was replaced, the glass tube that pierced it was attached to a hand pump. A partial vacuum was then drawn and maintained at 0.5–0.8 atm. for 10–50 minutes. The length of the treatment time varied with the size and number of stones being treated, as well as with the apparent success of the treatment process. Every few minutes the test tube was removed from the water and the contents visually examined. If any minute bubbles were still rising from the stone(s) or significant unfilled areas were noted in fractures, the treatment was continued. When it was felt that no further filling would take place, the vacuum was released and the test tube was removed from the water and allowed to cool to room temperature. At this point, the stones were removed from the Opticon and were wiped clean of any excess liquid that remained.

The stones were next immersed for a minute or two in Opticon hardener and then allowed to sit in air for 10 minutes before the excess hardener was wiped off. Last, the treated stones were rinsed in water and dried with a soft cloth.

It appears that there are also variations with respect to the filling material itself. Stone dealers in Brazil told one of the authors (RCK) of a number of hardening agents, produced for use with other resins, that have proved somewhat successful in extending the "life" of the filling when they are mixed with Opticon before it is used to fill fractures. One published report confirms this (Themelis and Federman, 1990). The newest popular hardening agent mixed with Opticon is a product called Nu Seal, which is commonly used to harden dental resins (J. Crescenzi, pers. comm., 1991). However, there is some bias in the trade against this practice because it makes removal of the filling very difficult, should this become necessary. In this study, we used the hardener only as a sealant.

For comparison purposes, the authors also treated emeralds, synthetic emeralds, and other beryls with cedarwood oil and with Canada balsam, the two most familiar "traditional" fillers. The same filling procedure as for Opticon was used, except that no hardener or other agent was applied to seal the filled breaks.

THE EFFECTIVENESS OF OPTICON TREATMENT

The refractive index of Opticon, 1.545, is higher than that of either the cedarwood oil (1.512) or Canada balsam (1.520) we used and thus closer to the R.I. range of natural emerald (1.577 to 1.583 ± 0.017). Opticon may be, therefore, somewhat more effective in improving the apparent clarity of emeralds that have surface-reaching fractures. Individual fractures that were easily seen with the unaided eye before treatment often could not be detected without magnification after the filling procedure. Some stones used in our study had localized areas of dense fractures that, before treatment, collectively reflected and scattered so much light that they gave the areas a whitish appearance (figure 5, left). After treatment, such areas appeared green (figure 5, right). In fact, in some stones this reduction in light scattering also appeared to increase the depth of color.

IDENTIFYING FEATURES NOTED IN OPTICON-TREATED STONES

The authors performed some preliminary tests on the liquid resin itself. Opticon is transparent and near-colorless, showing only the slightest hint of yellow. As mentioned above, it has a refractive index of 1.545. It fluoresces weak to moderate white-blue to long-wave ultraviolet radiation, with no phosphorescence; it is inert to short-wave U.V.

The characteristics described in this section were determined on the following Opticon-treated stones: three emeralds treated and provided by Stone World (1.03, 1.19, and 2.65 ct); 24 emeralds treated by the authors (ranging from 0.20 to 5.74 ct); and one hydrothermal synthetic emerald (0.37 ct) that was first intentionally fractured ("quench crackled") by the authors using thermal shock.

Visual Observation. As mentioned above, Opticon treatment produced a marked improvement in apparent clarity. In some cases, the reduction in reflections and light scattering appeared to have improved the color as well.

Although for the most part the treated breaks were not visible to the unaided eye, some treated stones—especially those with the greatest number of filled breaks—showed a less-than-ideal transparency, or an optical distortion, that did not appear to be due to inclusions and would not be expected in a "flawless" single-crystal gem material (again, see figure 1 and figure 5, right). The



Figure 5. Before treatment (left) the whitish, reflective areas of dense fractures are easily seen in this 5.71-ct emerald. After treatment (right), most of the whitish areas are no longer visible. Photo © GIA and Tino Hammid.

effect is reminiscent of the so-called “heat-wave effect” noted in some hessonite garnets and the “treacle” color zoning often observed in rubies from Burma.

Ultraviolet Fluorescence. A relatively small percentage of the Opticon-treated fractures fluoresced a weak, chalky white to white-blue, similar to Opticon itself, to long-wave ultraviolet radiation. The others did not fluoresce, and all were inert to short-wave U.V.

Magnification. Magnification in conjunction with various lighting techniques revealed numerous identifying features. We did not see all of the features described below in all of the Opticon-treated emeralds examined, but we observed at least one in every stone.

Locating Where Filled Fractures Reach the Surface. The most constant visual feature of filled fractures is their very low relief. An untreated break—that is, one that contains air rather than a filling material such as Opticon—would have high relief, making it quite noticeable, even to the unaided eye. However, in addition to fractures, emeralds often contain numerous crystalline and fluid inclusions (see, e.g., Gübelin and Koivula, 1986) that can complicate the location and identification of filled fractures.

Thus, the first step in detecting possible filled fractures is to locate where any breaks reach the

surface. An effective way of determining this is to position a light source close to the surface of the gemstone, so that only the surface is viewed in reflected light. The best results are obtained with an intense incandescent light source—such as that provided by fiber-optic illumination, a Tensor lamp, or a coaxial illuminator system—rather than fluorescent light. In this surface-reflected light, the fine, hairlike lines that mark the entry points of the fractures will often be readily visible (figure 6).

Another method is to use darkfield illumination and, holding the stone low in the microscope well, rock it until light reflects off the surface being examined. If entry points are detected, it is then easy to examine the interior of the stone immediately under those points.

Dispersion Flash Effects. The majority of the filled breaks exhibited flashes of dispersion color similar to the orange and blue flash effects shown by some diamonds with filled separations (see, e.g., Koivula et al., 1989). Examined nearly edge-on—that is, approaching a direction parallel to the plane of the fracture—some filled breaks in the Opticon-treated emeralds exhibited a slightly orangy yellow dispersion color: The entire fracture or a large portion of it seemed to “light up” with this color (figure 7, left). When the stone was rocked very slightly—in some, but not all instances—this changed to blue (figure 7, right). In instances where the blue flash was not noted, the filled break would



Figure 6. The use of surface-reflected light with the microscope enables the location of surface-reaching fractures in treated emeralds. Photomicrograph by John I. Koivula; magnified 25 \times .

flash orange, seem to disappear, and then reappear as the stone was rocked back and forth. At first, we thought that the green body color might be partially masking the blue flash. However, Opticon-filled fractures in near-colorless beryls that we treated also showed the orange flash alone more consistently than with the blue flash.

Both darkfield and oblique fiber-optic illumination were effective in revealing these flashes. Horizontal fiber-optic illumination was also effective alone or in conjunction with darkfield lighting. In some instances, this latter technique re-

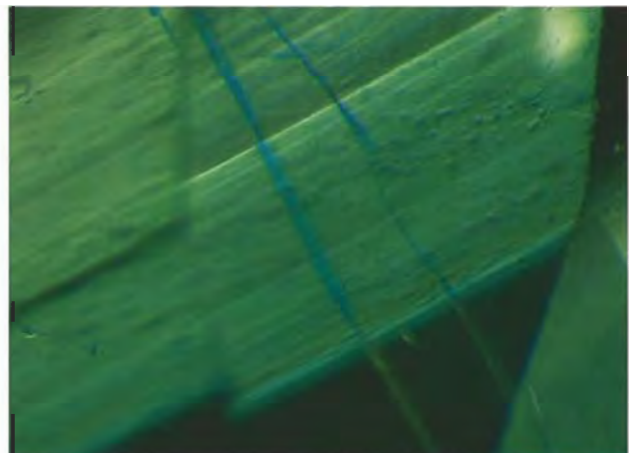
vealed a blue flash that was not noted with darkfield conditions alone. In many instances, we detected at least an orange flash using transmitted light; and in some, we detected dispersion flash colors with diffused overhead illumination.

We found these flash effects to be less prevalent in the Opticon-treated emeralds than in diamonds with filled surface-reaching separations we have examined (see Koivula et al., 1989). They were not observed in any of the cedarwood oil- and Canada balsam-treated stones we examined.

Trapped Bubbles. Discontinuities, actually flattened bubbles in the filling, were noted in many of the filled breaks with darkfield, oblique or pinpoint fiber-optic, or overhead illumination. Unlike natural, unfilled breaks, which have a mirror-like appearance, these bubbles were always at least partially surrounded by filled areas that were either transparent or "cloudy." With overhead illumination, some trapped bubbles exhibited bright interference colors, a thin-film effect similar to that seen in some natural, partially healed fractures. The trapped bubbles occurred in a great variety of sizes and shapes, singly and in groups (see, e.g., figure 8).

Outlining of Fractures. Careful examination with darkfield or fiber-optic illumination often revealed a faint outlining of the filled breaks. This was generally noted at an oblique angle of observation, as when the plane of the break was at approximately 45° to the line of sight.

Figure 7. A slightly orangy yellow flash (left) was observed in the filled fractures of this Opticon-treated emerald. When the stone was tilted slightly and the background became lighter, the flash turned blue (right). In some stones, only one color is seen. Photomicrograph by John I. Koivula; magnified 20 \times .



Flow Structure. Some filled breaks revealed a flow structure that gave them a faintly textured appearance, in some cases reminiscent of the so-called “heat-wave” effect sometimes noted without magnification. This was best seen using darkfield illumination with the stone positioned so that the background became brighter through secondary reflection from back facets (figure 9). The presence of air bubbles trapped along such “flow planes” also helps delineate these areas.

Cloudy Areas. In some of the filled breaks, we noted small, irregular, slightly whitish cloudy patches with a somewhat textured appearance. These may represent a partial alteration of the filler. One trade press report cites claims that Opticon-filled breaks become “cloudy after several months” (Everhart, 1989).

It is possible that at least some of these cloudy areas may be due to an incomplete reaction of the Opticon with the hardening agent. To test this, we placed a small amount of Opticon on a glass microscope slide and incompletely mixed it with a drop of the hardening agent. After approximately 20 minutes, we noted whitish, swirled, “cloudy” areas interspersed with still-colorless, transparent areas. This suggests that the hardening agent may partially penetrate the filled break and cause an incomplete localized reaction.

TRT Reaction. A thermal-reaction tester (“hot point”) brought close to the surface of the stone will typically cause an unsealed fluid-filled break to “sweat” out some of the filler. Although we found that, for the most part, the fluid would not “sweat” out of an Opticon-treated break that had been sealed at the surface with hardener, with magnification we did observe visible movement of the still-liquid filling in the fractures. Note that because this procedure is potentially destructive, it is not recommended for routine testing.

Other Tests. One commercial treater recommends immersion microscopy as the best means of detecting fracture filling (Themelis and Federman, 1990; Themelis, 1990). With this method, the stone is immersed in a liquid with an R.I. very close to that of the stone being tested; for emerald, he suggests using bromoform, which has an R.I. of 1.56. Anything within the immersed stone should be visible to the degree to which its R.I. varies from that of the emerald. In addition to filled fractures,

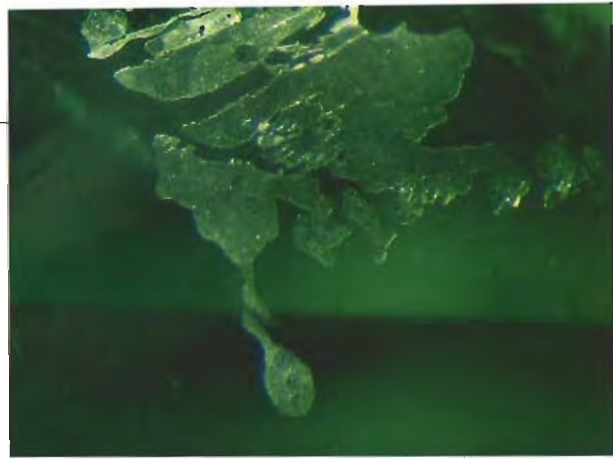


Figure 8. Trapped air bubbles may be an important identifying feature for filled emeralds. Although they vary greatly in size and shape, large bubbles with irregular outlines—such as those illustrated here in an Opticon-treated emerald—are not unusual. Some of the bubbles may be highly reflective with a silvery white hue. Photomicrograph by John I. Koivula; magnified 15 \times .

this would include crystalline inclusions, unfilled voids, and fluid inclusions.

Unfortunately, the immersion liquid might also act as a solvent that could partially remove near-surface filling material. As mentioned above, tests that are potentially destructive to either the host material or the treatment should be avoided for routine gem identification. Moreover, the bromoform might enter breaks in untreated emeralds,

Figure 9. Careful examination of the areas surrounding trapped air bubbles will sometimes reveal subtle flow structures within the filling agent, which in this case is Opticon. Photomicrograph by John I. Koivula; magnified 20 \times .



BOX B: CAVITY FILLING

While this article focuses on the use of Opticon for filling fractures, it is apparent that other irregularities, such as surface cavities, could also be filled with hardened Opticon and similar substances. One emerald examined by the GIA Gem Trade Laboratory had a surface cavity filled with a soft, "plastic-like" substance. The stone also had been fracture-filled (Hurwit, 1989).

Discussions with one dealer familiar with Opticon treatment indicated that sometimes, in the course of treatment, the point where a fracture breaks the surface of a stone becomes enlarged, producing a cavity. Such a fracture is first filled with Opticon, after which a mixture of hardener and Opticon is used to simultaneously seal the break and fill the cavity. Alternatively, the Opticon may be mixed at a 1:1 ratio with Nu Seal (J. Crescenzi, pers. comm., 1991).

Another report suggests using Opticon to fill fractures and then a different epoxy resin, Epoxy 330

Figure B-1. This filled pit in an emerald shows spherical gas bubbles trapped within the epoxy. Photomicrograph by John I. Koivula; darkfield illumination, magnified 30×.

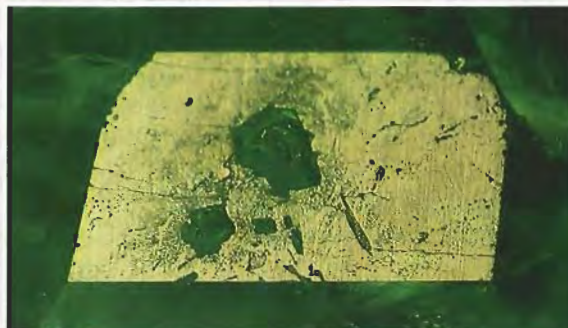


Figure B-2. Epoxy-treated surface pits in an emerald may be only partially filled. Photomicrograph by John I. Koivula; surface-reflected illumination, magnified 15×.

(which is marketed by the same firm that markets Opticon), to fill cavities (Jones, 1986). The authors obtained some of this product for experimentation. First, we mixed equal amounts of this epoxy resin with its hardener and allowed it to cure on a glass slide. The resulting hardened substance was transparent to semitransparent and colorless.

We then mixed additional epoxy and hardener and used it to fill surface cavities of various shapes and sizes on both natural and synthetic emeralds. After a minimum of 24 hours, the excess cured epoxy was polished down to the level of the stones' surfaces. The filled cavities can be readily identified with magnification and darkfield or surface-reflected illumination. In addition, they may contain gas bubbles (figure B-1), and some pits may be only partially filled (figure B-2). As is the case with rubies and sapphires, however, such fillers generally are not as durable as the host gem. If the cavities are large, the filler could add to the weight of the stone.

causing them to be unintentionally filled. Last, bromoform is highly toxic.

COMPARISON WITH CEDARWOOD OIL AND CANADA BALSAM

As mentioned earlier, cedarwood oil and Canada balsam have historically been the preferred substances for filling fractures in emeralds. For comparison purposes—in terms of effectiveness and identifying features—we treated two groups of five samples, one with cedarwood oil and the other

with Canada balsam. Each group consisted of three emeralds ranging from approximately one-half to one-and-a-half carats, one flux-grown synthetic emerald less than a carat, and one very pale (near colorless) aquamarine of approximately 2 ct. Additional beryls were fracture filled for durability testing (see below).

All of the treated stones showed clarity improvement, although some breaks were still evident. Both fillers especially improved the appearance of the pale aquamarines, in which extensive

fractures had been induced by quench crackling. With magnification, it was relatively easy to detect the filled breaks, which generally exhibited a slightly higher relief than did Opticon-filled breaks. In all cases, the cedarwood oil- and Canada balsam-treated stones could be positioned so that the fractures produced bright reflections that plainly revealed their contours—more clearly than in the Opticon-treated stones. We also noted some irregular trapped bubbles. Additionally, some fractures filled with cedarwood oil had areas that appeared to contain a whitish material, perhaps representing some of the oil that had dried out (or residue from a previous filler that had not been completely removed). Combined darkfield and pinpoint fiber-optic illumination revealed a muted orange dispersion effect in some of the breaks in the Canada balsam-filled aquamarine but not in any of the other samples.

The filled fractures in the five samples treated with cedarwood oil were inert to both long- and short-wave ultraviolet radiation. Filled fractures in all the Canada balsam-treated samples exhibited a weak greenish yellow to yellow fluorescence to long-wave U.V. radiation, with no phosphorescence; they were inert to short-wave U.V.

In general, for purposes of identification, the only consistent difference we noted between stones we treated with either cedarwood oil or Canada balsam and those filled with Opticon was the presence of the orange or blue flash in the Opticon-treated emeralds. However, we do know from our investigation of other filling materials (as will be described in part 2) that these flash effects are not specific to Opticon and can occur when other fillers are used.

DURABILITY OF TREATMENT

Of key concern is the durability of a filled stone during normal cleaning procedures, as well as the stability of the filling material itself. Ringsrud (1983) related the claims of several Colombian emerald dealers that "since the majority of emeralds have such fine fractures . . . the oil seldom dries out or, at the very least, the natural oils of the wearer replace the oil in the stone." Ringsrud, however, went on to state that there is variability in the permanence of this treatment. Nassau (1984) mentioned a number of specific factors—heat, reaction with atmospheric oxygen, contact with solvents, and cleaning procedures—that could negatively affect emerald fillings. Others

(e.g., Crowningshield, 1972; Mumme, 1982; Webster, 1983; Martin, 1987) have also warned against using various cleaning techniques on oiled emeralds, as these could remove the filling material. In particular, oiled emeralds that have been subjected to ultrasonic cleaning or exposed to high temperatures have been known to exhibit whitish dendritic deposits in the fractures, residue of oil that has dried out (Crowningshield, 1984).

To test the durability of Opticon treatment relative to "oiling," we first subjected some of the stones we had treated by the different methods to ultrasonic and steam cleaning.

Ultrasonic Cleaning. For this portion of the investigation, we used a Gesswein Ultrasonic Cleaner model 87 containing BRC, a standard jewelry cleaning solution. The unit was set to the high setting and the heating element was turned on. Stones to be tested were put in a perforated plastic container which was then placed in the ultrasonic unit. Stones were checked at five-minute intervals for any change in appearance; total time in the unit was 30 minutes for each stone.

The results of cleaning at five-minute intervals for a 1.94-ct pale aquamarine treated with Canada balsam, a 1.78-ct pale aquamarine treated with cedarwood oil, and two Opticon-treated pale aquamarines (1.88 and 3.11 ct) are reported in table 1. Of the four stones, the two treated with Opticon appeared to have held up significantly better to this cleaning procedure than the Canada balsam- and cedarwood oil-treated stones. The overall negative effect and amount of material removed from these latter two stones appeared roughly equivalent (see, e.g., figure 10).

The ultrasonic cleaning procedure used in this phase of testing was admittedly more severe than that to which a jeweler would normally submit a stone. However, this test may realistically represent the cumulative effects of repeated ultrasonic cleanings on a fracture-filled stone. While the amount of material removed may have been minor, fractures that could not be seen without magnification before cleaning were eye visible afterward. This, in turn, could leave a jeweler open to claims of damaging (or even switching) a stone.

Steam Cleaning. Stones subjected to various filling treatments were also cleaned with a Reimers Model JR steam cleaner to test the fillings' durability to this procedure as well. In all cases, stones were initially subjected to a pressure of 60 p.s.i. and

Table 1. Results of the ultrasonic cleaning of "filled" pale aquamarines.

Weight (ct)	Treatment material	Results (minutes)					
		5	10	15	20	25	30
1.94	Canada balsam	Fine-appearing fractures visible breaking pavilion surface	Additional fractures visible	Two fractures more noticeable	Same two fractures appear larger	Same two fractures appear larger	Same two fractures more prominent
1.78	Cedarwood oil	A few surface-reaching fractures on pavilion appear as hairline marks	Numerous additional fine fractures visible breaking both crown and pavilion	Same fractures more prominent	Same fractures more visible; one breaking table surface appears iridescent in one area	Same fractures more visible	Same fractures more visible
1.88	Opticon	No apparent change	Some pavilion-breaking fractures appear as faint whitish lines	Same fractures slightly more visible	No additional change	No additional change	No additional change
3.11	Opticon	No apparent change	No apparent change	No apparent change	No apparent change	No apparent change	Three surface-reaching fractures noticeable on crown

held approximately 1/2 to 1 in. from the steam nozzle. After about five minutes, when the pressure had dropped to about 30–35 p.s.i., the stones were examined. The pressure in the unit was allowed to build to 60 p.s.i. again and the stones were steam cleaned for an additional five minutes. They were then re-examined, and the steam cleaning was subsequently repeated for a third five-minute period. During this testing, both the crown and pavilion surfaces were exposed to the steam jet for roughly equal periods of time.

The results of this testing for a 3.98-ct pale aquamarine treated with Canada balsam, a 1.75-ct pale aquamarine treated with cedarwood oil, a 2.83-ct Opticon-treated pale aquamarine, and a

3.24-ct colorless beryl treated with Opticon are reported in table 2. Although all four stones had poorer apparent clarity after the steam cleaning, the Opticon-treated stones seemed to have been affected the least. In all cases, the steam cleaning appeared to have removed more of the filling than did ultrasonic cleaning. Even the Opticon-treated stones, which are "sealed" at the surface, lost some filling material (figure 11); possibly, the prolonged attack at least partially broke through the hardened areas, creating exit points for the still-fluid Opticon. Again, although a jeweler would not normally steam clean a colored stone for five minutes or more, the results could represent the likely effects of multiple cleanings.



Figure 10. Before ultrasonic cleaning, no fractures were visible in this 1.78-ct cedarwood oil-treated aquamarine (left). Within 10 minutes in the ultrasonic, some of the oil had been removed; after 25 minutes, a multitude of fractures had become visible (right). Photos by Maha Smith.

Table 2. Results of the steam cleaning of "filled" pale aquamarines.

Weight (ct)	Treatment material	Results (minutes)		
		5	10	15
3.98	Canada balsam	Some filled fractures visible	Larger fractures more visible; all surface-reaching fractures had some filling removed	Some fractures more noticeable
1.75	Cedarwood oil	Large number of hairline-appearing fractures visible	Fractures more visible; slight "fuzzy" appearance to stone	"Fuzziness" more pronounced
2.83	Opticon	No apparent change	Several white hairline fractures visible on pavilion	Same fractures more visible
3.24	Opticon	One crown-breaking fracture visible	Three fractures visible	No additional change

REACTION OF OPTICON-TREATED STONES TO JEWELRY SETTING AND REPAIR

Another important durability consideration is the potential for damage to stones during jewelry setting or repair procedures. For example, a number of reports (e.g., Crowningshield, 1972; Themelis and Federman, 1990) warn bench jewelers that failure to detect filled fractures might result in excessive pressure being exerted on the stones during setting. Therefore, we performed a number of additional tests on Opticon-treated stones to determine how well they held up to other conditions that might be experienced.

Retipping Prongs. As mentioned above, Opticon is a very slightly yellow, almost colorless substance. During the treatment procedure – which included heating the Opticon-immersed stones in hot water – we noted a gradual darkening of the Opticon to a medium yellow after about two hours. This might not have a noticeable effect on the color of

an emerald or other medium to dark stone that has been Opticon-treated. However, it could conceivably influence the appearance of a pale or colorless stone, although probably no more than would Canada balsam.

The retipping of prongs requires significantly higher temperatures. Although the retipping of prongs with an emerald in place is generally discouraged, it is occasionally done. There is also the risk that a stone other than emerald may have been fracture filled (see Box C). Therefore, we subjected a 2.40-ct Opticon-treated colorless beryl to the heat that would be generated in retipping prongs. To this end, the stone was secured in tweezers and held against a charcoal block. A 14k white hard solder with a 14k bead was then placed on a corner facet. The stone was evenly preheated with a #40 torch tip for approximately five seconds; then the torch was brought to bear on the solder until it flowed onto the bead, simulating retipping. This procedure caused the Opticon to flow out of fractures in the vicinity of the bead and

Figure 11. Before steam cleaning, no major fractures were evident in this 2.83-ct Opticon-treated aquamarine (left). Steam cleaning for 15 minutes resulted in partial removal of the Opticon, making the fractures readily apparent (right). Photos by Maha Smith.



produce a brownish residue on the surface of the stone (figure 12).

Metal Polishing. Both friction-generated heating and abrasive action take place during the polishing of metal prongs. To determine what, if any, negative effect this might have on a mounted stone with Opticon-filled fractures, a 1.20-ct treated colorless beryl was held in grooved locking tweezers, which were then "polished" for 30 seconds on

a high-speed (3450 r.p.m.) 4-in. (10-cm) stitched muslin buff impregnated with tripoli compound. This had no effect on the appearance of the stone to the unaided eye. The procedure was then repeated, using a rouge buffing wheel impregnated with Bendick's rouge compound. Although we saw no effect with the unaided eye, magnification revealed some extremely fine whitish areas along a large filled fracture that broke the surface of the stone close to where the metal had been polished

BOX C: OPTICON AND OTHER GEMS

Opticon has also been recommended for treating cracks in fashioned stones and mineral specimens of agate, quartz, beryl, topaz, tourmaline, and "any other transparent hard gem with a refractive index close to Opticon" (Jones, 1986). From time to time, the GIA Gem Trade Laboratory has detected fillings in fractures in other faceted gemstones—including pink, green, and blue tourmalines, blue sapphire, and green zoisite—although the feeling is that these usually have been treated with oils. To explore the effectiveness of Opticon in filling fractures in other gem materials, the authors induced fractures in three

(1.88, 2.83, and 4.54-ct) faceted, light greenish blue aquamarines; a 7.58-ct faceted medium purple amethyst; a 2.59-ct dark green tourmaline cabochon; a 2.87-ct faceted light, slightly greenish blue synthetic spinel; and a 3.34-ct faceted medium-dark green-blue synthetic spinel. Also treated were two essentially colorless cat's-eye tourmaline cabochons of 1.81 and 3.68 ct.

The improvement in appearance was most noticeable in the faceted aquamarines (see, e.g., figure C-1) and amethyst (figure C-2); fractures that showed high relief before treatment could not be detected



Figure C-1. The fractures in this 4.54-ct aquamarine were readily apparent before Opticon treatment (left) and almost invisible afterward (right). Photos by Maha Smith (left) and © GIA and Tino Hammid (right).



Figure C-2. Because its refractive index is close to that of Opticon, quartz also responds favorably to filling with this substance, as seen in this 7.58-ct amethyst before (left) and after (right) treatment. Photos by Maha Smith.

(figure 13). Apparently, the hardened Opticon had been abraded by the action of the wheel.

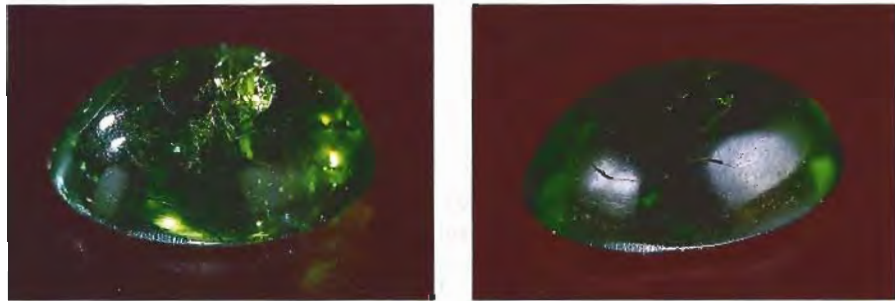
Ultraviolet Radiation. Another concern is the stability of the filling material itself. According to one report (Themelis, 1990), the various materials used to fill emeralds, including Opticon, are not stable to light unless various "plasticizers" are used. As one test to determine the stability of Opticon, an Opticon-treated near-colorless beryl

was exposed to short-wave ultraviolet radiation from a 4-watt fluorescent lamp for approximately 36 hours. This appeared to have no effect on the filling material.

DISCUSSION

Opticon would seem to offer some advantages over Canada balsam and cedarwood oil for filling fractures in emeralds. Because it is closer in refractive index to emerald than either of the other sub-

Figure C-3. Even though the refractive index of tourmaline is somewhat higher than that of Opticon, treatment of this 2.59-ct tourmaline (left) still produced significant improvement in the apparent clarity of the stone (right). Photos by Maha Smith.



with the unaided eye after filling. This is to be expected, as the refractive indices of these two gem materials [aquamarine = 1.560–1.566 and amethyst = 1.544–1.553] are quite close to that of Opticon (1.545). The R.I. of tourmaline, about 1.624–1.644, is further from that of Opticon; even so, the improvement here, too, was very good (figure C-3). Only when the difference in refractive index between the gem and the filling material was considerably greater, as in the case of the synthetic spinel (R.I. 1.728; figure C-4), did the fractures remain visible to the unaided eye. Yet even in this case, we saw an overall improvement in apparent clarity. The filling of the growth tubes in the cat's-eye tourmalines caused these to become

much less noticeable, so that the stones appeared more transparent after filling.

All features of filled breaks in the aquamarines were consistent with those previously noted in emeralds. This was also the case with the amethyst, with the exception that overhead fluorescent lighting revealed blue but no orange flashes from many of the filled breaks (both colors were noted under darkfield conditions). Irregular gas bubbles, but no dispersion colors, were noted in filled fractures and filled growth tubes in the green tourmaline. Both darkfield and overhead illumination clearly revealed the outlines of the filled breaks in both synthetic spinels; again, no flash effects were noted.

Figure C-4. Because the refractive index of spinel is considerably higher than that of Opticon, treatment is less effective. Many of the fractures visible in this 3.34-ct stone before Opticon treatment (left) were still apparent after treatment (right). Photos by Maha Smith.

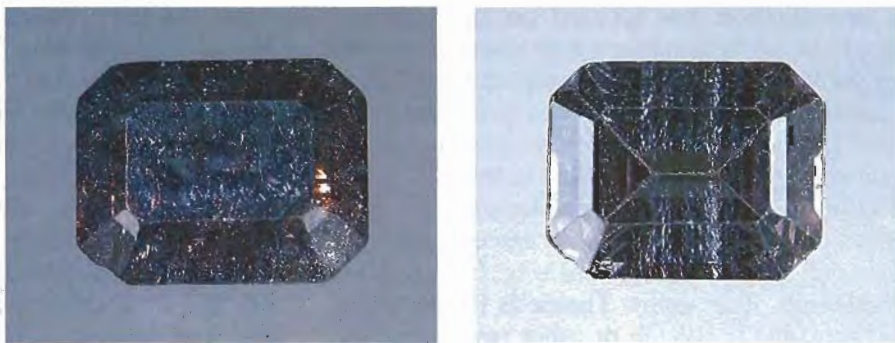




Figure 12. When this Opticon-treated beryl was exposed to the heat of a jeweler's torch during a procedure approximating the retipping of prongs, Opticon boiled out of some of the fractures and darkened, leaving a brown residue on the surface. Photomicrograph by John I. Koivula; magnified 30 \times .



Figure 13. Rapid polishing of the prongs that held this Opticon-treated beryl resulted in abrasion of the hardened Opticon at the surface of the stone. Photomicrograph by John I. Koivula; magnified 50 \times .

stances, it may be more effective in masking surface-reaching breaks. Detection of any of these treatments is best accomplished using magnification with a variety of lighting techniques.

With respect to durability, extended ultrasonic and steam cleanings appear to remove less filling material from sealed, Opticon-filled breaks than from breaks filled with either Canada balsam or cedarwood oil, indicating that the former is a more durable treatment.

The long-term durability of Opticon-filled fractures is not known at this time. It is possible that the sealing of filled fractures at the surface of a stone may inhibit or retard alteration/decomposition of the filler itself by preventing direct exposure to air, airborne caustic agents, or solvents. Such sealing at the surface might also extend the effective life of other fracture-filling substances.

CONCLUDING COMMENTS

This investigation has focused on the fracture filling of emeralds using the epoxy resin marketed under the brand name Opticon, which is sealed at the surface of the stone to which it has been applied, and has compared this to fracture filling using cedarwood oil and Canada balsam.

However, it appears that a number of substances—or combinations of substances—are now being used to fill surface-reaching fractures in emeralds and other gems. Themelis (1990) mentions that Canada balsam or other resins may be mixed with cedarwood oil or other oils. Various other oils have also been used, including castor,

coconut, corn, linseed, lubricating, mineral, Neats-foot, olive, palm, peanut, rapeseed, soybean, tung, and whale (Nassau, 1984). In the course of this investigation, the authors experimented with additional substances for fracture filling, all of which improved the apparent clarity of the treated stones to some extent; two in particular, a U.V.-curing glue and a polyester casting resin (the latter, R.I. of 1.555), were very effective.

More recent reports note that an apparently new type of low-polymer epoxy resin is being used to treat the majority of emeralds being imported into Japan from Colombia ("Fluid Epoxy Resin Reported in Emerald Fractures," 1991; "Filled Emeralds," 1991). The substance, referred to as "palm oil," reportedly has an R.I. of 1.57 and exhibits trapped bubbles and weak bluish green to orangy red dispersion colors. The reports also mention emeralds filled with a cyano-acrylic that exhibits a white brushmark-like appearance in fractures. A third filling substance mentioned is a hardened epoxy resin that exhibits very few bubbles and no dispersion colors.

As mentioned at the beginning of this article, we do know of other, proprietary treatments being used on emeralds, including the one offered by the firm that pioneered what has become known colloquially as the "Yehuda" procedure for filling fractures in diamond; another, offered by CRI Laboratories of Grand Rapids, Michigan, which has received widespread notice in the trade press; and a third, being offered commercially in Japan. The investigators are in the process of examining stones treated by these processes; reports on these

findings will be published in the second part of this series.

What appears obvious at this stage in our investigations, however, is that there is considerable overlap in the gemological features of filled surface-reaching breaks regardless of the substances used. It would, therefore, seem both inappropriate and misleading, in describing a filled fracture, to use wording that implies that the filling substance has been conclusively identified if in fact it has not. It would also seem unwise to use the term *oiling* as a general term to refer to emeralds with filled surface-reaching breaks. Instead, a generic term referring to the treatment process would be better advised. The general process so described herein is fracture filling. The GIA Gem Trade Laboratory uses the following statement, as appropriate, on identification reports: "Note: Foreign material is present in some fractures reaching the surface."

The GIA Gem Trade Laboratory has periodically encountered gem materials other than emeralds and diamonds that have been fracture filled. It would seem prudent, therefore, to keep in mind the possibility of filled surface-reaching

breaks when examining any gem material.

While Opticon-filled breaks appeared to withstand both ultrasonic and steam cleaning better than breaks treated with either cedarwood oil or Canada balsam, prolonged exposure to either cleaning method adversely affected stones treated with any one of these three substances. It would thus appear inadvisable to use these procedures when such fillings are present or even suspected (as is believed to be the case with most emeralds). High temperatures and surface abrasion, as associated with some jewelry repair procedures, were also shown to negatively affect Opticon-filled stones. It would thus seem prudent to remove stones suspected of treatment from their mountings whenever possible before repair procedures are attempted.

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EMERALDS FROM THE URAL MOUNTAINS, USSR

By Karl Schmetzer, Heinz-Jürgen Bernhardt, and Rudolf Biehler

Emeralds are again being mined in the historic district of the Ural Mountains. Physical, chemical, spectroscopic, and microscopic characteristics of stones from the recent production are presented and compared with data on older samples as well as those reported in the literature. Chemical analysis and visible and infrared spectroscopy provide information on crystal chemistry and color-causing trace elements that is useful both to characterize these stones and to separate them from their synthetic counterparts. A variety of mineral inclusions as well as liquid, two-phase, and three-phase inclusions were seen with magnification. All of the data are critically evaluated with respect to the confirmation of unknown samples as Uralian.

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Historically, the most important emeralds came from the famous mining districts of Muzo and Chivor, in Colombia, and from the Ural Mountains of Russia (figure 1). Emeralds were discovered in Russia in 1830, near the Takovaya River, about 90 km northeast of Sverdlovsk (formerly Ekaterinburg), on the east side of the Ural Mountains (Bauer, 1896). Significant amounts were produced through the 19th and into the early 20th century. For the last several decades, however, emeralds from this source were only occasionally available—either historic stones or stones that resulted from the limited mining that continued in the region.

Today, though, there appear to be large quantities of Russian emeralds entering the trade, many of very fine color (figure 2). Faceted stones as large as 37 ct have been reported (figure 3). Soviet colleagues (e.g., V. Balitsky, pers. comm., 1991) have told the authors that these emeralds are from a mine called Malysheva, situated in the old Takovaya River mining area. Apparently, the Malysheva mine has been exploited in recent decades for beryllium, with emerald as a byproduct. Not until 1990, however, when a joint venture called Emural was formed between the Soviet government and a Panamanian company (that includes two Israeli partners) to cut and market the emeralds, did significant quantities of Russian emeralds appear in the market (see, e.g., "New Joint Venture to Market Soviet Emerald," 1990; "USSR Supplies Rough Emerald to Israel," 1991; B. Harel, pers. comm., 1991).

Although a small number of Russian emeralds have been included in modern research into the diagnostic properties of natural and synthetic emeralds (e.g., Schrader, 1983; Stockton, 1984; Schwarz, 1987), no general summary of physical, chemical, and gemological characteristics of Uralian emeralds has been published since the appearance of the detailed study of inclusions in gemstones by Gübelin (1953). Relatively recent papers in

Russian published by Lokhova et al. (1977), Zher-nakov (1980), Granadchikova et al. (1983), and Gromov et al. (1990), which might fill this gap, are generally not accessible to non-Russian-speaking gemologists.

The authors selected 100 fashioned samples from a parcel of more than 1,000 Russian emeralds that had recently entered the marketplace. On the basis of his decade-long study of known samples from the Takovaya River mining area, the senior author concluded that the properties of these new samples were identical to those of older emeralds known to have come from this general mining district. To characterize this new production for the gemological community, the authors conducted a comprehensive gemological, spectroscopic, and chemical study of these 100 stones.

THE HISTORIC RUSSIAN DEPOSITS: LOCATION AND OCCURRENCE

A detailed geologic description of the Takovaya River mining area and the emerald-bearing rocks, as well as an account of the historic development of mining activities in the area, was published by Fersmann (1929) and summarized in part by Sinkankas (1981). In general, the mining area consists of two emerald-bearing belts. The main belt runs approximately north-south over a distance of more than 20 km; at its southern end it intersects a second belt, about 8 km long, that runs northwest-southeast. Historically, the most important mines in the main belt were (from north to south) the Mariinsky, Troitzky, Lubinsky, and Stretjensky mines; and, in the smaller belt (from northwest to southeast), the Ostrowsky, Krasnobolotsky, and Chitny mines (as illustrated in Sinkankas, 1981).

The emeralds occur in Paleozoic metamorphic rocks trapped between the acidic rocks of a granite massif to the west (granites, albitites, pegmatites, and kaolinities) and ultrabasic rocks (peridotites, serpentinites, dunites, pyroxenites, and gabbros) to the east. The metamorphic rocks of the emerald-bearing central contact zone include talc, mica, chlorite, and actinolite schists. This zone follows the granite/ultrabasic contact for about 25 km. As summarized by Sinkankas (1981), emerald mineralization resulted when elements such as beryllium from the silica-rich granites to the west and chromium from the basic rocks to the east were brought together during the process of metamorphism.



Figure 1. The historic deposits in the Ural Mountains have produced some superb crystals. This 6.5-cm-long crystal from the Takovaya River mining area is courtesy of the American Museum of Natural History, New York. Photo © Harold & Erica Van Pelt.

On the basis of his interpretation of more than 200 geologic profiles, Fersmann (1929) concluded that the emerald deposits consist of four dominant rock types:

1. Pegmatites or pegmatitic rocks, including albitite and kaolinite (white, up to 2 m thick)
2. Emerald-bearing biotite schists (black, 1.5 m thick)
3. Chlorite-actinolite schists (green, 1 m thick)
4. Talc schists (blue and yellow, more than 3 m thick)

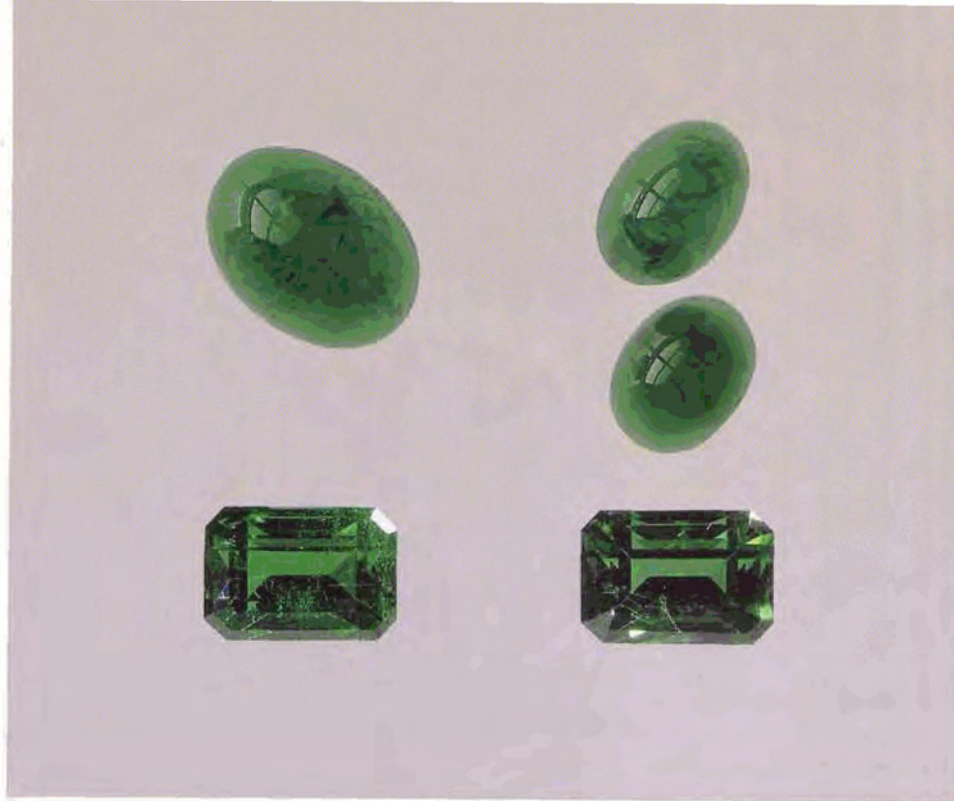


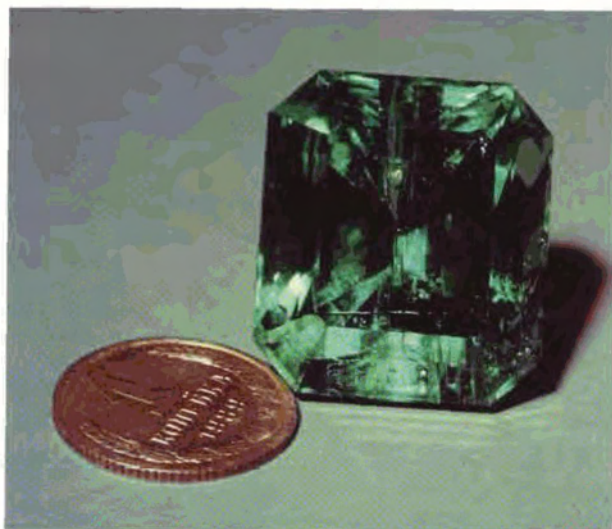
Figure 2. Some of the emeralds that have emerged recently from the Ural Mountains are of very fine color, as evidenced by these 2–3 ct cabochons and faceted stones.

According to Fersmann, emeralds are found only in the biotite and actinolite schists, but Zhernakov (1980) mentioned emeralds from talc schists as well. Fersmann also reported that dark green emeralds are confined to the biotite schists that are in contact with massive pegmatite bodies, and light green material is found in the biotite schists that are in contact with smaller pegmatites and/or in the albitic feldspar itself. Zhernakov main-

tained that the crystals from the actinolite and talc schists are not of gem quality.

The emerald-bearing host rock has been described differently by different researchers: Fersmann (1929) describes the mica as biotite, whereas Zhernakov (1980) and later authors mention only brownish gray phlogopite micas. At the June 1991 International Colored Gemstone Association (ICA) Congress, A. F. Laskovenkov, chief geologist of the Malysheva Mines Management, reported that in most cases the host rock was phlogopite.

Figure 3. This 37-ct emerald is reportedly from the new production in the Ural Mountains. Photo courtesy of B. Harel, Hargem.



MATERIALS AND METHODS

The present study is based on the examination of about 120 Uralian samples, 100 from the recent production and 20 older specimens that have all of the characteristics associated with Uralian stones. Included among these older stones are data from three faceted samples that were made available by a private collector who had obtained them as Uralian emeralds after they were removed from period jewelry; these stones are designated samples X, Y, and Z in this study. Also available were two reportedly Russian emeralds that had been in the possession of an Idar-Oberstein gem-dealing family for more than 50 years.

From a large parcel of more recently produced Russian emeralds (available since the end of 1989) that contained cut samples between 0.5 and 8.0 ct,

TABLE 1. Physical and chemical properties of Uralian emeralds.

Sample ^a		X	Y	Z	5A	5E	3A	5B	3J	3B	3E	5C	3C	3L	1B	5D	5F	
		Fac. square	Fac. round	Fac. oval	Cab. oval	Cab. oval	Fac. emerald cut	Cab. oval	Fac. emerald cut	Fac. emerald cut	Fac. emerald cut	Cab. oval	Fac. emerald cut	Fac. emerald cut	Fac. emerald cut	Cab. oval	Cab. oval	
		8.0 x 8.0	7.3	7.9 x 5.4	8.7 x 7.4	8.8 x 7.0	6.4 x 5.0	8.3 x 7.0	7.3 x 5.4	6.8 x 5.5	7.7 x 5.7	8.4 x 7.5	6.8 x 5.8	5.7 x 5.6	4.6 x 9.9	8.4 x 6.9	9.5 x 7.3	
Color		Light green	Light green	Light green	Light yellowish green	Light green	Light green	Light green ^b	Light green	Medium green	Light green	Medium green	Light green	Light green	Very intense green	Medium green	Light green	
Refractive indices	n _o	1.582	1.587	1.589	1.581	1.583	1.587	1.587	1.588	1.586	1.588	1.589	1.589	1.589	1.589	1.590	1.589	1.590
	n _e	1.576	1.579	1.581	1.575	1.577	1.580	1.580	1.580	1.579	1.581	1.581	1.581	1.581	1.581	1.582	1.581	1.582
	Δn	0.006	0.008	0.008	0.006	0.006	0.007	0.007	0.008	0.007	0.007	0.008	0.008	0.008	0.008	0.008	0.008	0.008
Density (g/cm ³)		2.72	2.73	2.74	2.71	2.72	2.72	2.73	2.73	2.72	2.73	2.73	2.74	2.73	2.74	2.74	2.75	
Number of analyses		3	3	3	20	25	15	20	20	20	20	25	20	20	15	24	24	
Microprobe analyses (wt.%) average composition	SiO ₂	65.02	64.68	64.77	65.88	65.83	65.70	65.17	65.30	65.69	65.15	65.35	65.63	65.13	65.40	65.09	65.08	
	Al ₂ O ₃	17.15	16.55	15.96	18.29	17.71	17.47	17.33	17.15	17.25	16.69	16.90	16.27	16.79	16.56	16.49	15.84	
	Cr ₂ O ₃	0.10	0.05	0.12	0.04	0.11	0.07	0.02	0.06	0.18	0.06	0.13	0.08	0.09	0.50	0.13	0.09	
	V ₂ O ₅	0.01	—	0.02	0.02	0.02	0.01	0.01	0.03	0.01	0.03	0.03	0.04	0.04	0.04	0.03	0.03	
	FeO ^c	0.31	0.40	0.35	0.16	0.24	0.25	0.24	0.37	0.28	0.42	0.37	0.57	0.47	0.39	0.44	0.35	
	MnO	n.a. ^d	n.a.	n.a.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
	MgO	0.82	1.45	1.75	0.42	0.74	0.97	0.97	1.09	0.99	1.40	1.10	1.71	1.28	1.21	1.38	2.05	
	K ₂ O	0.05	0.03	0.07	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	
	Na ₂ O	0.63	1.19	1.42	0.62	0.77	1.14	1.21	1.14	1.15	1.28	1.30	1.13	1.36	1.10	1.49	1.73	
	Total		84.09	84.35	84.46	85.46	85.44	85.65	84.99	85.17	85.57	85.05	85.20	85.46	85.19	85.22	85.08	85.22
	Cations calculated to O = 18, assuming BeO = 3.0	Si	5.998	5.977	5.989	5.970	5.979	5.968	5.967	5.970	5.975	5.975	5.979	5.993	5.968	5.985	5.976	5.977
		Al	1.864	1.802	1.739	1.954	1.896	1.870	1.870	1.849	1.849	1.804	1.822	1.751	1.813	1.787	1.784	1.715
Cr		0.007	0.004	0.009	0.003	0.008	0.005	0.002	0.005	0.013	0.005	0.009	0.006	0.006	0.036	0.010	0.007	
V		0.001	—	0.002	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.003	0.003	0.003	0.003	0.002	0.003	
Fe		0.024	0.031	0.027	0.012	0.018	0.019	0.019	0.029	0.022	0.032	0.029	0.043	0.036	0.030	0.034	0.027	
Mn		n.a.	n.a.	n.a.	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	
Mg		0.113	0.200	0.241	0.057	0.100	0.131	0.132	0.148	0.134	0.191	0.149	0.233	0.174	0.165	0.189	0.280	
K		0.006	0.004	0.008	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.004	
Na		0.113	0.213	0.255	0.109	0.135	0.202	0.215	0.202	0.202	0.227	0.230	0.200	0.242	0.195	0.265	0.309	
Sum of alkalis and transition metal oxides			1.10	1.67	1.98	0.87	1.16	1.51	1.52	1.63	1.64	1.81	1.85	1.85	1.99	2.05	2.12	2.25

^aSizes in mm; cab. = cabochon; fac. = faceted.

^bAlmost colorless; selected as the stone with the lightest color among hundreds of stones.

^cTotal iron as FeO.

^dn.a. = not analyzed.

we selected about 100 cabochon-cut and faceted samples for examination. The stones were chosen to cover the complete quality range from extremely clean samples to very heavily included stones, as well as the complete color range from very light green, almost colorless, beryls (sample 5B) to very intense green emeralds (sample 1B; also, see figure 2). After microscopic examination and determination of refractive indices, 30 samples from this group of 100 were selected for spectroscopic investigation; 13 of these 30 were also subjected to chemical analysis (see table 1).

Refractive indices were obtained by a standard gemological refractometer, and densities were determined hydrostatically.

Microprobe analyses of the older samples X, Y, and Z were performed by K. Schmetzer in 1987 on

an ARL SEMQ instrument with an operating voltage of 20 kV and a beam current of 10 nA; values were calculated by the MAGIC IV correction program provided by the manufacturer. The 13 samples of the new production of Uralian emeralds were analyzed by H.-J. Bernhardt in 1991 with a Cameca Camebax electron microprobe using an acceleration voltage of 15 kV and a beam current of 15 nA; for the calculation of values, the correction procedure described by Pouchou and Pichoir (1984) was applied. For the examination of chemical zoning within the samples, 15–25 point analyses were performed at uniform distances across the table facets of the faceted samples and across the bases of the cabochons.

In recent gemological papers, crystal chemistry and isomorphic replacement schemes of emer-



Figure 4. Most of the samples from the new Russian production range from light to medium green. These stones, which range from 0.32 to 1.77 ct, are courtesy of Adrian Klein, A. Freeman Precious Stones; photo © GIA and Tino Hammid.

alds have been evaluated by correlation diagrams. Using the results of microprobe analyses, correlation diagrams were plotted for different cation pairs—e.g., for Na versus Mg (Hammarstrom, 1989)—or for different oxide pairs—e.g., for Na_2O versus MgO (Schwarz, 1990). Because plots of oxide pairs cannot indicate some details, specifically, details of coupled isomorphous substitution schemes in beryl, we evaluated the results of 268 microprobe analyses of our 13 Uralian samples using plots of various cation pairs. Such plots show the relationships among the elements that substitute for one another in a given site, which may be useful in establishing origin.

We also used both microprobes mentioned above to analyze biotite-phlogopite inclusions that were exposed at the surfaces of the fashioned emeralds.

Spectral data in the U.V.–visible range were obtained with a Leitz-Unicam model SP800 spectrophotometer; infrared spectra were obtained with a Perkin-Elmer model IR 180 infrared double-beam grating spectrophotometer, using between 1 and 2 mg of emerald powder for the preparation of KBr disks.

Photomicrography was performed on a Schneider immersion microscope with Zeiss optics.

RESULTS

Visual Appearance. The older stones examined by the senior author were light green to medium green. The few rough samples available were dark green and revealed a typical prismatic habit with residual mica crystals bound to the prism faces. Microprobe analyses of some mica platelets taken from two of the emerald crystals confirmed the micas as members of the phlogopite-biotite series with iron contents in the range of 4 to 8 wt. % FeO.

Most of the stones of the new production also appeared to be light to medium green (figure 4, table 1). Visually, these samples resembled light to medium green material from Colombia, specifically Chivor, or from Nigeria (Lind et al., 1986). On the basis of the stones seen on the market to date, it appears that a relatively small percentage of samples from the new production are a very intense green, comparable to that of the finest Colombian emeralds (sample 1B, table 1).

In the parcels examined, we saw very few light green, almost colorless (sample 5B, table 1) or light yellowish green (sample 5A, table 1) stones. Undoubtedly, most such material either was not cut or was sorted out before the stones were brought to market.

For the most part, both the older and newer stones revealed weak pleochroism of yellowish green parallel to the c-axis and bluish green perpendicular to the c-axis.

Physical Properties. On the gemological refractometer, the shadow edges for n_o and n_e of most of the stones examined were found to be slightly broader and less distinct than are usually seen for well-polished emeralds. These results indicate a distinct chemical zoning across the table facets or (for the cabochons) flat bases of the stones examined, which was confirmed by microprobe analysis. The refractive indices were found to range from 1.581 to 1.590 for n_o and from 1.575 to 1.582 for n_e , with a birefringence of 0.006 to 0.008 (table

1). Densities measured ranged between 2.71 and 2.75 g/cm³. These values are within the range reported for Uralian emeralds, as well as for emeralds from other sources (Sinkankas, 1981; Schrader, 1983; Granadchikova et al., 1983; Schwarz, 1987; Gromov et al., 1990).

Chemical Properties. The microprobe analyses also showed a distinct chemical zoning in all of the stones, which was clearly indicated by the 268 point analyses of the 13 stones from the new production. For example, the Cr₂O₃ content in sample 3B ranges from 0.11 to 0.22 and in sample 3L, from 0.05 to 0.14. This chemical zoning is responsible for the weak color zoning observed with the microscope in many of the stones.

All samples revealed significant amounts of sodium and magnesium, which were also indicated by qualitative analyses using the energy-dispersive system of the electron microprobe. However, the presence of distinct sodium and magnesium peaks in the energy-dispersive spectrum of an emerald of unknown origin is useful only to confirm that the sample is natural; it is not sufficient to indicate locality of origin.

The iron and chromium contents of the light green to medium green samples are characteristic for Uralian stones (Lokhova et al., 1977; Sinkankas, 1981; Franz, 1982; Schrader, 1983). The average chromium content in the very intense green emerald (sample 1B), however, is distinctly higher than that of its paler counterparts.

Note that electron paramagnetic resonance data on Uralian emeralds published by Lokhova et al. (1977) indicate that this material contains between 0.05 and 0.15 wt.% Fe³⁺. Lokhova et al. also determined contents of manganese and titanium in the range of 0.004 to 0.016 wt.% Mn and 0 to 0.016 wt.% Ti. Schrader (1983) determined low concentrations of nickel (approximately 0.002 wt.% Ni) in two Russian emeralds he analyzed.

Spectroscopic Data. Absorption spectroscopy in the near-infrared, visible, and ultraviolet ranges revealed the same type of absorption spectra for all samples examined. In the visible area, a typical emerald spectrum with chromium absorption bands was found (figure 5). In addition, strong absorption bands of divalent iron with a maximum at 12,200 cm⁻¹ (820 nm) were observed in the spectrum perpendicular to the c-axis, whereas the generally known absorption maximum of divalent

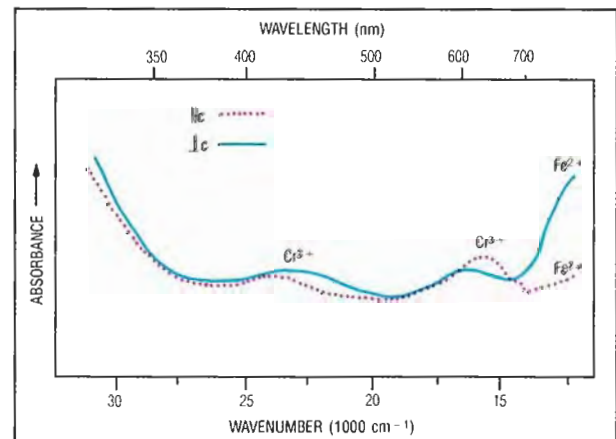
iron at 12,000 cm⁻¹ (833 nm) in the spectrum parallel to the c-axis was only of low intensity. Absorption bands of trivalent iron observed in some stones at 23,500 and 27,000 cm⁻¹ (426 and 370 nm) were weak or extremely weak if present at all.

In the yellowish green samples—e.g., sample 5A—an additional absorption is superimposed on the chromium-iron emerald spectrum described above. This additional absorption consists of an absorption maximum in the ultraviolet range with a low-energy tail that extends into the visible area, causing an almost continuously increasing absorption from green to violet. This additional absorption is responsible for the shift in color from a bluish to a yellowish green.

The spectra obtained were consistent with the nonpolarized spectrum of a Uralian emerald presented by Lokhova et al. (1977), as well as with polarized spectra of natural Russian emeralds from the Ural mountains published by Granadchikova et al. (1983) and Gromov et al. (1990). The presence of two types of iron absorption bands in the near infrared, in some cases in combination with weak absorption bands of trivalent iron in the bluish violet and ultraviolet range, is useful to characterize these samples as natural emeralds (Schmetzer, 1988).

The infrared spectra of three samples in the range of water-stretching vibrations (3500–3800 cm⁻¹) revealed the presence of three absorption

Figure 5. This visible-range absorption spectrum is typical of the stones examined for this study—and of natural emeralds from certain localities. It reveals absorption maxima of chromium and divalent iron.



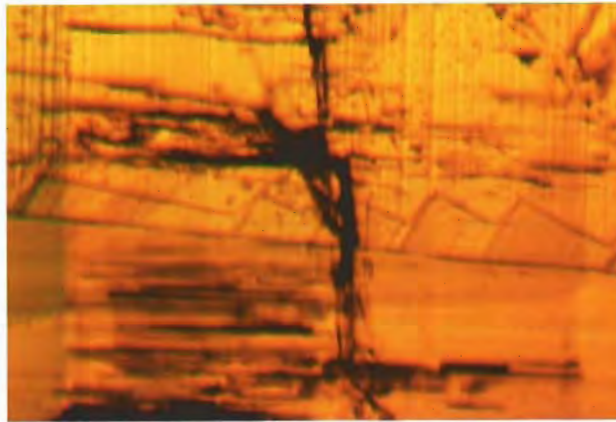
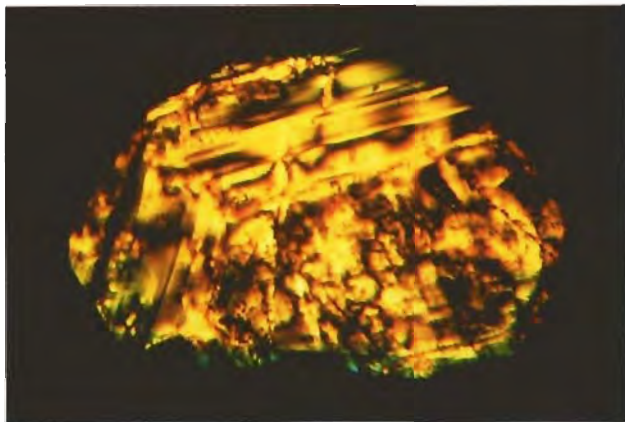


Figure 6. As with beryls and emeralds from other geographic localities, material from the Urals can exhibit prominent growth features. On the left, growth structures parallel to the first- and second-order hexagonal prism faces m ($10\bar{1}0$) and a ($11\bar{2}0$) are seen parallel to the c -axis (immersion, crossed polarizers, magnified $25\times$). The view on the right reveals growth structures parallel to the basal pinacoid c (0001), parallel to the first-order hexagonal dipyrmaid p ($10\bar{1}2$), and parallel to the first-order hexagonal prism m ($10\bar{1}0$). In this view, taken perpendicular to the c -axis, the zig-zag pattern of the growth structure is readily apparent and proves the natural origin of the sample (immersion, magnified $30\times$).

maxima: at 3694 cm^{-1} (band A), at 3592 cm^{-1} (band B), and at 3655 cm^{-1} (band C). The intensity ratios of these three absorption maxima were observed as $B > A > C$. This infrared spectrum is typical for medium alkali-bearing natural emeralds, as described comprehensively by Schmetzer (1989) and by Schmetzer and Kiefert (1990).

Microscopic Properties. Some of the "older" Uralian stones available for microscopic examination were heavily included. Most of the samples we examined (more than 70%) from the more recent production were of typical cabochon quality and were cut accordingly; they also revealed a high concentration of healing fractures and mineral inclusions. The remainder of the samples from the newer production, however, were high-clarity, faceted stones.

All of the Uralian stones examined showed a number of inclusions that are useful to confirm that the samples are natural. However, a natural emerald of unknown origin can be characterized as Uralian on the basis of its microscopic properties only in exceptional cases, because most of the microscopic features observed in the Uralian emeralds have also been seen, if rarely, in emeralds from other sources.

Growth Structures. Growth structures parallel to prism faces were frequently observed (figure 6). In general, the first-order hexagonal prism m ($10\bar{1}0$) is the dominant prism face, and the second-order hexagonal prism a ($11\bar{2}0$) is subordinate if present

at all. Occasionally, the growth structures parallel to the prism faces are also confined to a weak color zoning. Rarely, a mosaic-like growth structure consisting of frequently alternating growth planes parallel to the first-order and second-order hexagonal prism faces is seen. In some cases, growth structures were also present parallel to the basal pinacoid c (0001) that are occasionally confined to a growth zoning parallel to the first-order hexagonal dipyrmaid p ($10\bar{1}2$). Similar growth structures have been observed in emeralds from other localities (Kiefert and Schmetzer, in press).

Solid Inclusions. Different forms of birefringent mineral inclusions were frequently present: densely clustered and/or irregularly distributed small brown crystals; rounded platelets or tabular crystals (figure 7); and, occasionally, needle-like mineral inclusions or elongated tabular crystals (figure 8). In one stone, we found two columnar developed crystals with prismatic cross-sections (figure 9).

Several crystalline inclusions exposed at the surfaces of the faceted emeralds were examined by electron microprobe. Qualitative investigations of all types of mineral inclusions mentioned above (figures 7–9), using the energy dispersive systems of the microprobes, indicated that the crystals consist mainly of Mg, Al, Si, and K, with variable amounts of Fe also detected; quantitative analyses (table 2) revealed a chemical composition typical for phlogopite or for intermediate members of the biotite-phlogopite solid-solution series. In general,

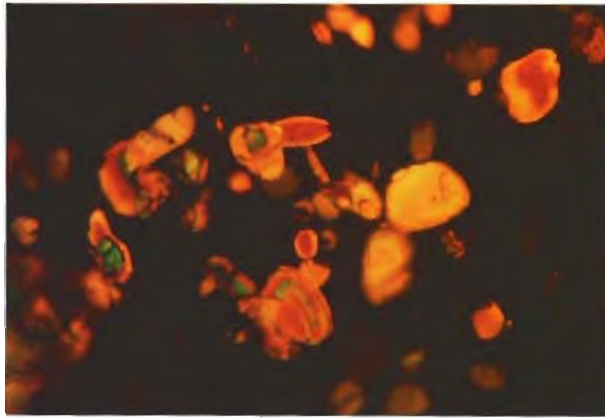


Figure 7. Frequently present in the Russian specimens examined were rounded platelets of a birefringent mineral that was subsequently identified as phlogopite. Under polarized light, these inclusions show a vivid display of interference colors. Immersion, crossed polarizers, magnified 85 \times .

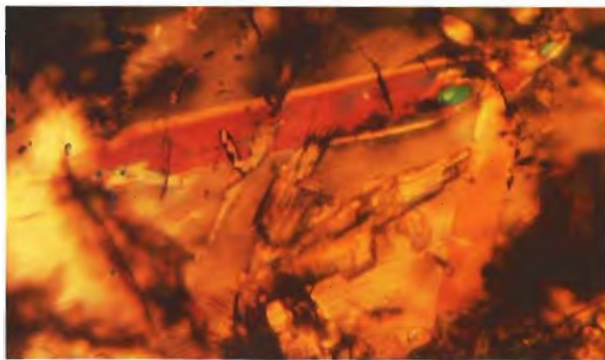


Figure 8. Larger, elongated tabular crystals, also subsequently identified as phlogopite, were occasionally seen in the Russian specimens. Immersion, crossed polarizers, magnified 60 \times .

iron-poor phlogopites appear virtually colorless in the gem microscope (figures 7 and 8), and crystals of the biotite-phlogopite series with higher iron contents take on a brown hue (figure 9). The chemical data for these brown micas are similar to the data reported by Fersmann (1929) for a "biotite" schist rock (table 2) from one of the historic Uralian emerald mines.

Actinolite needles, which are mentioned occasionally in the literature as inclusions in Uralian emeralds (Gübelin, 1973; Gübelin and Koivula, 1986), were neither seen nor revealed by electron microprobe analysis in either the older or the more recent samples.

Liquid and Two-Phase Inclusions. The crystals examined contained several types of liquid and

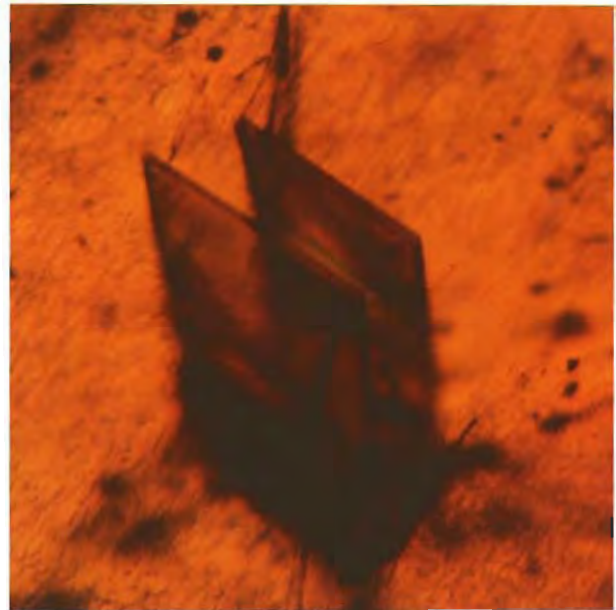


Figure 9. Present in one of the Ural Mountains specimens were two interesting "columnar" crystals with prismatic cross-sections that were later identified as biotite-phlogopite. Immersion, magnified 25 \times .

two-phase inclusions. The most noteworthy were found in the form of thin, flat cavities oriented on planes parallel to the basal pinacoid (figure 10). When the stones were examined perpendicular to the c-axis, these planes appeared as small lines at right angles to the c-axis. In general, extremely thin channel-like structures running parallel to

TABLE 2. Chemical properties of phlogopite and biotite-phlogopite inclusions in Uralian emeralds (wt. %).

Oxide	Phlogopites, almost colorless ^a		Biotite-phlogopites, brown ^a		"Biotite" schist, Mariinsky mine ^b
	Range of 5 crystals	Average	Range of 3 crystals	Average	
SiO ₂	40.05-42.13	41.35	40.88-41.79	41.29	43.88
Al ₂ O ₃	12.08-13.15	12.86	12.55-13.15	12.70	12.26
Cr ₂ O ₃	0.08- 0.15	0.12	0.52- 0.79	0.68	0.12
V ₂ O ₃	—	—	0.02- 0.04	0.03	n.a.
FeO ^c	3.98- 4.53	4.15	6.88- 7.53	7.23	9.17
MnO	n.a. ^d	n.a.	0.09- 0.21	0.15	0.33
MgO	24.61-25.88	25.29	17.85-18.78	18.54	18.79
Na ₂ O	0.55- 0.93	0.75	0.25- 0.41	0.33	0.71
K ₂ O	8.53- 8.94	8.78	8.02- 8.44	8.27	9.77

^aAs determined by microprobe analysis.

^bDetermined by wet chemical analysis, as published in Fersmann (1929).

^cTotal iron as FeO.

^dn.a. = not analyzed.

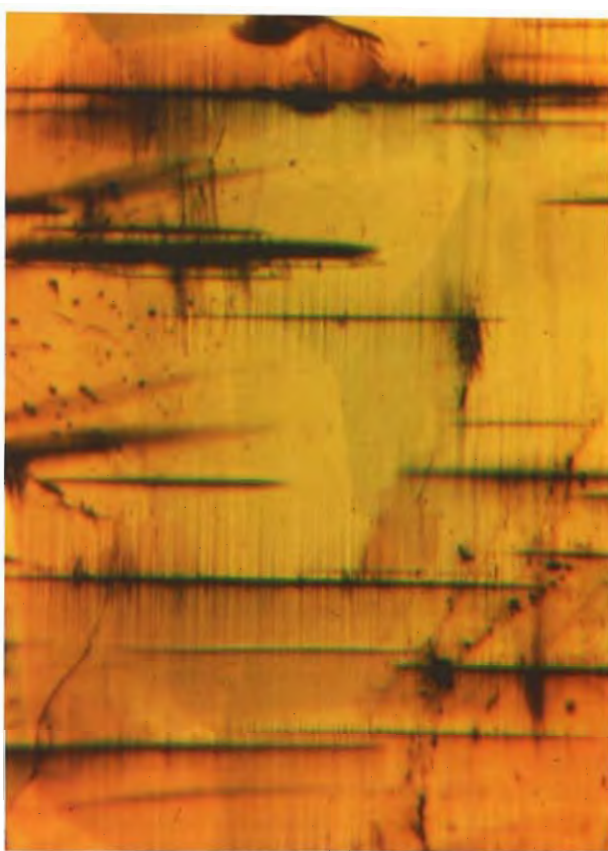


Figure 10. When some of the Russian material was examined perpendicular to the *c*-axis (running vertically in this photo), primary liquid and two-phase inclusions were observed in a characteristic orientation on planes parallel to the basal pinacoid, confined to channel-like structures oriented parallel to the *c*-axis (i.e., perpendicular to the cavity). Immersion, magnified 25 \times .

the *c*-axis, that is, perpendicular to the flat cavities, are confined to these planes. A view in a direction parallel to the *c*-axis reveals that these thin, flat cavities consist of liquid (figure 11) and/or two-phase inclusions (figure 12). Tilting the crystal slowly, so that the angle between the *c*-axis of the crystal and the microscope axis is increased, causes total internal reflection of the gaseous components of the two-phase inclusions, which are transparent when viewed exactly parallel to the *c*-axis (again, see figure 12).

Less frequently, we also observed channel-like growth tubes parallel to the *c*-axis and elongated fluid inclusions trapped on growth planes parallel to prism faces.

Undoubtedly, the phlogopite and biotite-phlogopite inclusions, the growth channels parallel to the *c*-axis, and the liquid and multiphase inclusions oriented parallel to the basal pinacoid or to prism faces are primary inclusions; that is, they were trapped during crystal growth. We do not

know the exact growth mechanism of the channel-like structures, with liquid and two-phase inclusions, that are confined to planes parallel to the basal pinacoid. However, we regard these inclusions (figures 10–12) and the different forms of mica (figures 7–9) to be the most typical and diagnostic inclusions in Uralian emeralds.

Numerous partly healed fractures were observed irregularly traversing most of the crystals. Although for the most part these healing “feathers” consisted of liquid inclusions, occasionally two- and even three-phase inclusions were observed in larger cavities of these feathers. These secondary (or pseudosecondary) inclusions were trapped after the host crystal had formed. However, we also observed some isolated cavities with multiphase fillings in these healing fractures (figure 13) that we could not establish as primary or secondary on the basis of their microscopic appearance. These isolated inclusions frequently form flat, more-or-less elongated cavities with the same orientation described above for the primary liquid and two-phase inclusions.

A typical two-phase inclusion consists of a cavity with a liquid filling that contains an additional gaseous phase. Most of the three-phase inclusions consist of two immiscible liquids and one gaseous component, but in one sample we observed a solid/liquid/gas three-phase inclusion (figure 13). Extremely rare are healing fractures in which larger birefringent mineral inclusions (as yet unidentified) are trapped with smaller liquid and/or gaseous components.

According to a recent paper by Gromov et al. (1990), the multiphase inclusions in Uralian emeralds were determined to consist of halite crystals, liquid CO₂, a saline aqueous solution, and a gaseous component.

DISCUSSION

Crystal Chemistry and Cause of Color. Although the general chemical formula of beryl, Be₃Al₂Si₆O₁₈, looks quite simple, natural beryl in general contains major amounts of impurities. A great number of isomorphic substitution schemes are discussed in the literature (see Shatskiy et al., 1981; Aurisicchio et al., 1988), but only some of these schemes are generally accepted:

1. Substitution of Al³⁺ in octahedral sites of the beryl structure by trivalent transition metal ions or by divalent transition metal ions or

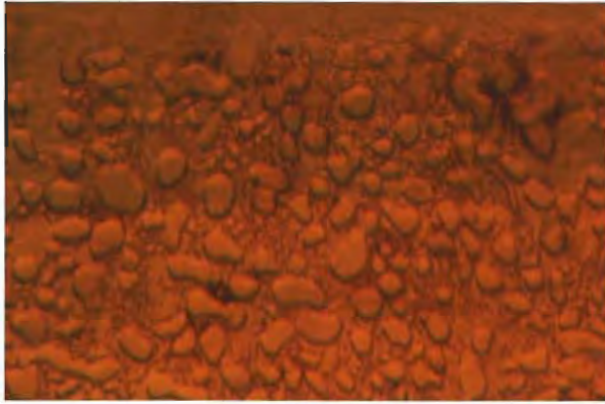


Figure 11. Although these are not unique to emeralds from the Urals, this material often contains primary liquid inclusions trapped on planes parallel to the basal pinacoid, as is shown in this view parallel to the *c*-axis. Immersion, magnified 65 \times .

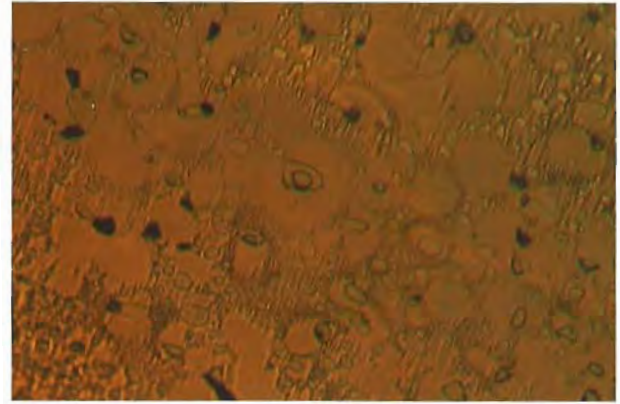


Figure 12. Some of the crystals examined contained several types of liquid and two-phase inclusions. In a number of instances, as shown here, they occurred trapped on a plane parallel to the basal pinacoid. Immersion, view parallel to the *c*-axis, magnified 60 \times .

magnesium, with alkali metal ions entering empty channel sites in the beryl structure for charge compensation.

Al^{3+} (octahedral) \rightarrow V^{3+} , Cr^{3+} , Fe^{3+} , Mn^{3+} (octahedral) or

Al^{3+} (octahedral) \rightarrow Mg^{2+} , Fe^{2+} , Mn^{2+} (octahedral) + Li^+ , Na^+ , K^+ , Cs^+ (channel)

2. Substitution of Be^{2+} in tetrahedral sites of the beryl structure by divalent transition metal ions or by lithium, with alkali metal ions entering empty channel sites for charge compensation.

Be^{2+} (tetrahedral) \rightarrow Fe^{2+} (tetrahedral) or
 Be^{2+} (tetrahedral) \rightarrow Li^+ (tetrahedral) + Li^+ , Na^+ , K^+ , Cs^+ (channel)

In both substitution types, octahedral and tetrahedral, the alkali ions in channel sites are bound to water molecules; however, free water molecules—that is, which are not bound to alkali ions—are also present in channel sites of the beryl structure (Schmetzer, 1989; Schmetzer and Kiefert, 1990).

Infrared spectroscopy established the presence of both alkali-bonded and non-alkali-bonded water molecules in channel sites of the beryl structure for the Uralian specimens examined. Specifically, the I.R. spectra revealed absorption bands B and C, at 3592 and 3655 cm^{-1} , which are assigned to alkali-bonded water molecules, and band A, at 3694 cm^{-1} , which is assigned to alkali-free water molecules.

Unfortunately, the standard electron microprobe cannot measure lithium, beryllium, oxygen, and water contents. However, the presence of small

amounts of lithium was established by Vlasov and Kutakova (1960), Franz (1982), and Aurisicchio et al. (1988), and may not be neglected.

The visible-range absorption spectra (figure 5) revealed the presence of strong absorption bands that are generally assigned to trivalent chromium (Cr^{3+}) in octahedral sites. Since the absorption bands at 23,500 and 27,000 cm^{-1} (426 and 370 nm), due to trivalent iron (Fe^{3+}) in octahedral sites, are weak or absent, most of the iron in the samples examined is assumed to be divalent (see also, Lokhova et al., 1977) and replacement of Al^{3+} by Fe^{3+} is limited if present at all.

According to Solntsev et al. (1984, 1985), near-infrared absorption maxima at 12,200 cm^{-1} /820 nm (perpendicular to the *c*-axis) and 12,000 cm^{-1} /833 nm (parallel to the *c*-axis) can be assigned, respectively to (1) Fe^{2+} replacing Be^{2+} in tetrahedral sites, and (2) Fe^{2+} replacing Al^{3+} in octahedral sites. Thus, most of the iron in Uralian emeralds is found as Fe^{2+} , primarily in tetrahedral sites with lesser amounts in octahedral sites, and with only minor amounts of Fe^{3+} present. The absorption bands of divalent iron in the infrared do not affect the visible area of the absorption spectra of Uralian emeralds. Nor does the absorption band of Fe^{3+} in the bluish violet region—usually weak or extremely weak, if present at all—influence the color of the samples. In general, the low concentrations of other transition metal elements present—including Mn, Ti, and V, as well as the low nickel concentrations (approximately 0.002 wt.% Ni) found by Schrader (1983)—also do not influence the color of the samples.

Consequently, as for most natural emerald, the

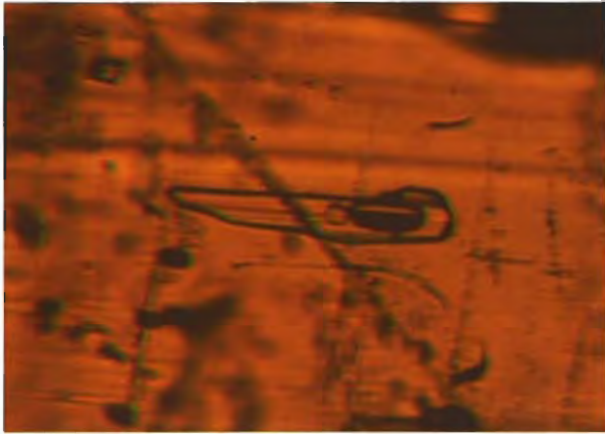


Figure 13. Although three-phase (liquid/solid/gas) inclusions are observed less frequently in Russian emeralds than in their Colombian counterparts, they do occur. This photomicrograph illustrates one type of three-phase inclusion we saw. It is interesting to note that it lacks the characteristic jagged outline often associated with Colombian stones. Immersion, magnified 70 \times .

bluish green color of Uralian emeralds is mainly due to chromium, and the intensity of the coloration is caused by the average chromium content of the individual crystal (table 1). The color in yellowish green samples is caused by a chromium spectrum superimposed by the absorption spectrum of naturally radiation-induced color centers, most probably confined to iron ions, that contribute a yellow component. For some time, the authors have been familiar with this absorption in natural untreated yellow beryl, natural untreated yellowish green emerald, and irradiated yellow or irradiated bluish green Maxixe-type beryl (Rink et al., 1990).

Complex aspects of crystal chemistry determined for the Uralian stones in the study are discussed in box A. Such data are useful in understanding modes of isomorphic replacement and in pursuing methods of determining emerald origin (locality as well as natural vs. synthetic). For example, as stated earlier, the sodium (Na) and magnesium (Mg) contents of the Uralian emeralds clearly establish their natural origin. Moreover, the variation in physical properties, especially the variation in refractive index, is explained as a function of chemical composition. For beryl, it is generally established that increasing amounts of

alkalis as well as increasing amounts of transition metal oxides cause an increase in refractive index (Cerny and Hawthorne, 1976; Deer et al., 1986). Although the exact water and carbon dioxide contents of the samples, which also influence the optical properties of beryl (Lebedev and Kokukin, 1984), are unknown, a direct relationship between increasing amounts of impurities and increasing refractive indices is confirmed by the results of this investigation. In figure 14, the refractive indices of the 13 new and three older samples are plotted as a function of the sum of alkalis (sodium and potassium) and transition metal oxides (vanadium, chromium, iron, and manganese). With increasing impurities, increases in birefringence and density are also observed (table 1).

Diagnostic Features of Uralian emeralds. Most of the data presented in this article confirm the natural origin of the samples and demonstrate the applicability of modern analytic techniques to supplement conventional microscopic examination. In the present case, however, optical microscopy is the most appropriate technique to prove the natural origin of the samples and provide some indication of locality of origin.

Phlogopite crystals are typically seen as inclusions in gem-quality Russian emeralds, which are known to originate from phlogopite-bearing host rocks (Zhernakov, 1980; Sinkankas, 1981). In earlier papers (e.g., Fersmann, 1929), these micas are often described as biotites, but microprobe analyses (table 2) strongly indicate iron contents typical for phlogopite or members of the biotite-phlogopite solid-solution series rather than for pure biotite. However, neither phlogopite nor biotite is unique to Uralian emeralds, and either may be found in natural emeralds from various other deposits.

In the gemological literature, biotite flakes, actinolite rods, and tourmaline crystals have been mentioned as characteristic mineral inclusions in Uralian emeralds (Gübelin 1953, 1973; Gübelin and Koivula, 1986). Zhernakov (1980) noted, in addition to phlogopite and actinolite inclusions, the presence of rutile in emeralds from both phlogopite and actinolite schists, and of talc, tremolite, and chromite in emeralds from talc schists.

Another type of inclusion previously regarded as characteristic for Uralian emeralds (Gübelin,

BOX A: Crystal Chemistry

Using the information available from chemical and spectroscopic investigations of the Uralian material in this study, as well as the generally established schemes for an isomorphic replacement in beryl, the crystal chemistry is summarized as follows.

The 268 point analyses performed on 13 samples by electron microprobe clearly indicate that, as the number of magnesium ions increases, the number of trivalent ions in octahedral sites decreases, one for one. That is, if we neglect the small amounts of iron (Fe^{2+} and Fe^{3+}) that may be present in octahedral aluminum sites, the sum content of $\text{Al}^{3+} + \text{Cr}^{3+} + \text{V}^{3+}$ is inversely related to the magnesium (Mg^{2+}) content (figure A-1). A similar inverse relationship is established for the sum of $\text{Al}^{3+} + \text{Cr}^{3+} + \text{V}^{3+}$ and the sum of monovalent alkalis ($\text{Na}^+ + \text{K}^+$; figure A-2). A direct relationship, however, is established between magnesium (Mg^{2+}) and the sum of $\text{Na}^+ +$

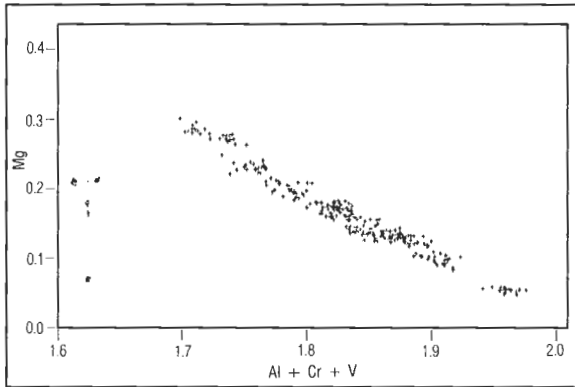
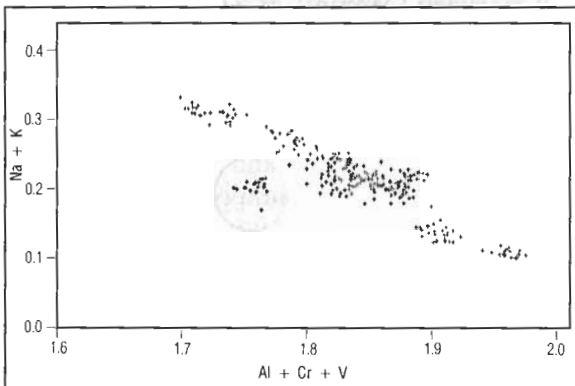
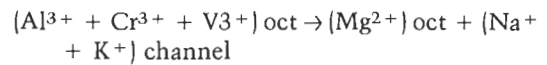


Figure A-1. This plot of $\text{Al}^{3+} + \text{Cr}^{3+} + \text{V}^{3+}$ in octahedral sites versus Mg^{2+} in octahedral sites in 13 samples clearly shows that as the number of magnesium ions increases, the sum of the trivalent aluminum, chromium, and vanadium ions decreases.

Figure A-2. This plot of $\text{Al}^{3+} + \text{Cr}^{3+} + \text{V}^{3+}$ versus $\text{Na}^+ + \text{K}^+$ shows a similar relationship to that indicated in figure A-1; in this case, it illustrates that monovalent alkalis in channel sites decrease as trivalent ions in the octahedral sites increase. The shaded section indicates analyses of sample 3C.



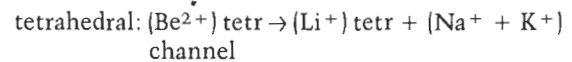
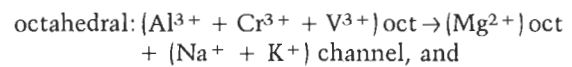
K^+ (i.e., as Mg^{2+} content increases, so does $\text{Na}^+ + \text{K}^+$; figure A-3). From these diagrams, the following substitutional scheme is established:



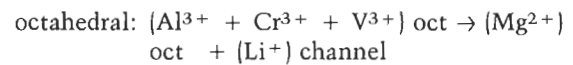
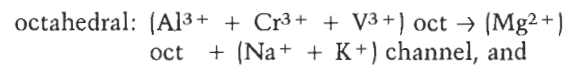
For 12 of the samples, the sum of monovalent alkali ($\text{Na} + \text{K}$) ions exceeds the sum of Mg ions; for only one stone (sample 3C) does Mg content exceed the sum of alkalis (point analyses shaded in figures A-2, and A-3). These results can be explained by the presence of small amounts of lithium, which is assumed

- to replace Be^{2+} in tetrahedral sites (in 12 samples), or
- to enter empty channel sites for charge compensation (in one sample)

Thus, for those 12 samples in which $\text{Na} + \text{K}$ exceeds Mg content—that is, for which the expression $(\text{Na} + \text{K} - \text{Mg})$ is positive—the following substitutions are established:

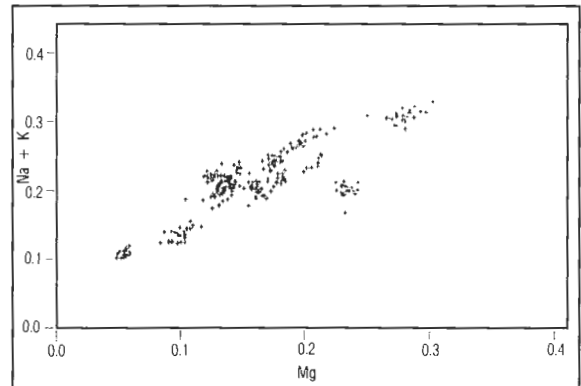


For sample 3C, in which Mg content exceeds $\text{Na} + \text{K}$ —that is, the expression $(\text{Na} + \text{K} - \text{Mg})$ is negative—two octahedral substitution schemes are established:



In summary, in all the samples we examined, an octahedral substitution is dominant; and in 12 of the 13 samples, a subordinate tetrahedral substitution is also established.

Figure A-3. The graph of octahedral Mg^{2+} versus $\text{Na}^+ + \text{K}^+$ in channel sites reveals a direct correlation; that is, as the former increases, so does the latter. Sample 3C analyses are indicated by the shaded area.



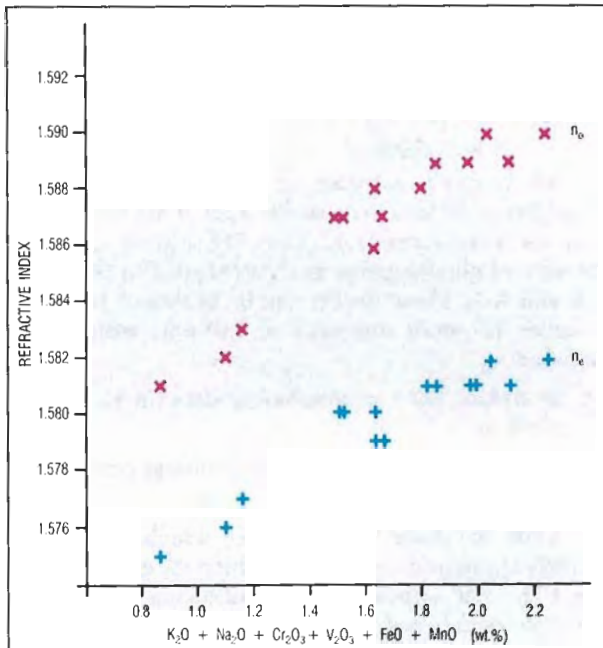


Figure 14. This graph of refractive index versus impurities reveals that an increase in impurities correlates directly to an increase in refractive indices (n_o and n_e).

1953) was also observed in the samples examined for this study: thin cavities of liquid or two-phase inclusions oriented with their flat planes parallel to the basal faces of the emeralds (figures 10–12). Although, like Gübelin, the authors found this type of inclusion to be most typical of Russian emeralds, identical inclusions have been observed by the senior author in some emeralds from a distinct source in Africa (probably the Gravelotte mining district in the Transvaal, South Africa) and illustrated by Schwarz (1987) for a sample from Socotó, Bahia, Brazil. Consequently, this type of inclusion cannot be regarded as unique for Uralian emeralds, but may be characteristic of samples that originate from a group of genetically related emerald deposits (Schwarz, 1987).

Our examination established the presence of multiphase inclusions in emeralds from this mining area and confirmed the findings of Gromov et al. (1990). They mentioned all five types of multiphase inclusions in Uralian emeralds that we also observed in our samples: (1) primary two-phase, aqueous solution and gas (the most common); (2) primary and pseudosecondary three-phase –

aqueous solution, gas, and liquid carbon dioxide (frequently seen); (3) primary and pseudosecondary three-phase – aqueous solution, gas, and a small halite crystal (rare; figure 13); (4) pseudosecondary and secondary aqueous solution with a small gas component (the most common of the nonprimary inclusions); and (5) extremely rare pseudosecondary inclusions consisting of small aqueous solution and/or gas phases with larger crystal inclusions.

Gromov et al. (1990) also mentioned as extremely rare two types of two- and three-phase inclusions with a dominant gaseous component and subordinate liquid and solid phases, which we have not yet observed. However, inasmuch as three-phase inclusions are known to occur in emeralds from other localities (e.g., Thurm, 1972; Yu, 1974; Graindorge, 1974; Schrader, 1985, 1986), they do not help prove the geographic source of an emerald.

Those features determined by researchers in recent years to separate natural from synthetic emeralds were found to be valid for Uralian emeralds. Thus far, we have not observed absorption bands of Fe^{2+} in the near-infrared in synthetic emeralds (Schmetzer, 1988). In addition, the high sodium and magnesium contents of our samples, which can be determined by quantitative microprobe analysis (table 1) as well as by qualitative chemical analysis using the energy dispersive system of an electron microprobe, prove the natural origin of the sample (Hänni, 1982; Schrader, 1983; Stockton, 1984). Infrared spectroscopy is also useful for this separation (Leung et al., 1986; Stockton, 1987; Schmetzer, 1989; Schmetzer and Kiefert, 1990). For the samples examined in our study, intensity ratios of $B > A > C$ were found for the three independent infrared absorption bands in the range of water-stretching vibrations; to date, this has not been observed in synthetic emeralds.

In summary, we determined that the Uralian stones reveal a number of interesting properties and diagnostic features. However, it must be emphasized that, at present, we know of no single property that would allow one to designate stones of unknown origin unequivocally as Uralian emeralds. Only by using a combination of physical, chemical, spectroscopic, and microscopic features can one suggest that an unknown sample probably originates from the Takovaya area near Sverdlovsk, USSR.

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TREATED ANDAMOOKA MATRIX OPAL

By Grahame Brown

Matrix opal from Andamooka, in South Australia, is a precious opal-included porous rock that is commonly color enhanced (carbon impregnated) to imitate the highly prized black opal from Lightning Ridge in northern New South Wales, Australia. This material has been commercially available since the mid-1950s and is often referred to as "sugar treated." A basic sugar acid-carbonizing technique is used to carbonize, and thus darken, the cream-colored matrix of prepolished stones so that the play-of-color is more prominent. The carbon impregnator in treated Andamooka matrix opal can be readily identified with low-power magnification.

The carbon impregnation of matrix opal from Andamooka, in South Australia, has produced many thousands of carats of treated opal with a broad range of appearances (figure 1). Most untreated matrix opal from Andamooka displays little play-of-color and is virtually worthless (figure 2). However, carbon impregnation of the matrix creates a dark body color that shows off the play-of-color, producing stones that may resemble black opal from Lightning Ridge and other localities (figure 3). Today, sugar-acid treatment of matrix opal forms the basis of many small commercial enterprises throughout Australia, and treated Andamooka matrix opal is available worldwide. This article discusses the occurrence of Andamooka matrix opal, its treatment, and methods that may be used to assure its identification.

THE LOCATION AND OCCURRENCE OF MATRIX OPAL AT ANDAMOOKA

The Andamooka opal fields are located a little over 500 km north-northwest of Adelaide, near the northwest edge of Lake Torrens, in South Australia

(figure 4). The South Australia Department of Mines and Energy estimated that in 1988 the Andamooka fields, at \$A3 million, were the third most important opal deposit in Australia, in terms of value of rough produced (SADME, 1989); they followed Mintabie (\$A39 million) and Coober Pedy (\$A21 million).

According to Barnes and Townsend (1982), precious opal usually occurs at Andamooka in an essentially horizontal layer at or near the contact

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Dr. Brown is the principal of ALLGEM Services, Brisbane, Queensland, Australia, and current president of the Gemmological Association of Australia.

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Figure 1. A variety of appearances result from carbon impregnation ("sugar treatment") of Andamooka matrix opal. These treated samples range from 4.73 to 13.69 ct. Photo © GIA and Tino Hammid.

of a sandy boulder bed (conglomerate band or concrete) with an underlying water-retentive light brown, yellow, or grayish white claystone. The boulder bed (which is less than 0.5 m thick) contains rounded pebbles, cobbles, and boulders of quartzite, silicified shale, and silicified limestone lying at the base of a deeply weathered white claystone known locally as *kopi*. The clays of the conglomerate band were deposited in a shallow sea during Early Cretaceous times, and the boulders were apparently dropped from rafts of floating sea ice, having been entrapped on nearby beaches by shoreline freezing. The presence of these boulders, which can be over 2 m across, provided a unique environment for the later deposition of opal and gave rise to several types of opal formation (Barnes and Townsend, 1982), including: *painted ladies*—thin films of opal filling joints in quartzite boulders; *colored concrete*—opal cementing pebbles, cobbles, and boulders in the conglomerate band; and *matrix*—opal partly replacing boulders that were formerly carbonate rich, mainly limestone and dolomite, and filling pore spaces in some sandstone and claystone within the opal level. Opal is also found in thin horizontal seams above the opal level, and filling minor joints and faults both above and below it.

The matrix opal found at Andamooka (again, see figure 2) is predominantly a cream-colored to grayish white porous rock that displays an indistinct patchy play-of-color from its scattered content of included grains and patches of precious

opal. However, the range of hues in which Andamooka matrix opal does occur includes porcelain white, gray to black, pink, bright green, gold, and black-and-white splashed peacock matrix (George Brooks, pers. comm., 1991). This rock is better described as matrix opal than as opal matrix since, at Andamooka, opal is found replacing both clasts and matrix (J. Keeling, pers. comm., 1990). In Australia, the occurrence of matrix opal appears to be restricted to the Andamooka opal fields (Barnes and Townsend, 1982), with matrix boulders weighing hundreds of kilos commonly recovered from the opal level.

Figure 2. Before treatment, most Andamooka matrix opal displays little play of color. Here, the largest cabochon is 9.84 ct. Photo © GIA and Tino Hammid.



Figure 3. Treated Andamooka opal (lower right, 7.22 ct) not only resembles natural black opal from Lightning Ridge, Australia, but also oolitic opal (the carving, 35.76 ct) and black opal from Honduras (upper right, 24.53 ct). Photo © GIA and Tino Hammid.

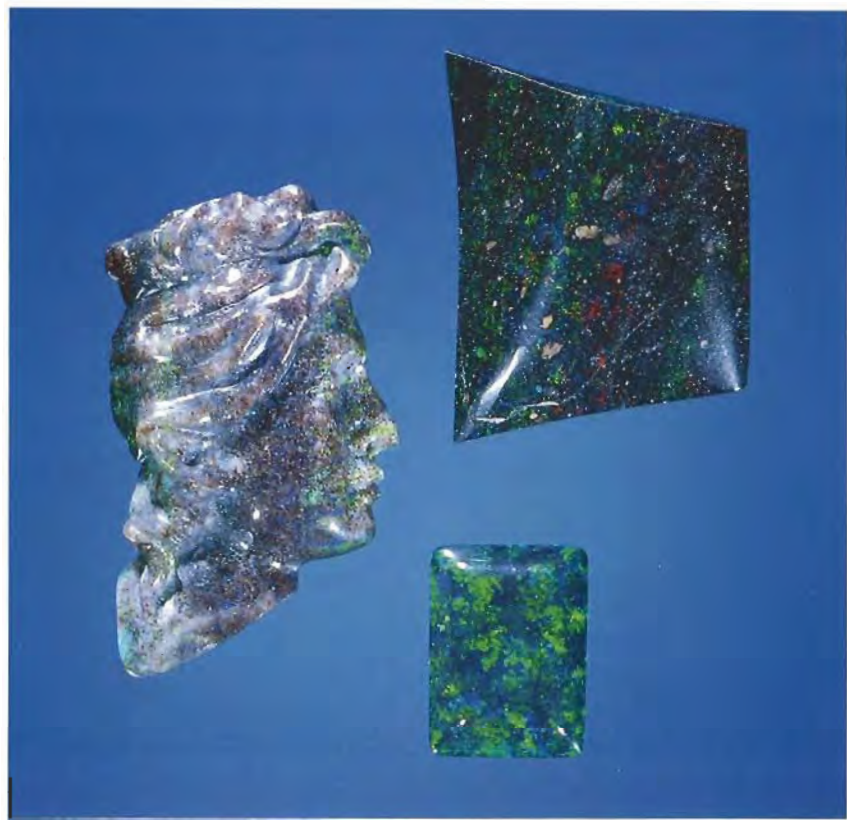


Figure 4. The Andamooka opal fields lie near the northwest edge of Lake Torrens, in South Australia. Artwork by Carol Silver.

On the basis of their examination of two specimens of Andamooka matrix opal with both optical and scanning electron microscopy, geologists at the Geological Survey of South Australia (Keeling and Farrand, 1984) found that the matrix opal "is composed of an intimate mix of silica spheres and finer grained amorphous or partly crystalline silica." They attribute its relatively high porosity to numerous voids within patches of opal and along the contact zones of the opal with the fine-grained silica. They concluded from their investigation that the matrix opal probably formed when limestone erratics within Cretaceous marine sandy clay were partially dissolved, and the remaining carbonate rock was replaced by fine-grained silica at the same time that silica spheres were deposited and grew in existing solution cavities.

It is the intrinsic porosity of Andamooka matrix opal that makes possible the impregnation of its surface with black carbon particles to enhance the play-of-color (figure 5).

TREATED ANDAMOOKA MATRIX OPAL

Andamooka matrix opal has been color enhanced by carbon impregnation since the mid-1950s (Keeling and Farrand, 1984). For almost four decades, this color-enhanced opal has been variously ter-

med *carbonized matrix opal* (McColl, 1966), *dyed opal matrix* (Altmann, 1979), *opal matrix* (I. Townsend, pers. comm., 1990), *dyed matrix opal* (J. Keeling, pers. comm., 1990), and *sugar-treated opal* (Koivula, 1984).

McColl (1966) provided one of the first comprehensive descriptions of this enhancement technique:

1. The matrix opal is selected for treatment based on the following factors:
 - The quality, size, and distribution of precious opal in the individual matrix piece
 - The purity, porosity, and fineness of grains in the matrix
 - The ability of the nonopaline groundmass to accept a lustrous polish

The best matrix opal for treatment has a clean, sand-free, cream-colored matrix with sufficient porosity to facilitate its impregnation with carbon particles, but will accept a lustrous polish with minimal undercutting.

2. Color enhancement is best performed between the final sanding and polishing steps, not after polishing. Not only will the impregnation process severely etch the polished surface, but polishing also decreases the permeability of the matrix. In addition, the black carbon impregnator usually only penetrates to a very shallow depth (figure 6).

Figure 5. Treatment of different colors of Andamooka matrix opal (top) produces different types of carbonized matrix opal (bottom). Experienced treaters know which types of untreated material will produce the most attractive carbonized opal.



3. The following sugar-acid carbonizing technique is generally used:

- Step 1. The surface of the matrix opal is ground and sanded to prepolish smoothness.
- Step 2. The prepolished specimen is immersed in two to three times its volume of an acidified glucose-lactose impregnator—a 20% solution of glucose and lactose, in 1:4 proportions, to which a few drops of concentrated sulfuric acid have been added.
- Step 3. The impregnator is heated at 105°C for up to 10–12 hours until the solution evaporates. At this point, the temperature is raised to 125°C, so that the sugars impregnating the matrix opal will solidify and then dehydrate.
- Step 4. The sugar-impregnated matrix opal is gently broken from the darkened sugary mass. After excess sugar has been scraped from its surface, the impregnated piece is immersed in a glass vessel filled with concentrated (98%) sulfuric acid that is slowly heated to 100°C for 4–5 hours. This treatment reduces the impregnating sugars to black carbon.

Figure 6. In most cases, the carbon treatment penetrates the matrix opal only at the surface of the prepolished stone. Here, the chipped surface of the cabochon at top reveals the whitish color of the original matrix opal. Cut lengthwise, the cabochon at the bottom graphically illustrates the relatively shallow depth of penetration of the carbon.





Figure 7. Treated Andamooka matrix opal is used not only in cabochons but also for carvings, such as this 13 × 26 mm sample.

Step 5. After slow cooling, the carbonized (carbon-impregnated) matrix opal is washed in running water for 8–12 hours to remove residual sulfuric acid.

Step 6. The treated matrix opal is carefully and lightly polished to minimize removal of the (usually thin) external carbonized layer.

Note that opal itself (potch or precious) cannot be “dyed.” Only the matrix around patches or discrete grains of opal in Andamooka matrix opal will change color.

Although McColl’s description of sugar-acid carbonization of Andamooka matrix opal is 25 years old, this same technique—or variations of it—is still being applied today in much the same sequence of steps. As the carbonization of Andamooka matrix opal is mainly a “cottage industry” pursued by various miners, gem merchants, and professional lapidaries throughout Australia, valid estimates of production are impossible to obtain. This lack of reliable production information is not unique to carbonized Andamooka matrix opal. Indeed, virtually all production figures for Australian opal should, at best, be considered either “guesstimates” (on behalf of the government) or precautionary underestimates (on behalf of tax-paying miners).

Figure 8. Some extremely large pieces of Andamooka matrix opal have been treated and are currently in the trade. This approximately 10,500-ct treated Andamooka matrix opal is courtesy of Jim Rose, Opal America. Photo © GIA and Tino Hammid.



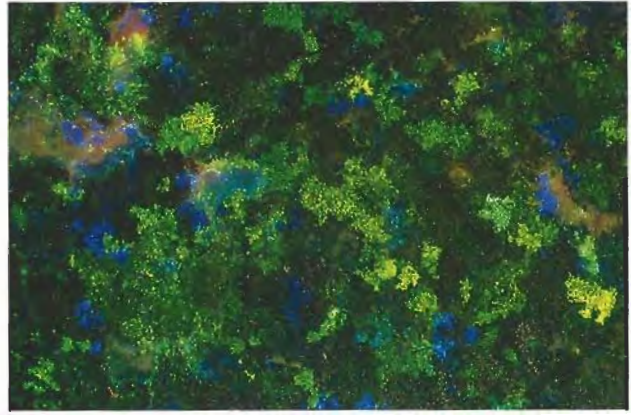
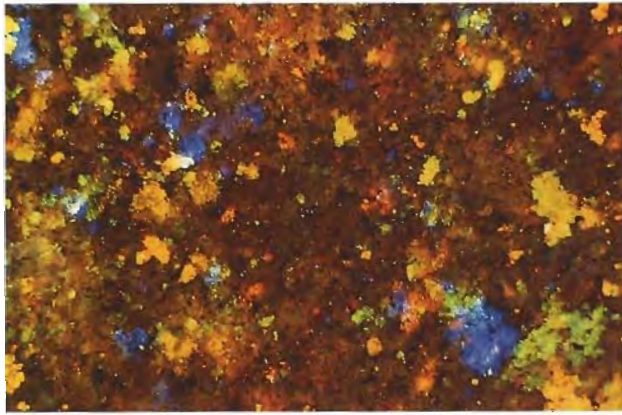


Figure 9. With 10× magnification (a hand lens), the coarsely granular groundmass of carbon-treated Andamooka matrix opal is readily apparent. In addition, the carbon impregnator can be seen to surround and include randomly distributed, irregularly sized patches of precious opal. Photo on left is by the author; photo on right is by Robert Weldon.

Carbonized Andamooka matrix opal is now available on the international gem market, both as cabochons (again, see figure 1) and carvings (figure 7). Some extremely large “boulders” have also been treated (figure 8). Inasmuch as some of the carbonized opals have been misidentified as black opal in the gem community, the following guidelines are provided.

IDENTIFICATION OF TREATED ANDAMOOKA OPAL

The matrix of this material will have a siliceous groundmass with a macroscopic texture that ranges from smoothly opal-like to fine or coarsely granular. Regardless of the texture, the presence of the black carbon impregnator is readily visible with magnification (using a 10× loupe or low-power binocular microscope) and carefully directed incident illumination. The treatment can be seen either in and around scattered patches of precious opal (figure 9), or filling voids and fractures in the surrounding nonprecious opal siliceous matrix (figure 10).

While treated Andamooka matrix opal has been used to imitate valuable Lightning Ridge black opal, side-by-side comparisons will reveal the following discriminatory features (figure 11):

1. Treated Andamooka matrix opal never displays the velvety lustrous polish of Lightning Ridge black opal.
2. The body color of treated Andamooka matrix opal is opaque and uniformly black. In contrast, the translucent to opaque body color of Lightning Ridge black opal is typically dark blue, dark green, dark brown, or gray, and only very rarely black.

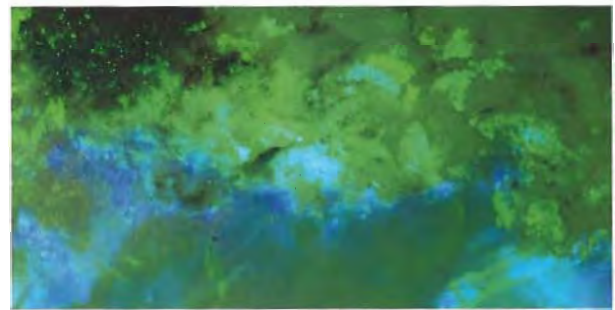


Figure 10. Black carbon particles can also be seen filling voids, fractures, and surface defects in carbonized Andamooka matrix opal that has an essentially opaline groundmass. Magnified 10×.

Figure 11. Treated Andamooka matrix opal (left, 13.69 ct) may be mistaken for Lightning Ridge black opal (right, 11.88 ct), although there are several distinguishing characteristics. Photo © GIA and Tino Hammid.



3. Treated Andamooka matrix opal has patchy to spotty play-of-color that emanates from an obvious black carbon-impregnated matrix.

As treated Andamooka matrix opal has quite distinctive hand-lens characteristics, other gemological tests will seldom be needed to identify this treated opal. Depending on the porosity of the original material, this color-enhanced matrix opal has gemological properties (hardness = 6, specific gravity = 1.98 to 2.05, a "spot" refractive index of 1.44/1.45, and patchy blue-white fluorescence to long-wave ultraviolet radiation) that are identical to those of solid light-colored Andamooka opal.

Owners of treated Andamooka matrix opals should avoid damage to the surface of the stone, because the carbon impregnation often is no deeper than 1 mm (although the immersion of a particularly porous matrix opal in the sugar solution for several days may alter the color throughout the entire stone; G. Brooks, pers. comm., 1990). While treated Andamooka matrix opal has the same toughness as solid Andamooka opal, the color in the treated opal may be removed by repolishing.

CONCLUSION

In Australia, the term *matrix opal* is used to describe a range of sandy, clay-like, or siliceous rocks that have their pore spaces and fractures

filled with precious opal. Almost all treatable matrix opal comes from the Andamooka opal fields in South Australia.

For almost 40 years, Andamooka matrix opal has been color enhanced by sugar-acid treatment of the prepolished matrix opal.

Dyed Andamooka matrix opal is simple to identify, because at 10× magnification the black particulate carbon impregnator can be seen either within or surrounding discrete grains of precious opal, or impregnating the nonopaline siliceous matrix surrounding these patches of color.

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AMBER, Damaged in Cleaning

Recently the East Coast laboratory received a telephone call from an acquaintance who was quite agitated as she described the appearance of a necklace of amber beads that she had attempted to clean by immersion in denatured alcohol. Some of the beads had turned chalky white and others had lost all luster. She explained that she often "washed" natural and imitation stone bead necklaces in this fashion, with great results. If it worked with those materials, why not amber?

While she was still on the telephone, we selected a piece of amber and dipped it into the alcohol we use to clean diamonds while grading. In an instant, our sample was "ruined." Figure 1 shows the 30-in. (75 cm) necklace that she subsequently sent to us for examination.

A check of the literature for information about the reaction of amber to alcohol turned up nothing. In fact, one source implies that amber is attacked only by acids and strong solvents. (One test for amber is its resistance to ether—surely a strong solvent.) Evidently, the alcohol in perfumes does not affect amber, or surely it would have come to our attention by now.

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

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Figure 1. When these amber beads (10.25 × 7.34 mm to 25.30 × 16.75 mm) were "washed" by immersion in alcohol, many of them acquired a white film that could only be removed by repolishing.

Our friend's necklace had been assembled to illustrate the broad range of color and quality of amber from Santo Domingo. Resistance to alcohol appears to be another variable. Several of the lighter, more transparent beads showed little damage, while most of the beads that were darker and more translucent developed an opaque white layer. Repolishing the beads removed the coating. The reaction of these beads makes it evident that alcohol should

be included among the list of solvents that may attack organic materials such as amber. GRC

DIAMOND**Electron-Treated, Large**

The East Coast laboratory has seen a marked increase in diamonds that have been color treated by electrons. With magnification and diffused illumination, electron treatment can be

recognized in some diamonds by the presence of a zone of color at the culet or along facet junctions (as discussed in the article by Fritsch and Shigley, *Gems & Gemology*, Summer 1989, pp. 95–101).

Recently, we examined the largest electron-treated diamond we have seen to date in this lab. The 37.43-ct radiant-cut yellow diamond measured approximately 22.14 × 16.98 × 11.48 mm. A yellow color zone, typical of that produced by electron treatment, was observed in the culet area. DH

Electron Treated, in Period Jewelry

At about the same time, the East Coast lab examined a yellow old-European-cut diamond, set in a white metal Art Deco brooch, that also revealed the tell-tale yellow “cone” around the culet that proves electron treatment. The stone measured approximately 7.00 × 5.00 mm.

The curious thing was that the brooch was probably manufactured before electron treatment was available. Although the cutting style of the treated stone matched that of the other diamonds in the pin, careful inspection revealed that the bezel setting encasing that stone had been replaced. This suggests that the original stone was either (1) unmounted, treated, and reset or (2) replaced with a treated diamond that was carefully selected to match the other stones in cutting style. TM

Fracture Filled

Over the last few years, the filling of fractures in diamonds has been the subject of great concern and study. A comprehensive article published in the Summer 1989 issue of *Gems & Gemology* (Koivula et al., “The Characteristics and Identification of Filled Diamonds,” pp. 68–83) discussed the orange/blue flash effect that is a major identifying characteristic of a filled stone. In that article, however, near-colorless diamonds were used to illustrate this feature with the exception of one yellowish brown dia-

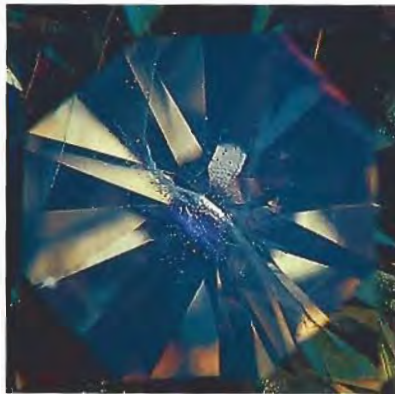


Figure 2. A purple flash is readily visible in this filled yellowish brown diamond when viewed with darkfield illumination and 20× magnification.

mond. This exception pointed out the fact that unless the stone is oriented properly, the flash effect might be more difficult to detect with darkfield illumination in colored than “colorless” diamonds.

A subsequent update (*Gem News*, *Gems & Gemology*, Spring 1990, pp. 103–105) illustrated a near-colorless diamond with new flash-effect colors: pinkish purple and yellowish green.

Recently, the East Coast laboratory examined an obviously filled yellowish brown diamond with the “new” flash-effect colors (figure 2). Unlike the “old” (orange/blue) flash-effect colors in the fracture-filled yellowish brown diamond shown in the 1989 article, the “new” (purple/green) flash-effect colors are readily visible with darkfield illumination and magnification. Figure 3 shows both orange and green flashes in this same stone. *Nicholas DelRe*

Green Surface-Colored Rough Fashioned to a Fancy Light Yellow

A client recently allowed the East Coast laboratory to follow the progress of a 22.94-ct light green rough octahedral diamond through sawing, cutting, and polishing and record its gemological and spectral characteristics at each stage.



Figure 3. In the same stone as figure 2, these filled fractures reveal both the “original” orange flash-effect color and its newer green counterpart. Magnified 15×.

Examination of the rough diamond with both the unaided eye and a gemological microscope, using diffused illumination, led us to speculate that the green color was confined to the surface. Once the crystal was cut and polished, we believed, the green color would disappear and the resulting faceted stones would have a yellow body color.

Infrared spectroscopy of the rough crystal revealed that it was a type IaA + B, with the body color due to absorption caused by the presence of nitrogen. The crystal displayed the classic Cape absorption lines in the Beck hand-held spectroscope.

We then examined the rough crystal with a Pye Unicam Model 8400 UV-VIS spectrophotometer to look for absorption lines associated with the radiation damage to the lattice structure that contributes to a green color. The crystal did reveal this type of absorption, known as the GR1, with its characteristic sharp band at 741 nm.

Although we saw no natural brown or green radiation stains on the rough crystal, we believe that the green coloration was natural. The stone was reported to be from Angola, and Central Africa is known to be uranium rich; natural radiation from uranium can affect the coloration of diamond crystals. Further-



Figure 4. Even after a diamond with what appeared to be a green "skin" was sawed, the green surface color was still prominent. The 6.56-ct piece is shown here.

more, there was no artificial color zoning such as is induced by electron or cyclotron treatment.

The crystal was then sawed into two pieces, 15.93 and 6.56 ct. Although these two pieces retained the original greenish coloration (figure 4), we were surprised that both showed a very weak absorption line at 503 nm that was not present in the original piece of rough. Perhaps this was caused by the heat of sawing, which required three eight-hour days to complete.

The larger piece of rough yielded an 11.01-ct radiant cut with no trace of green color visible; this stone was graded "fancy light yellow." Thus, our original speculation about the final color proved to be correct. The U.V.-visible spectrum of the fashioned stone also showed that the GRI radiation absorption band was no longer present, undoubtedly because the green surface had been completely removed in fashioning. *DH*

Green, with Radiation Stains in Etch Channels

We have often noted a relationship between a face-up green color in diamonds and the presence of brown or green radiation stains. In many polished stones where the surface is entirely removed during cutting,

these stains are confined to etch channels, with figures 5 and 6 being two good examples. The striated or sculpted surfaces of these epigenetic features show specific preferential attack at defects in the crystal structure caused by the etching fluid. Etch channels are usually V shaped and narrow as they penetrate the crystal. Thus, the narrow portion of the channel remaining on a polished diamond may appear at first glance to be a mechanical fracture or cleavage. However, the absence of a fracture or cleavage surface suggests that it is actually the result of etching.

A possible explanation for this association of radiation stains and etch channels is that the same fluid causes both. Diamonds have been etched in the laboratory (producing etch channels, trigons, and other features observed in natural diamonds)

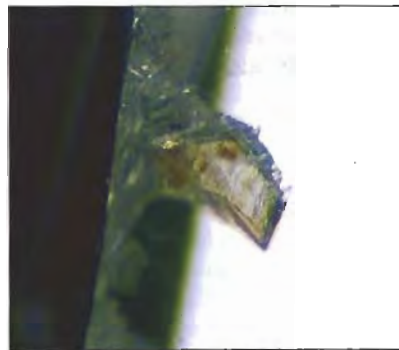


Figure 5. Brown irradiation stains are evident in this etch channel at the girdle of a very light green 2.49-ct old-mine-cut diamond. Magnified 45 \times .

with potassium chlorate and sodium perchlorate, potassium and sodium nitrate and hydroxide, and silicate melts including kimberlite (as summarized in Orlov's *Mineralogy of the Diamond*, English edition published by John Wiley & Sons, Toronto, 1977, pp. 85–103). Any fluid that contains potassium will include some of the long-lived radioactive isotope K-40, which makes up 0.01% of all potassium in nature. In addition, two



Figure 6. Green stains line the etch cavities that extend into this 0.60-ct marquise-cut diamond and may contribute to its overall color. Magnified 50 \times .

other long-lived radioactive nuclides, thorium-232 and uranium-238, are frequently found in natural fluids rich in potassium. Whatever the precise composition of the etching fluids that attack natural diamonds, irradiation could easily occur at the same time.

Such radiation stains, which line the channels and penetrate into the diamond approximately 1 or 2 mm, may be the cause of the apparent color in the stone shown in figure 6. The "stained" channel illustrated in that figure is just visible along the lower edge of the diamond at its belly. There is another, similar stain in the pavilion at the left point of the marquise-cut stone. The presence of these stains is a strong indicator of natural color, although further corroboration is usually necessary.

TM and Ilene Reinitz

PEARL

Cultured "Demi-Pearl"

Staff members at the West Coast lab had the opportunity to examine a unique pearl formation. At first glance, the 6-mm round drilled bead (figure 7) resembled another unusual pearl formation that we had described as a "demi-pearl" in the Fall 1989 Gem Trade Lab Notes section.

Like the earlier sample, the two halves of this bead also were different

colors: The white part showed the pearly luster and orient commonly associated with fine pearls, while the medium dark pinkish brown part showed some areas of darker color concentration, but no other structural characteristics. Visually, the darker portion resembled the calcareous concretions produced by clams or oysters. Since this pearl was drilled, we were able to see through the drill hole a distinct demarcation between the bead nucleus and the fairly thin overlying partly nacreous, partly concretionary layer. The X-radiograph clearly showed the difference in transparency between the bead nucleus and the top layer, thus proving that this "demi-pearl," unlike the one previously described, was the result of a culturing process. As would be expected in a cultured pearl, the fluorescence of the shell nucleus to X-radiation was visible through the lighter-colored nacreous layer, but it was masked by the darker pinkish brown layer. Again, we do not know under what circumstances this unusual "demi-pearl" was formed in the mollusk. KH



Figure 7. Half of this 6-mm cultured "demi-pearl" is nacreous and half resembles a calcareous concretion.

Freshwater "Rosebud" Pearls

The necklace of graduated freshwater pearls shown in figure 8 generated great interest in the East Coast laboratory. It consisted of natural freshwater "rosebud" pearls ranging from



Figure 8. The bumps, ridges, and high luster of the graduated pearls in this necklace strongly suggest that they are freshwater "rosebud" pearls, which are characteristically found only in American waters.

approximately $6.70 \times 4.80 \times 3.20$ mm to $15.50 \times 13.80 \times 5.50$ mm. Although a few pearls appeared to be slightly out of place, the overall match of color, overtone, and luster was consistent.

This necklace resembled those illustrated and described in the Spring 1989 (p. 35) and Fall 1990 (p. 220) Lab Notes sections. It appears to be an American product from the *Unio* mussel and probably was assembled in the early 1900s, when American pearl production peaked.

"Rosebud" pearls have been described by Sweaney and Latendresse (*Gems & Gemology*, Fall 1984, pp. 125-140): "This characteristically American freshwater pearl is typically high domed, with a flat back and roughly roundish outline." The pearls in this necklace also had the prerequisite bumps and ridges as well as a high luster. As expected, the pearls luminesced strongly to X-rays, and the X-radiograph showed only a few features in the structure.

TM

Rare Assembled Cultured Blister Pearls

At first glance, the beads shown in the ring in figure 9 appeared to be $3/4$ cultured blister pearls, which were first described in *Gems & Gemology*

in the Summer 1981 issue. However, the X-radiograph (figure 10) taken in our East Coast laboratory indicates that these are "plugged" cultured blister pearls with relatively thick nacre. That they were grown on an Australian *Pinctada maxima* yellow-lip shell is shown by the yellow worked area of shell evident around their backs. One might be tempted to call them mabe pearls, but that would be misleading since almost all mabe pearls are grown in the black-winged pearl oyster, *Pteria penguin*, which is called mabe by the Japanese.

Characteristically, mabe pearls have a very thin nacreous layer that is grown around (but does not adhere to) steatite (soapstone) hemispheres, which are discarded when the blister is sawed from the shell. After it is cleaned thoroughly, the inside of the thin nacre may be lacquered to enhance the color; then a hemisphere of mother-of-pearl is cemented into the cavity and covered with a low cabochon shell base. This contrasts with the $3/4$ cultured blister pearls, which retain their large saltwater shell nuclei and require no assemblage. Because of the setting, we could not determine how these "plugged" cultured blister pearls were finished on the base.

GRC



Figure 9. Unlike mabe pearls, these "plugged" cultured blister pearls (approximately 17 mm in diameter) have a relatively thick nacre and were grown in an Australian *Pinctada maxima* oyster.

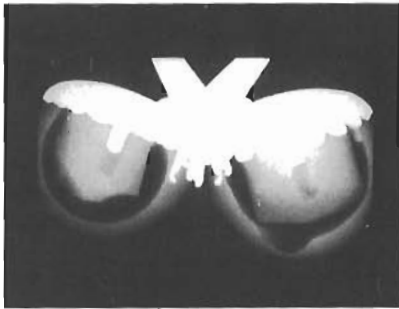


Figure 10. The X-radiograph of the cultured blister pearls in figure 9 clearly shows the "plugs."

An Early(?) Flux-Grown SYNTHETIC RUBY

When the staff of the New York laboratory first reported their examination of flux-grown synthetic rubies in the Spring 1965 issue of *Gems & Gemology*, they undoubtedly referred to something similar to the synthetic ruby shown in figure 11, which was recently submitted to us. However, at that time the journal was not published in color, and the fact that the seed crystal used to initiate crystal growth was outlined in blue was not noted. Later, in the Winter 1969-1970 issue, they did note the blue outline, but could give no explanation for it; again, the ma-

terial was not illustrated in color.

We can now speculate that the presence of iron and titanium in the natural corundum seed crystal provides the mechanism for the blue color. It is probable that the heat from the synthesis process draws the Fe and Ti to the surface of the crystal and, when they come into contact with the flux solution, creates the blue outline.

By the mid-1970s, the manufacturers were evidently growing crystals large enough to eliminate all evidence of the seed crystal in faceting. We have not seen a blue-zoned flux-grown synthetic ruby such as the one pictured here for many years. However, we have noted in some of the rubies from Vietnam blue zones (rather than outlines) that remind us of some of the early faceted flux-grown synthetic rubies we examined so long ago. GRC

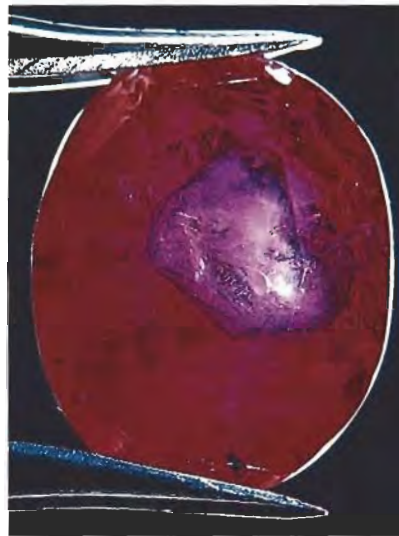


Figure 11. This early flux-grown synthetic ruby reveals a blue outline around the natural corundum seed. Magnified 10×.

SPINEL, with Unusual Green Fluorescence

The attractive 9.78-ct oval mixed cut shown in figure 12 in incandescent



Figure 12. This 9.78-ct spinel showed an attractive color change from bluish violet in fluorescent light to slightly pinkish purple in incandescent light.

light was recently submitted to our West Coast laboratory for identification. A medium dark, slightly pinkish purple in incandescent light, this stone exhibited a medium dark bluish violet when viewed in fluorescent illumination. Routine gemological testing established its identity as a natural spinel.

Specifically, although the single refractive index reading of 1.714 is slightly lower than is normally expected, it is the same as that recorded for a 16.39-ct color-change cobalt spinel described in the Fall 1990 Gem News section of *Gems & Gemology*. When we viewed the stone with a Chelsea filter, we observed a weak dull brownish pink throughout most of it, with flashes of dull brownish red in the crown facets. Moderate anomalous double refraction was seen in the polariscope. A specific gravity of 3.60 was determined by the hydrostatic method. Microscopic examination revealed an interesting display of inclusions: a complex interweaving of "needles" (figure 13) and stringers of fine particles intersecting in three directions, as well as a few small crystals and fractures (several with brownish orange iron-oxide stains).

When exposed to long-wave ultraviolet radiation, this color-change spinel exhibited a striking moderate to strong chalky, slightly yellowish

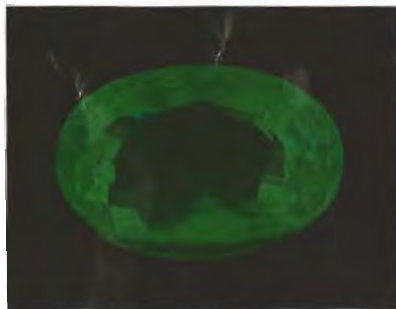


Figure 13. These needle-like inclusions were seen in the spinel shown in figure 12. Magnified 25×.

green fluorescence (figure 14). A similar, but much weaker, reaction was observed with short-wave U.V. radiation. Green fluorescence is quite unusual for a natural spinel. We recall having seen it only once before, in a natural spinel that exhibited a color change from pinkish purple to purplish pink (see the Winter 1984 Lab Notes section).

Figure 15 shows the absorption curve as recorded with a Pye Unicam Model 8800 UV-VIS spectrophotometer in GIA Research. The spectrum shows features related to

Figure 14. The spinel in figure 12 fluoresced a striking chalky, slightly yellowish green to long-wave U.V. radiation.



Fe^{2+} , with trace amounts of Co^{2+} , both in tetrahedral coordination. These two elements are responsible for the bluish violet coloration and the moderate color change. The very sharp peak at about 428 nm is attributed to Mn^{2+} in tetrahedral coordination (see Schmetzer et al., 1989, *Neues Jahrbuch für Mineralogie Abhandlungen*, Vol. 160, No. 2, pp. 159–180). Energy-dispersive X-ray fluorescence confirmed those assignments by showing the presence of Mn, Fe, Zn, and Ga in addition to the major constituents Mg and Al. Trace amounts of Co are below the detection limits of our EDXRF system. The green fluorescence is due to the tetrahedral Mn^{2+} , which is known to give rise to a green fluorescence in other materials, such as feldspars and some glasses (see Waychunas, 1988, *Reviews in Mineralogy*, Vol. 18: *Spectroscopic Methods in Mineralogy and Geology*, Mineralogical Society of America, Washington, DC, pp. 639–664). Also, flame-fusion synthetic spinel doped with manganese shows a very strong green fluorescence.

RK and Emmanuel Fritsch

Cobalt-Colored SYNTHETIC SPINEL, with Unusual Inclusions

An attractive, 2.51-ct oval blue stone was submitted to the East Coast laboratory by a dealer who thought it was a rare cobalt-colored blue spinel. However, its optical characteristics—R.I. of 1.728, red fluorescence to long-wave ultraviolet radiation, and chalky yellow fluorescence to short-wave U.V.—matched those of cobalt-bearing synthetic spinel. The fact that natural cobalt-colored blue spinels are usually inert to both long- and short-wave U.V. (see the Kane entry in the Summer 1986 Lab Notes section) strongly indicated that our stone was indeed a synthetic.

When we examined the stone with magnification, we were surprised to see misty stringers and veils unlike anything we had ever seen in synthetic spinel (figure 16). To find a single known synthetic spinel with the same wispy inclusions—and thus confirm that this was indeed a synthetic—we had to examine well over 100 similar-colored synthetic spinels with binocular magnification. The known synthetic spinel we found

Figure 15. The U.V.-visible absorption spectrum of the spinel in figure 12 reveals features related to Fe^{2+} and Co^{2+} that are responsible for the bluish violet coloration and moderate color change.

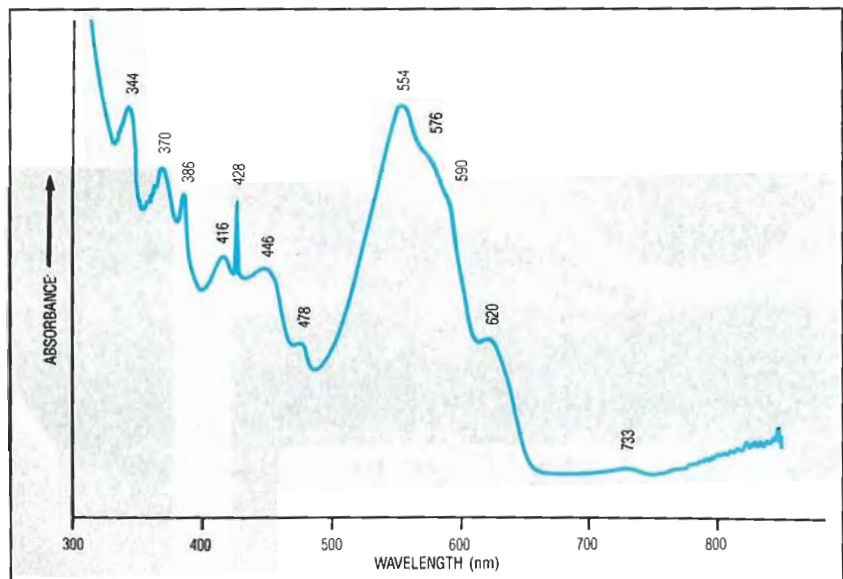




Figure 16. The unusual wisps and veils in this cobalt-colored synthetic spinel appeared to be associated with strain patterns. Magnified 50 \times .

looked like our sample. When both synthetic spinels were examined with crossed polarizers, the wisps and veils appeared to be associated with strain patterns. GRC

Dark Blue TOPAZ Damaged by Treatment

Blue topaz is one of the most common gems in the trade today. It is widely known that most of the various shades of blue marketed do not occur naturally, but are usually produced by treatment with irradiation followed by heat. Presently, there is no routine gemological test to separate natural- from treated-color blue topaz.

Some stones, however, provide indicators of treatment. The pres-

ence of residual radiation, noted in rare instances, conclusively proves that the topaz has been treated. The Geiger counter we use in the East Coast lab registered only background levels when the 20.88-ct topaz illustrated in figure 17 was tested. Proof of electron treatment was provided by the internal damage, referred to as "internal lightning," that was evident. As reported by Nassau in the Spring 1985 issue of *Gems & Gemology* (p. 30), the halos around the individual crystals most likely are also the result of the electrical charge.

Even though topaz samples are cooled during treatment, the build-up of a negative charge from the accelerator can damage the stones. To avoid damage, higher energy



Figure 17. "Internal lightning" reveals damage in a topaz treated by electron irradiation. Magnified 20 \times .

levels are usually used so that most of the electron beam passes through the sample. TM

Radioactive ZIRCON

We recently received for testing an 11.56-ct stone that the dealer believed was zircon and suspected was radioactive.

Routine gemological testing proved that the stone was zircon, and the Geiger counter showed that it was in fact radioactive, emitting over 0.4 milliroentgens (mR) per hour (figure 18). As normal background level is about 0.02 mR/hour, it would probably be unsafe to wear this stone in jewelry.

Ordinary "high zircon" is zirconium silicate crystallized in the tetragonal system. If the crystal contains radioactive uranium or thorium, alpha particles will destroy the crystal structure over time, forming what is called "low zircon," or amorphous silica and zirconium. As expected for a "low zircon," no dichroism or doubling of facet junctions was observed in the stone we tested. Nor could we locate a uniaxial figure in the polariscope, since the crystal structure had deteriorated. Instead, we saw the bright circular bands of color (figure 19) typical of a metamict zircon. DH

Figure 18. This green zircon sitting on top of a Geiger counter probe shows a radiation reading of over 0.4 mR/hour.

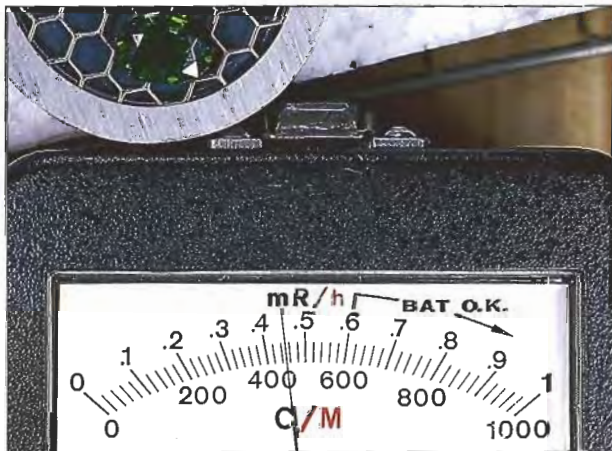
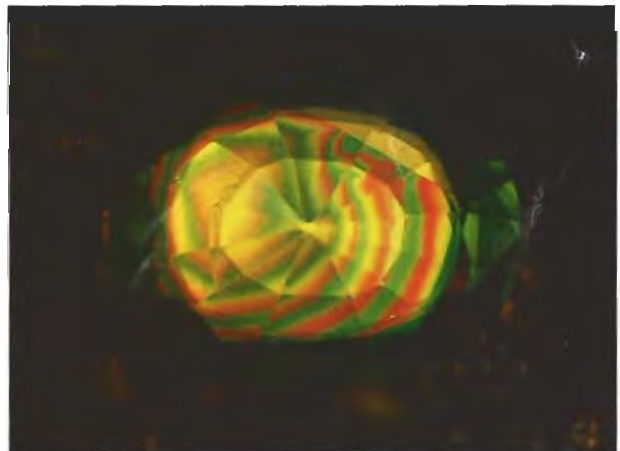


Figure 19. Only interference colors, but no optic figure, could be resolved in the metamict zircon shown in figure 18.



A HISTORICAL NOTE

HIGHLIGHTS FROM THE GEM TRADE LAB 25, 15 AND FIVE YEARS AGO

SUMMER 1966

The New York lab described and illustrated a remarkably thin—0.6 mm—rose-cut diamond that was 14.5 mm in diameter. This thin crown was used in conjunction with a cone-shaped metallic backing, also shown, to simulate a much larger diamond when set. Treated red-brown and red-orange diamonds were discussed and their absorption spectra illustrated.

SUMMER 1976

Chrysoberyl is well known for cat's-eye material, but it rarely shows asterism. A chrysoberyl showing a very distinct four-rayed star was seen in the Santa Monica lab. They also encountered another imitation amber with insect inclusions, in this case a large cicada in what turned out to be plastic.

The New York lab discussed diamonds and inclusions in diamonds. A cutter decided to eliminate a cloudy

area in the center of a 50-ct piece of rough by cutting an 8.55-ct cube containing the cloud. The cloud shows a dark cross at its center. Other unusual cuts and shapes of diamond were shown.

SUMMER 1986

The Los Angeles lab reported on some unusual items, including a nearly black devitrified glass that was being sold in Hong Kong as black "onyx." An unusual way to use thin slices of opal was illustrated in an assembled bead necklace where the opal had been applied in sections to a round bead backing material and then shaped and polished. A most unusual cat's-eye rutile was seen in Santa Monica. Although rutile does not normally have a structure that would produce chatoyancy, this material was apparently fibrous enough to produce a cat's-eye effect when fashioned.



This unusual cat's-eye rutile weighs 1.43 ct. Magnified 3×.

FIGURE CREDITS

The photos for figures 1–3, 5, 6, 8, 9, 11, and 16–18 were supplied by Nicholas DelRe. Figures 4 and 19 were taken by Dave Hargett. John I. Koivula shot the photomicrograph in figure 7 and the Historical Note. Bob Crowningshield took the X-radiograph in figure 10. Figure 12 is by Robert Weldon, figure 13 is by Robert E. Kane, and figure 14 is by Shane F. McClure. Mike Moon ran the UV-VIS spectrum illustrated in figure 15.

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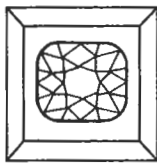
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GEMNEWS

JOHN I. KOIVULA AND ROBERT C. KAMMERLING, EDITORS

DIAMONDS

De Beers unveils Centenary diamond. On May 1, 1991, De Beers's Deputy Chairman, Nicholas Oppenheimer, unveiled the 273-ct Centenary diamond (figure 1). Described by De Beers as the largest reportedly flawless diamond outside the British Crown Jewels, the Centenary was fashioned from a 599-ct piece of rough recovered from the Premier mine in South Africa in July 1986. The rough was unveiled in Kimberley on March 11, 1988, to commemorate the 100-year anniversary (centenary) of De Beers Consolidated Mines Ltd.

The Centenary diamond is the third largest diamond to come from the Premier mine; the two largest are the 530.2-ct Great Star of Africa (Cullinan I) in the Imperial Sceptre and the 317.4-ct Lesser Star of Africa (Cullinan II) in the Imperial State Crown, both part of the Crown Jewels display in the Tower of London. These two stones, however, were fashioned prior to the development in the 1920s of modern, symmetrical cuts. The Centenary, therefore, is the largest modern-cut, top-color, apparently flawless diamond in the world.

A team of specialists spent three years preparing, cutting, and polishing the Centenary under the direction of famous cutter Gabi Tolkowski. Almost five months were needed for the initial shaping. Next, a total of 13 specific shapes were sketched and polished in hundreds of plastic models. By March 1990, a modified heart shape had been chosen and final polishing was begun; this process was completed more than a year later, in April of 1991. Although experts believe it is almost impossible to value, the Centenary diamond has been insured for over US\$100 million.

The Premier mine, which is also where the Cullinan rough was found, is situated near the small Transvaal village of Cullinan, east of Pretoria. The kimberlite pipe on which the mine was established is the largest of 14 in the Cullinan area and, at an estimated 1,200 million years old, is one of the oldest known kimberlite deposits. The Premier mine is famous for large and beautiful stones, often of superb quality. It has produced almost 300 stones larger than 100 ct.

Large "chameleon" diamond. Among the most notable of colored diamonds are those referred to as "chameleon" diamonds because of the unique color alteration they



Figure 1. The 273-ct Centenary diamond is one of the largest faceted diamonds in the world. Photo courtesy of the Central Selling Organisation.

show. These normally green stones will temporarily become yellow when they are either heated slightly or left in darkness for a period of time. The yellow color, however, is not stable, and the stones will revert in seconds or minutes to their original color when they are removed from the source of heat or exposed to light.

The editors recently examined an unusually large (9.92 ct) "chameleon" diamond, a round brilliant cut shown to us by Barry Shore of Dynamic Tangibles Corp., Los Angeles. Under normal conditions, the stone is light greenish yellowish gray (figure 2), but it temporarily changes to light brownish yellow when heated with the flame of an alcohol lamp.

Soviet production estimates updated. Vitaliy N. Efremov, deputy director of the Siberian branch of the USSR Institute of Geology and Geophysics, reported that 1989 production of diamonds in the USSR totalled approximately 15 million carats, half of gem quality. These represent the first production figures ever released by Soviet officials and exceed previous estimates by the

U.S. Bureau of Mines. (*Diamant*, October–November 1990)

Australian marine search for stones. The Australian company Cambridge Gulf Exploration is the first in that country to have obtained a permit to explore offshore waters for gems. The company believes that diamonds exist at the bottom of the Timor Sea. (*Diamond Intelligence Briefs*, October 18, 1990, p. 697)

World-record auction price for a diamond. At their November 14, 1990, auction in Geneva, Sotheby's sold a D-color, internally flawless, 101.84-ct diamond. The pear-shaped mixed cut brought a world-record auction price of \$US12,760,000. The stone, purchased by international jeweler Robert Mouawad, has been named the Mouawad Splendour. (Sotheby's press release dated November 16, 1990)

Update on diamond mining in Brazil. On a recent trip to Brazil, Patricia Maddison, senior staff gemologist in the GIA Gem Trade Laboratory, visited an alluvial diamond mine located in the far north of the country near the border with Guyana.

Mining is carried out on a high plateau in an almost dry river bed. A hydraulic cannon loosens the sediments (figure 3), which are then fed via a pipeline into a crude separator jig used to recover both gold and diamonds (figure 4). As in other areas of Brazil, the diamonds are a secondary product of what began as a gold-mining operation.

Figure 2. At 9.92 ct, this is an unusually large "chameleon" diamond. Photo by Robert Weldon.



Figure 3. A hydraulic cannon loosens the sediment prior to separation at this alluvial mining operation in northern Brazil. Photo by Patricia Maddison.

The owner of the mine stated that diamond production averaged approximately 15 carats a month; most of the diamonds Ms. Maddison saw were distorted octahedral and twinned crystals ("macles"), of gem quality. She visually estimated the weights as ranging from about 10 points to 3 ct. Many of the crystals had what appeared to be brown or green radiation stains on their surfaces, as is commonly seen on diamonds from Brazil. Ms. Maddison was told that a number of similar mines – with comparable production – were being operated elsewhere in the area, including across the border in both Guyana and Venezuela.

Jewelry-quality diamond crystals. While cutting is usually required to bring out the elegance of most "rough" gem-quality diamonds, occasionally we encounter natural crystals so beautiful in form that cutting seems



Figure 4. The separator jig shown here is used to recover both gold and diamonds in this Brazilian alluvial mining operation. Photo by Patricia Maddison.

unwarranted. Recently, the editors had the opportunity to examine two such crystals (figure 5) that were loaned for study by Marvin Finker, president of Trillion Diamond Co. of New York. The well-matched crystals weighed 0.97 ct and 0.92 ct, respectively, and measured 6.71 and 6.89 mm. Mineralogically, they would be classified as twins. Their form suggests that of twisted macles, with one twin member displaced by a rotation of 60° from the other, so that distinct hexagrams are formed. These six-pointed stars are in the shape of a Magen David (Star of David). Because of their similar size and weight, these make an exceptional pair.

Bluish gray synthetic diamond thin films grown on faceted diamonds. Since the mid-1980s, great progress has been made in the low-pressure synthesis of diamond (see, e.g., Fritsch et al., *Gems & Gemology*, Summer 1989, pp. 84–90). Although a number of industrial applications for these thin films have been developed, until recently the process was not refined to the point where it was useful with gem materials. Now, however, the deposition of a very thin film of type IIb blue synthetic diamond on the surface of a faceted near-colorless diamond has been accomplished, which has considerable potential for the gem industry.

To explore possible identification criteria for such a treatment procedure, Dr. Emmanuel Fritsch of the GIA Research Department had two faceted emerald-cut diamonds (0.33 ct and 0.36 ct) and a rough octahedron (1.15 ct) covered with such a thin film by Dr. Andrew Phelps, who at the time was with the Diamond Materials Institute, State College, Pennsylvania. The faceted stones originally color graded G and H–I (figure 6, left).

Deposition was carried out using the hot-filament technique. After a careful cleaning, the stones were placed on the assembly surface table-down, so only the pavilion and part of the crown could be coated. The substrate assembly was heated to 950°C during deposi-

tion. Carbon monoxide, used as a source of carbon, was metered into the reactor in the hydrogen gas stream. Boron was introduced into the growth environment as the extremely poisonous gas diborane, also diluted in hydrogen. Deposition time was typically 25 minutes.

The results were dramatic: All three stones appeared dark bluish gray (figure 6, right). Both the dark color and the high electrical conductivity (130 v on a Simpson meter, compared to 20 to 50 v for most natural blue diamonds) are attributed to the high concentration of boron in the thin film (approximately 220 ppm). The film produced is approximately a third to a quarter of a micron thick. It is monocrystalline, growing in atomic continuity with the substrate diamond.

Examination of the stones with a gemological microscope provided the most useful identification criterion: The thin film does not cover facet junctions very well, creating a whitish appearance similar to minor abrasion (figure 7). This feature typically is not seen on natural blue diamonds.

Figure 5. These “Star of David” diamonds (0.97 and 0.92 ct, respectively) make beautiful gems in their uncut form. Photo by Robert Weldon.





Figure 6. A dramatic difference can be seen in these two near-colorless faceted natural diamonds (0.33 ct and 0.36 ct) and one rough octahedron (1.15 ct) before (left) and after (right) they were coated with a synthetic bluish gray diamond thin film grown by low-pressure synthesis technology. Photos by Robert Weldon.

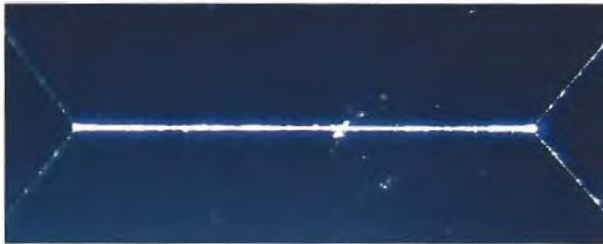


Figure 7. Whitish irregularities at the facet junctions of a diamond coated with a colored synthetic diamond thin film provide proof that this treatment procedure has been used. Photomicrograph by John I. Koivula; magnified 10 \times .

COLORED STONES

African gem update. On a recent trip to Idar-Oberstein, Dr. Emmanuel Fritsch received updates on gem production in a number of African countries. Eckehard Petsch gave GIA two parcels of tourmaline rough. One represents the wide range of colors produced at Karibib, Namibia. These include blue, bluish green, yellow, saturated pink, orange, and "watermelon." Some pieces were in the form of distinct gem nodules. The other parcel shows the range of colors from Chipata, Zambia: predominantly brownish green and brownish orange. Mr. Petsch also donated samples of rough morganite and emerald from Madagascar.

Local dealers reported that ruby production from the Morogoro area (Matombo and Maheng) of Tanzania has increased. The Uмба Valley in Tanzania is now producing pink sapphires with an orangy secondary color that is reportedly much closer to a true "padparadscha" color than the so-called "African padparadscha" that has been on the market for several years.

Madagascar is producing large quantities of brownish purple ("wine") colored tourmaline, although much is of a very low quality that is purchased primarily by Indian dealers for their domestic market. Karoi, Zimbabwe, is the source of large quantities of aquamarine. Some of the material is rather translucent but makes

good cabbing material. This locality also produces cat's-eye aquamarine.

Amethyst from Afghanistan. Amethyst has one of the widest distributions of all gem materials. Among its commercial sources are Brazil, Uruguay, Namibia, Zambia, Mexico, Sri Lanka, South Africa, the U.S., and the USSR.

Recently, Gary Bowersox of Gem Industries, Honolulu, Hawaii, came across a new source: Pasmazal, an area in Afghanistan that lies between Parian Village in the northern Panjshir Valley and the Anjuman Pass. He loaned GIA one fashioned and two rough specimens for gemological investigation. The 13.70-ct fantasy cut (fashioned by Bart Curren) is transparent and dark grayish purple (figure 8). All gemological properties were

Figure 8. Afghanistan is the source of the rough amethyst from which this 13.70-ct fantasy cut was fashioned. Photo by Robert Weldon.





Figure 9. These specimens, reportedly from Pakistan near the border with Afghanistan, consist of corundum and green muscovite mica. Photo by Robert Weldon.

consistent with those reported in the literature for amethyst. Magnification revealed color zoning and subhedral negative crystals, both of which are typical inclusions in this gem species.

Unusual corundum/mica carving material. One of the more unusual carving materials to be seen in recent years is a purple-to-red corundum in green zoisite matrix from Tanzania, which is popularly called "ruby in zoisite." Recently, Gary Bowersox showed the Gem News editors rough and fashioned pieces of a similar green-matrix material with center portions that ranged in color from pink-purple to red (figure 9). The samples superficially resembled the East African material but were mined near Wear Village, Timargara District, Dir, Malakand Agency, Northwest Frontier Province, Pakistan. Mr. Bowersox subsequently loaned some fashioned pieces, and donated a rough specimen, to GIA for gemological study.

One 22.81 × 18.12 × 5.19 mm fashioned piece tested had a translucent, purple-pink center with a thin, translucent, green "rim." Refractometer readings taken on the partially polished base revealed vague shadow edge readings of 1.76 for the central portion and 1.70 for the perimeter. When examined between crossed polars, both portions gave aggregate reactions. When exposed to long-wave ultraviolet radiation, the center portion fluoresced a very strong patchy red; the rim was predominantly inert, with two areas that fluoresced a moderate chalky greenish white. To short-wave U.V., the center fluoresced a moderate to strong patchy reddish purple while the rim was essentially inert. When examined with a desk-model prism-type spectroscope, the center portion showed an absorption pattern typical of ruby and purple sapphire; no distinct absorption features were noted for the rim. Magnification revealed numerous twinning planes in the "core" and some whitish veining in the rim.

X-ray diffraction analysis of a minute sample from the rim was performed by Christopher Smith, of the West Coast GIA Gem Trade Laboratory. The pattern

produced matched the standard ASTM pattern for muscovite mica. On the basis of this final piece of information, this particular piece of carving material was identified as a rock consisting of purple-pink sapphire and muscovite mica.

Joint venture for Russian emeralds. According to the Mazal U'Bracha News Service, a joint venture has been established to polish emeralds from the Ural Mountains in the Soviet Union and market them in the West, with a projected annual revenue of about \$40 million. The joint-venture company, known as Emural, was established by the USSR Ministry of Nuclear Energy, which is responsible for the production of Uralian emeralds. The Soviet partners in the joint venture are Moscow Plant Polimetal, Techsnabexport, and Malysheva Mines Management; the non-Soviet partner is Panama-based Vanico Group Inc., which is collaborating with an Israeli group that has the polishing skill and technology as well as the experience in marketing emeralds worldwide. Ben-Zion Harel of Hargem, in Israel, is chairman of the Emural board of directors.

Emural will be based in Moscow and is scheduled to employ about 160 Soviet citizens in two cutting factories, one in Moscow and one near the mine. Workers will be trained in Israel both to operate the cutting equipment and to sort, price, and market the finished goods. The joint venture will reportedly have at its disposal the entire emerald production from the Urals and intends to process standard sizes as well as matched stones. The emeralds will be marketed through four sales offices on as-yet-unspecified "different continents."

Large carved labradorite. At the February 1991 Tucson show, Regal Reflections, of The Woodlands, Texas, was offering a large selection of phenomenal labradorite from Madagascar. These were fashioned into various geometric shapes, including cubes of 50 and 70 mm on a side and spheres ranging from 20 to 200 mm in diameter. The material has a predominantly gray body color with blue labradorescence. The firm's owner, Robert Walker, stated that he had approximately 900 kg (one ton) of the material on hand, all of which had been fashioned in Madagascar.

Fine greenish blue opal. Most of the opal used in jewelry exhibits at least some play-of-color. Notable exceptions are those transparent-to-translucent materials with vivid body colors (such as the orange to red fire opal from Mexico) and those with saturated body colors (such as the yellowish green prase opal from Tanzania).

At the February Tucson show, we saw another attractive nonphenomenal opal. This material, fashioned as free-form cabochons, looked very similar to the finest chrysocolla in chalcedony: It was translucent to semitranslucent with a strong, medium slightly greenish blue "turquoise" body color (figure 10). According to Nanette Forrester of American Lapidary Artists, Los Angeles, the material was mined in the Andes Mountains of Peru. After it was identified as opal at the GIA



Figure 10. Copper is probably the cause of the unusual color of these opal cabochons (1.05 and 4.58 ct), which are reportedly from Peru. Photo by Maha Smith.

Gem Trade Laboratory, it was examined by Dr. Emmanuel Fritsch of GIA Research. EDXRF and U.V.-visible spectroscopy revealed Cu^{2+} as the coloring agent. Dr. Fritsch hypothesized that the copper is present as submicroscopic inclusions, as is the case with similar-appearing chalcedony colored by the mineral chrysocolla.

Another phenomenal organic gem material. A number of organic materials are used for ornamental purposes; among these, pearl and the mother-of-pearl variety of shell are especially prized for their iridescent colors, on the basis of which they are classified as phenomenal gems.

Another phenomenal organic "gem" was reported in the Fall 1989 Gem Trade Lab Notes section of *Gems & Gemology*: the chitinous, iridescent exoskeletons of beetles that embellished a diamond-set brooch. Recently, the Gem News editors came across similar insects being used for jewelry purposes: iridescent, yellowish green beetles approximately 1½ in. (38 mm) long with brass wire legs, antennae, and mounting pins. These had been fabricated for use as brooches (figure 11). According to the vendor, the beetle pins originated in Thailand.

Cultured pearls auction. The first auction of Cook Islands cultured black pearls was held in Rarotonga, Cook Islands, on June 12 of this year. Buyers from 32 companies, most of which were based in Japan, were in attendance. Fifty-four lots comprising 39,000 pieces were offered; 20, comprising 22,671 pieces, sold. The remaining lots were withdrawn when bids failed to reach the reserve price.

According to information provided the editors by the Cook Islands Pearl Farmers Association, some concern was expressed at the relatively large number of silvery gray baroque cultured pearls offered. Auction Administrator Reuben Tylor pointed out, however, that several buyers snapped up these pearls, preferring them to those with stronger hues.

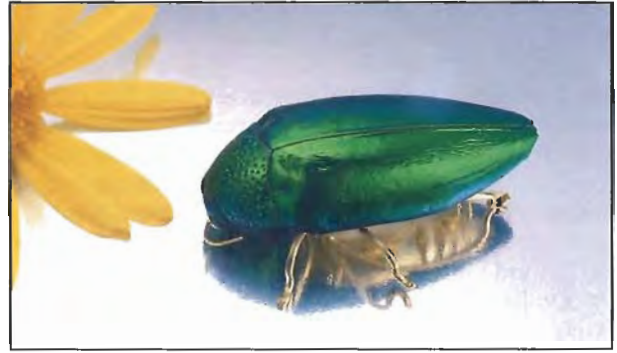


Figure 11. This iridescent beetle has been fitted with brass wire legs, antennae, and a mounting pin for use as a brooch. Courtesy of Erika Koivula; photo by Robert Weldon.

Green zoisite. One of the newer topics mentioned at the 1991 International Colored Gemstone Association (ICA) Congress and the International Gemological Symposium, both held last June, is the availability of green zoisite from Tanzania. According to Idar-Oberstein gem dealer Horst Krupp, who has worked extensively in Tanzania, some of this material is a rich "emerald" green color reminiscent of some of the green tourmalines from Paraíba, Brazil (figure 12). Although the existence of green zoisite has been known for years, the material that has come on the market recently represents the first significant production. Dr. Krupp informed us that the rough was found at a site called Opec in the Merelani district, which is the major source of tanzanite. Because

Figure 12. Commercial quantities of green zoisite have recently emerged from the Merelani district of Tanzania. This stone (over 2 ct) is courtesy of Pala International, Fallbrook, CA; photo © Tino Hammid.



this deposit was discovered during the Gulf War and the color of some of the material apparently resembled that of the Iraqi army uniforms, the local miners refer to it as "combat." A number of people in the trade are marketing this material as "green tanzanite" or "chrome zoisite"; some have suggested the name "Güblinite" in honor of Dr. Edward Gübelin.

Dr. Krupp reported that gem-quality pieces as large as 60 grams have been recovered from this primary deposit. The color ranges from a dark "petroleum-like" green to yellowish ("olive") to bluish green to greenish blue (similar to aquamarine). Production figures are not available at the present time.

ENHANCEMENTS

Faceted Aqua Aura update. In the Fall 1990 Gem News section, we reported on faceted quartz and topaz gems that had been treated with the Aqua Aura process, that is, the application of a thin film of gold to produce a blue apparent color with overlying iridescence. This note included information relating to the durability of the treatment.

In response to that entry, the editors were contacted by Al Gilbertson of Gem Profiles, Portland, Oregon, who subsequently did some durability testing of his own, which he kindly offered to share with our readers.

Because his concern centered on how the treatment would hold up under normal handling conditions when stones were mounted in jewelry, he gently buffed one of the stones on a buffing wheel with jeweler's rouge—the kind of abrasive action a stone might face when prongs were buffed. This procedure resulted in the removal of some of the gold coating from the stones where it came in contact with the polishing wheel. In a follow-up experiment conducted by the editors, similar damage was observed during the polishing of prongs on a ring set with an Aqua Aura-treated topaz. The fact that normal polishing in the course of jewelry manufacture or repair will remove some of the gold coating should be taken into consideration by anyone working with Aqua Aura-treated gems.

Plastic-treated jadeite. Plastics and synthetic resins have found a number of applications in the enhancement of gemstones. For example, Opticon, an epoxy resin, is used to fill surface-reaching breaks in emeralds; plasticizers have been used to seal the growth tubes in cat's-eye tourmalines.

Recently, the use of such a substance to enhance jadeite has been noted in the literature. A report in the November 1990 issue of *Jewellery News Asia* ("Coating on Jadeite"), based on information from Mrs. C. M. Ou Yang of the Hong Kong Gems Laboratory, described a resinous coating on polished jadeite that appears to improve both transparency and luster. Such treated material had been seen in both Japan and Hong Kong.

This article was soon followed by a press release from the Gemmological Association and Gem Testing

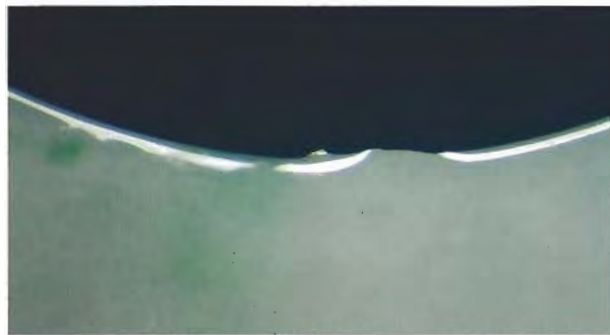


Figure 13. Concentrations of the transparent colorless coating on this carved jadeite were evident as irregularities on the inner surface of the hololith when examined under magnification. Photomicrograph by John I. Koivula; magnified 10 \times .

Laboratory of Great Britain that was subsequently distributed as ICA Laboratory Alert No. 43. This describes the GA/GTLGB's examination of a similar plastic-treated polished jadeite disc obtained in Hong Kong. They found that the R.I., S.G., Chelsea color filter reaction, and absorption spectrum as viewed through a desk-model spectroscope were consistent with untreated jadeite. Key identifying features of the treatment were the relative absence of the fine surface "fractures" normally associated with jadeite when viewed under magnification; concentrations of the coating material forming irregularities on the surface of the specimen (figure 13); and a melting, or softening, of the coating when a thermal reaction tester was placed close to the sample's surface. Infrared spectroscopy carried out on a surface scraping of the coating material identified it as a type of epoxy resin. Kenneth Scarratt, chief executive of the GTLGB, stated his belief that the treatment described in the *Jewellery News Asia* report is the same as that used on the specimen examined by his lab.

Dyed quartzite imitation of dyed jadeite. Yet another interesting imitation was spotted at a gem show recently: uniform strands of semitranslucent beads being offered as "dyed lavender jadeite." The Gem News editors purchased one strand of approximately 10-mm beads for study (figure 14).

Although at first glance the beads appear to be uniform in color, closer inspection revealed darker color concentrations. Magnification quickly showed these to be confined to a dense network of fine, surface-reaching cracks; the material itself was essentially colorless. To determine the depth of penetration of the dye, we split one of the beads in half; the dye was distributed throughout, from the surface to the core (figure 15).

Gemological testing readily identified the material as quartz. We concluded that the beads are dyed quartzite imitations of dyed lavender jadeite.

SYNTHETICS AND SIMULANTS

Chatham signs agreement with Japanese crystal grower... In a move designed to increase production and meet growing demand, Chatham Created Gems has agreed to a joint effort with a Japanese crystal growing concern in Kobe, Japan. In 1980, Earth Chemicals LTD, a multi-faceted conglomerate, purchased the production rights and facilities from Gilson S.A. of Geneva, manufacturers of Gilson synthetic emerald, opal, turquoise, and imitation coral. According to a Chatham spokesperson, the current agreement will reportedly lead to the production of Chatham Created Emeralds at the facility in Japan, while Chatham will become exclusive distributor in the U.S. and Canada for Gilson synthetic emerald (Gilson synthetic opal will continue to be marketed in the U.S. by the Gerry Manning Co. of New York).

... and issues warning on trademark infringements. In response to what it sees as growing misuse and abuse of the Chatham® name, Chatham Inc. has issued reminders to the jewelry industry to use the Chatham name only when selling Chatham products.

According to the Chatham firm, infringements on their trademarked name have taken two forms. In some cases the materials being passed as their products were of the same basic type as theirs but were manufactured by other firms. In other instances, the materials were imitations such as CZ and YAG. While some of the misidentification is attributed to misinformation, other cases are seen as deliberate misrepresentation with intent to deceive. Anyone who has ordered the firm's products by name but questions the authenticity of the goods received may send the questionable material to Chatham's California office for identification and, where possible, confirmation of supplier.

Novel fiber-optic glass. Man-made glasses consisting of bundles of parallel optic fibers have been used for many years to produce imitations of chatoyant gems. These have been marketed under such trade names as "Cats-eye" and "Cathaystone." These gems are oriented in cutting so that the optic fibers are parallel to the base and at right angles to the length of the cabochon, thereby centering the chatoyant band across the length of the dome.

This past year the editors came across similar material being sold at local gem shows under the name "Fiber Eye." According to a flier provided by the vendor, Andria Bree Gem Co. of El Cajon, California, this material is a "product of the laser industry." It was available in two colors, white and brown. Some of the brown material, sold as both "rough" cylindrical sections and as cabochons, had been deformed so that the optic fibers were no longer straight. In some cabochons, this produced a sharp, wavy band across the dome that was reminiscent of a lightning bolt.

Michael Gray, a local gem cutter, purchased some of this material and cut from it a very unusual faceted stone. With the optic fibers intentionally oriented per-



Figure 14. These 10-mm dyed quartzite beads were misrepresented as dyed lavender jadeite. Photo by Robert Weldon.

pendicular to the table, the back facets are "projected" onto the crown of the stone (figure 16). This is similar to the effect seen when the fibrous mineral ulexite is placed over newsprint, for which it has received the nickname "TV stone."

New glass imitation of lapis lazuli. Man-made glasses have been produced to imitate a great number of nontransparent gem materials. Recently, the ICA released Laboratory Alert No. 44, "New Glass Imitation for Lapis Lazuli," which contains information from gemologist Elisabeth Strack of Hamburg, Germany.

On two occasions in late 1990, Ms. Strack was asked to identify a material resembling lapis lazuli, first in the form of a bead necklace and then as a loose fashioned "stone."

Photo 15. Note the complete penetration of the dye through this quartzite bead. Photo by Robert Weldon.





Figure 16. When this 4.13-ct ($10.70 \times 6.39 \times 6.00$ mm) "Fiber Eye" glass was faceted, the optic fibers were oriented perpendicular to the table, so that the back facets appear to be "projected." A typical cabochon is shown for comparison. Photo by Robert Weldon.

According to her report, the material is opaque and predominantly medium blue with darker blue portions that are distributed in a marbled pattern. It has a spot R.I. of 1.62, is inert to long-wave ultraviolet radiation, and fluoresces a very faint, powdery blue to short-wave U.V. The material displays a uniform distribution of tiny transparent, highly reflective, slightly brown flake-like spots, most of which were seen to have triangular outlines when examined with magnification. No doubt, these were intended to simulate pyrite inclusions in natural lapis lazuli.

"Encapsulated" Mexican opal. Thin slices of opal are often used to make both doublets and triplets, and we have also seen composites consisting of many small opal chips encased in transparent plastic.

At Tucson this year, Rockyland Gems & Jewelry of El Paso, Texas, had interesting composites that used opal from Jalisco, Mexico. Called "Opal Encapsulado" (encapsulated opal) by the firm's owner, Sergio Enrique Ávila Camino, these consisted of a slice of colorless, white, or orange opal encased within an oval "single cabochon" of acrylic resin (figure 17). They appear to have been made by first pouring some of the liquid resin into a dome-shaped mold, then inserting a slice of opal—its base coated with a black substance to provide contrast for the play-of-color—and, last, pouring a thinner second layer of resin to form the base and seal in the opal. Mr. Ávila Camino volunteered that these assembled stones were produced in Guadalajara, Mexico.

Plastic imitation opal from Thailand. One of the editors purchased from street vendors in Bangkok two unusual bracelets set with cabochons that somewhat resemble opal (figure 18). One of the pieces is set with eight very dark blue oval cabochons, ranging from approximately 6.0 mm \times 9.0 mm to 10.0 mm \times 15.7 mm; the other is set with eight black round cabochons of about 6.7 mm diameter each. All of the cabochons display eye-visible iridescent inclusions.

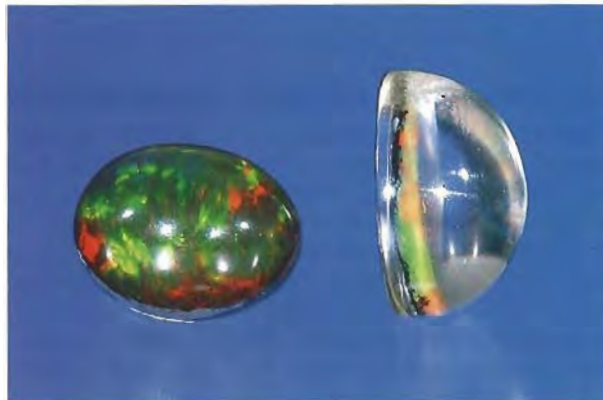


Figure 17. A thin slice of Mexican opal in acrylic resin is used to produce these "encapsulated" opal assemblages ($13.34 \times 9.68 \times 7.50$ mm, left; $12.13 \times 9.13 \times 6.76$ mm, right). Photo by Maha Smith.

Gemological properties were fairly consistent for the cabochons in both bracelets: vague spot R.I.'s of 1.57; a strong, chalky bluish white fluorescence to long-wave U.V. radiation and a moderate, chalky yellowish green fluorescence to short-wave U.V.; and, when examined with a desk-model prism spectroscope, a series of fine absorption lines at approximately 10 nm intervals from about 430 nm to 700 nm. One cabochon in each bracelet was tested for hardness and hot-point reaction. Both were readily indented and scratched with a metal pin, and the heated tip of the thermal reaction tester produced burn marks, smoke, and a somewhat acrid odor in both.

With magnification—and in some cases with the unaided eye—we saw a multitude of primarily spherical

Figure 18. The cabochon seen here in a bracelet from Thailand is a plastic imitation of opal. Note the telltale spherical bubbles. Photo by Maha Smith.



gas bubbles in all the cabochons. They also contained thin, transparent, highly iridescent inclusions of various shapes that in darkfield illumination looked like colored cellophane; these were reminiscent of the iridescent foils in the glass imitation opal known as "Slocum stone." On the basis of this examination, the "gems" in both bracelets were identified as plastic imitation opal.

Update on Soviet synthetics. The Spring 1991 Gem News column included an entry on synthetic gem materials seen at the February Tucson show. Recently, one of the editors received an informative letter from Dr. G. V. Bukin, chief director of the Special Design and Technological Institute of Monocrystals in Novosibirsk, USSR, which sheds further light on developments in this area.

Dr. Bukin has spent the last 25 years studying the growth of gems used for jewelry applications. During that time, the most promising advances have been in hydrothermal and flux-grown synthetic emeralds, synthetic alexandrite grown from melts, and flux-grown synthetic spinel. Dr. Bukin relates that the flux-grown synthetic red spinels recently reported in the literature were most likely produced at his institute. This material is grown using "defective crystals" mined in the Pamir Mountains as feed stock, so the properties of the finished synthetic; are very similar to those of natural Pamir spinel.

This past year, Dr. Bukin initiated what he describes as "large-scale production of created gems for marketing and trade." Materials being produced include all those mentioned above.

INSTRUMENTATION

Loupe with true darkfield illumination. The most versatile lighting technique for gem identification and clarity grading is darkfield. With this technique, the stone is illuminated from the side, causing small inclusions to stand out in high relief. Several portable instruments have been marketed that combine a magnifier with a penlight-type illuminator. None of these, however, has provided true darkfield illumination.

In response to this need, GIA GEM Instruments has developed the new Darkfield Loupe (figure 19): A fully corrected 10x magnifier in a darkfield housing is placed over a penlight source of illumination. The result is a magnification-plus-darkfield illumination unit that can be used virtually anywhere.

New cutting machines developed. Two new automated machines have been developed for cutting and polishing facets along the girdle of a diamond. The Robodiam machine, developed by the Belgian firm Hakodiam, has a grain-seeking capability, can polish a wide range of shapes, and can produce finished stones as small as 0.15 ct, polishing from four to 200 facets.



Figure 19. The GIA GEM Instruments' Darkfield Loupe combines true darkfield illumination with a 10× magnifier.

The Roundiam multifacet machine, introduced by the Israeli firm Varticovschi, can place between 16 and 110 facets on a diamond's girdle and features a special sequencing device that allows for the selection of several operations to be executed one after the other (*Diamond International*, November–December 1990, p. 16).

For colored stones, Sarin Research, Development & Manufacturing (1988) Ltd. of Ramat Gan, Israel, has announced the availability of their ROBOGEM computerized manufacturing system. According to a news release provided by the firm, the system uses image-processing technology to provide "optimal yield," a concept that links a marketing approach to a controlled manufacturing process. The system is said to be cost-effective for cutting even the most expensive gem materials, while its software permits the cutting of all common commercial shapes. There are operation programs for obtaining maximum weight, for shape preference, and for producing pairs and graduated sets. The basic work plan permits ROBOGEM to photograph the rough, select among the shapes possible the one that will result in maximum weight retention, and immediately perform the girdling, all within 30 to 60 seconds.

ANNOUNCEMENT

The Canadian Gemmological Association will hold their Second Annual Gem Conference on October 26 at the Novatel Hotel in North York, Ontario. The keynote speaker, David Callaghan of the Gemmological Association of Great Britain, will cover the Duchess of Windsor jewelry. Other speakers include David Pendergast of the Royal Ontario Museum, who will talk about Mayan jade; and Willow Wight from the National Museum in Ottawa, who will discuss their gem and mineral collection. For further information, call (416) 652-3137. Space is limited and early registration is recommended.

Editorial Forum

PROPOSAL TO UPDATE "SLIGHTLY IMPERFECT" CLARITY-GRADING SYSTEM

In my opinion, today's diamond clarity-grading system is slightly imperfect. It is no longer adequate to describe accurately the stones being cut and offered for sale on today's world diamond markets.

As a full-time professional diamond grader for the past 16 years, I have witnessed an increase in the number of included diamonds being submitted for laboratory grading and in the average number of inclusions in these stones. Manufacturers are cutting rough diamonds with more inclusions than they did 30 years ago. The high price of rough and consumer resistance to higher diamond prices have forced many manufacturers into buying poorer quality material. At the same time, the introduction and success of using small synthetic diamonds in the industrial sector has created a surplus of more-included rough than used to be processed for that market.

The influx of included diamonds being submitted for laboratory grading has greatly altered the SI (Slightly Included) category and changed the boundaries between SI₁, SI₂, and I₁ significantly from where they were 15 years ago. For this reason, I would like to propose to the gemological community some modifications to the presently used diamond-grading systems.

The most widely accepted and recognized system in the world today was introduced by the Gemological Institute of America in the 1950s. While this system is indeed admirable, I find that the clarity-grading portion is inadequate today for the SI grades and below.

At SI₁, a diamond may contain inclusions that are barely eye-visible to a trained observer or it may contain somewhat prominent inclusions that are visible only with magnification. The I₁ grade involves inclusions that are usually readily eye-visible to a trained grader, numerous small inclusions, or one or more serious, but difficult to see, inclusions.

Between these lies the SI₂ category, which purportedly encompasses larger, or two or three SI₁, inclusions. Yet, SI₂ has somewhat negative connotations—and a grader is not quick to place a diamond into this category. Consequently, the SI₁ grade becomes extended and one allows a stone to have more

and larger inclusions and still be graded as "low" SI₁.

Similarly, the I₁ grade has serious negative connotations. A grader is reluctant to place a stone into this category unless he or she is easily able to see with the unaided eye that a fairly large portion of the diamond is included. Therefore, the SI₂ grade has become too large and all encompassing to accommodate all the stones that fall between Slightly Included₁ and Imperfect₁.

I suggest a new category—"Moderately Included"—to be placed between the SI and I categories. This would allow graders to tighten up on the SI₁ grade and to establish a respectable SI₂ grade! The MI₁ and MI₂ grades would be used to classify those stones that have too many inclusions—or inclusions that are too large—for the SI category, but where the inclusions are still not readily eye-visible.

I would also like to suggest that the "Imperfect" category be replaced with one called "Highly Included"—changing the Imperfect grades to HI₁, HI₂, HI₃. *Imperfect* seems too harsh a term to describe some of today's very valuable jewelry items. Finally, I would propose the addition of an "Excessively Included" category to describe those diamonds that are so included that they have lost nearly all transparency and should never really have been fashioned into gemstones.

The revised grade categories would be:

Flawless (FL)
Internally Flawless (IF)
Very, Very Slightly Included (VVS₁ and VVS₂)
Very Slightly Included (VS₁ and VS₂)
Slightly Included (SI₁ and SI₂)
Moderately Included (MI₁ and MI₂)
Highly Included (HI₁, HI₂, HI₃)
Excessively Included (XI)

I think that such a system is necessary for today's environment, and I hope through this letter to start a dialogue in the gemological community. I think that a more descriptive, defined approach to the clarity grading of lower-grade diamonds is needed for the advancement of gemology into the 21st century.

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GEMOLOGICAL ABSTRACTS

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COLORED STONES AND ORGANIC MATERIALS

Gemmology Study Club lab reports. G. Brown, *Australian Gemmologist*, Vol. 17, No. 6, 1990, pp. 221–230.

This interesting report, with references included in individual entries, covers a number of gem materials examined by the author and other Study Club members. The first item is a ruby that contained a partially filled fracture. It apparently had been treated with a colorless "oil" to improve its transparency.

So-called "rainbow lattice sunstone" is described next and the gemological properties of two specimens listed. The investigator concludes that the aventures-

cence of this material is caused by thin-film interference from hematite and hydrated iron oxide (e.g., goethite) lath-shaped inclusions. The tentative conclusion is also reached that the material has properties very similar to those of an untwinned aventurescent microcline-microperthite (Harts Range sunstone) previously described in the literature.

Description of a silicon imitation of hematite is followed by a study of "variscite" from Keppel Bay, Queensland, that exhibited the following properties: color—pale slightly yellowish green with internal fractures healed by ingrowths of darker green variscite; hardness—3–4; fracture—splintery to uneven; S.G.—2.56; spot R.I.—1.58; diaphaneity—translucent; ultraviolet fluorescence (LW and SW)—inert; absorption features—nothing diagnostic. Magnification revealed irregular masses of drusy quartz, pale green masses of possibly metavariscite, and a silvery gray mineral of undetermined identity. The author presents an argument that the material investigated should be more correctly described as variscite-metavariscite.

Also mentioned are an assembled imitation of amethyst consisting of two colorless quartz sections joined by a colored cement; two materials mined near the town of Dungowan in New South Wales, described respectively as nephrite and a non-gem-quality "semi-nephrite"; "Aqua Aura"—colorless quartz crystals coated with a thin film of pure gold; prasiolite (green quartz) from Camfield Station in Australia's Northern Territory; beta-quartz; and Argentine rhodochrosite.

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

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

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

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All entries are illustrated, and a map indicates the localities of the various Australian materials described.

RCK

Gemmology Study Club lab reports. G. Brown, S. M. B. Kelly, R. Beattie, and H. Bracewell, *Australian Gemmologist*, Vol. 17, No. 7, 1990, pp. 279–286.

Brown et al. report on several interesting natural, enhanced, and man-made gem materials in this series of brief entries. An ornamental white chalcedony included with greenish cuprous dendrites had a high S.G. (around 2.76) that varies according to the amount of copper minerals present. Next covered are $3/4$ cultured (bead-nucleated) pearls that had been silver-nitrate treated to produce a black color and then wax coated. Also discussed are key considerations in faceting calcite, the heat treatment of pale yellow sapphire to turn it colorless, and a diamond with surface etching caused by heat damage.

Among the man-made and assembled materials covered are a purple synthetic spinel "triplet" with a very thick center layer of colored adhesive; didymium-doped, color-change CZ; translucent "powder" blue synthetic quartz resembling blue chalcedony; a banded (yellow, green, and brown) synthetic quartz; Japanese synthetic citrine with two distinct bands of "breadcrumb" inclusions; reconstructed New Zealand kauri gum; and a single glass imitation pearl in a necklace of otherwise natural pearls.

Other materials covered are scenic common opals reportedly from Peru and some questionable turquoise with a brecciated texture that was reminiscent of reconstructed material but yielded a negative test to hydrochloric acid.

RCK

Some rare ivories. G. Brown, *Australian Gemmologist*, Vol. 17, No. 7, 1990, pp. 256–262.

Beginning with a brief historic note on what constitutes the "ivory of commerce," the author goes on to describe and illustrate the general appearance/morphology and microscopic features of five rare ivories and the X-radiographic appearance of three of them.

First described is a commercially marketed, wax-treated walrus ivory, sold as a "fossilized" material and claimed to be recovered from walrus skulls buried in Arctic soil for 100 to 2,000 years. The second, crocodile ivory, is from the estuarine crocodile of Papua–New Guinea. The feline ivory described is from the canine teeth of the Bengal tiger, while the boar ivory is from the tusks of the wild boar native to Oceania. The final ivory discussed is from the tusks of the dugong, an aquatic herbivorous ungulate of northern Australia and islands of the Torres Strait.

Although brief, this very descriptive article is a nice addition to the literature on organic gem materials.

RCK

Spessartine garnet in Brazilian topaz. J. I. Koivula, C. W. Fryer, and R. C. Kammerling, *Journal of Gemmology*, Vol. 22, No. 6, 1991, pp. 366–368.

Inclusions of spessartine garnet were identified in pale brownish yellow topaz crystals from Minas Gerais, Brazil. Identification of the macroscopically visible inclusions was based on a combination of microscopy, refractive index, and X-ray diffraction. The included crystals are described as transparent to translucent "slightly pinkish-brownish orange" and often exhibit obvious dodecahedral symmetry. One included crystal was removed from the host topaz and revealed a refractive index (by the Becke line method) of slightly below 1.81. X-ray diffraction of another exposed crystal yielded a pattern almost identical to that of end-member spessartine.

CMS

Technology and weathering of Mesoamerican jades as guides to authenticity. L. A. Garza-Valdes, in *Materials Research Society Symposium Proceedings Volume 185, Materials Issues in Art and Archaeology*, ed. by P. B. Vandiver, J. R. Druzik, and G. Wheeler, 1991, pp. 321–357.

Pre-Columbian jade artifacts are much prized by museums and collectors alike. Often, however, they have been removed from the site where they were originally found before they can be authenticated by a reputable expert. In this article, Dr. Garza-Valdes explores methods by which evidence from ancient and modern lapidary techniques as well as from the nature of surface weathering can be used to determine the age—and, hence, authenticity—of worked "jade" specimens from Mesoamerica, primarily Guatemala.

The term *jade* is used by the author in the loose, nongemological sense and refers to a variety of minerals and rocks, usually with some tinge of green color, that can be worked by ancient lapidary techniques. Almost 80% of the more than 10,000 specimens examined for this study consist primarily of albite; only slightly over 7% contain any jadeite or chemically related mineral, and even fewer contain actinolite (including nephrite). The remainder are composed of a wide assortment of materials, including amazonite, basalt, jasper/quartzite, serpentine, and the like.

Each of the minerals used by pre-Columbian lapidaries has a different rate of weathering (dissolution). Since weathering on a worked surface occurs only after the material was last freshly exposed—presumably at the time of fracturing or polishing—then the date of working can be determined from the amount of weathering, given the rate at which dissolution of the particular material occurs. The author provides dissolution formulas for the most common minerals encountered in pre-Columbian artifacts. By using comparison samples of known age and provenance, he determined, the authenticity of most unknown artifacts could be ascer-

tained. Occasionally, a genuinely ancient piece is repolished by a modern collector to improve its attractiveness; such a practice will destroy the evidence of weathering.

Also useful in authenticating pre-Columbian artifacts is evidence of ancient lapidary techniques. Infrared spectroscopy can identify remnants of polishing compounds; some (such as tin oxide) were not used in ancient times and others (e.g., tripoli) were used prehistorically but continue to be used today. Moreover, ancient lapidary techniques left characteristic features of drilling and polishing—resulting from the use of stone and botanic instruments—that are distinctly different from the evidence left by modern drills and laps.

Accompanying the article are numerous black-and-white photographs and photomicrographs (the latter of use to the gemologist in identifying gem materials used in carvings) as well as infrared spectra of polishing compounds and minerals that will be of interest to advanced gemological laboratories. CMS

The tourmaline. E. L. F. Locke, *Town & Country*, Vol. 145, No. 5133, June 1991, pp. 136–139, 172.

The relatively short but fascinating history of tourmaline is detailed in this lively and well-researched article. Unknown in mineralogy texts before the 18th century, tourmaline first made its appearance in Holland as pipe cleaners. By the end of the 19th century, the bulk of southern California's Himalaya mine tourmaline was being shipped to China for the Dowager Empress Tz'u-hsi's vast collection. The development of the tourmaline market in this century was, until recently, largely due to the efforts of George F. Kunz and Tiffany & Co. A bit of inspired claim-jumping brought the New York store rights to the Himalaya mine's rich yield at the turn of the century, but the sea-green colors of Maine tourmaline had figured in the Art Nouveau designs of Charles Comfort Tiffany since the 1890s. Today, Paloma Picasso uses enormous stones from many locales to create her one-of-a-kind jewelry.

Many contemporary designers make use of tourmaline's extraordinary palette of colors. The article shows pieces from Marina B., Bulgari, Tivol, Black Starr and Frost, H. Stern, and Van Cleef and Arpels, among others; the versatility of this stone is obvious.

The search for gem-quality tourmaline can take the serious collector into the wilderness of Brazil's mining country; but as more designers start to work with these lovely stones, the search need only go as far as the neighborhood jeweler. LES

An unusual Indian aquamarine. J. Koivula and R. Kammerling, *Australian Gemmologist*, Vol. 17, No. 7, 1990, pp. 270–272.

The authors studied a rectangular emerald-cut aquamarine that they were told had been mined and faceted

in Madras State in southeastern India. The stone showed a rich, slightly greenish blue color (reportedly natural) and was a sizable 41.76 ct.

The authors documented the stone's gemological properties, noting that the refractive index, specific gravity, U.V. fluorescence, and absorption spectrum all fell within the ranges previously published for this gem variety of beryl. When examined with magnification, the stone displayed a distinct layered growth structure, which was oriented parallel to the crystal axis; polarized light revealed heavy strain.

While trying to obtain an optic figure, the authors noted an unusual characteristic: a uniaxial optic figure in some directions and a biaxial optic figure in others. Although such strain-induced biaxial anomalies had been reported before, the authors had previously seen this feature only in sliced crystals that had been prepared for cross-sectional strain studies. This was the first time they had observed such an obvious dual optic character in a faceted aquamarine. Glen R. Hodson

Vulcanite or gutta-percha? That is the question. G. Brown, *Journal of Gemmology*, Vol. 22, No. 5, 1991, pp. 292–297.

This intriguing article provides information on two poorly documented materials that were used to imitate jet during the 19th and early 20th centuries. Gutta-percha is a naturally occurring polymer obtained from the milky latex of two species of Malaysian tree. Jewelry-grade material is obtained by remelting and filling raw gutta-percha with a variety of inert materials such as zinc oxide, chalk, waxes, or resins. The resulting mixture can be molded as desired and yields a reddish to brownish gray solid that can be painted black to simulate jet. Jewelry-grade gutta-percha is soft (Mohs hardness of 1; easily scratched with a fingernail) and brittle, with a specific gravity that varies from 0.96 for pure gutta-percha to as high as 1.9 when filled. Its spot refractive index of about 1.58 is difficult to determine due to the solubility of gutta-percha in refractometer fluid. Gutta-percha softens at temperatures as low as 40°C and melts between 65° and 70°C.

Vulcanite, the second jet simulant discussed, is a compound of natural rubber and sulphur that is thermoset at 168°C and 90 psi into a solid. The resulting material lacks the thermal instability and elasticity of pure natural rubber, which is produced from the milky latex of a variety of trees from Asia and Central and South America. Jewelry-grade vulcanite, also known as "ebonite," consists of 50% natural rubber, 30% sulphur, 3% black pigment, and 17% fillers. It is initially black but oxidizes to shades of brown; it is slightly harder than gutta-percha (hardness 1–2; not scratched by fingernail, but can be scratched by gypsum); and has a specific gravity of 1.20+, depending on fillers, and a spot refractive index of 1.60/1.61.

Vulcanite can be distinguished from the less common gutta-percha on the basis of microscopic examination of the surface as well as by hot-point and solubility testing. With low-power magnification, gutta-percha will often reveal areas from which the black coating has worn away, will have a fibrous or granular surface, and—where the coating is absent—may appear finely crazed. Vulcanite, on the other hand, is evenly colored and has a uniformly smooth texture. A hot point, applied judiciously, yields an odor of burning rubber from vulcanite, while the odor from gutta-percha is distinctly different. Moreover, gutta-percha will soften at a much lower temperature than will vulcanite, which tends to char. Finally, a carefully applied, minute drop of toluene will quickly soften gutta-percha in the same time that the surface of vulcanite softens only slightly.

Gemologists who deal with period jewelry will find this article especially useful. Black-and-white illustrations and photos illuminate the text. CMS

Why the Vietnam reds are giving us the blues. R. Weldon, *Jewelers' Circular-Keystone*, Vol. 162, No. 5, May 1991, pp. 46–48.

This report gives a fairly comprehensive view of the current status of the gem-quality ruby finds in Vietnam. The first rubies to emerge were typically small—roughly 1 ct or less—but of excellent color, according to Dr. A. Peretti, director of the Gübelin Gemmological Laboratory, Lucerne, Switzerland. Recent reports from Thailand, however, claim that some stones weighing 6 ct to 11 ct have been found; colors range from pink to red. Dr. Henry Hänni, of the Swiss Foundation for the Research of Gemstones, suggests that if the stones were heat treated they might compare with Burmese or East African rubies in color.

To date, there is only one operating mine, Luc Yen, although other secondary alluvial deposits have been found. Weldon quotes sources who have determined (from inclusion studies) that the original occurrence must have been in a mineralized marble zone, which is similar to the geologic formations of Mogok in Burma, the Hunza Valley in Pakistan, Djegdalik in Afghanistan, and the Pamir range in the Soviet Union.

Drs. Ulrich Henn and Hermann Bank of the German Foundation for Gemstone Research, in Idar-Oberstein, report the refractive indices as 1.760–1.762 and 1.768–1.770, the pleochroism as red to yellowish red, and inclusions that consist of “healing cracks of unusually vermicularly-shaped fluid inclusions” and lamellar twinning. The rubies also tend to fluoresce to visible light.

The Vietnamese government formed Vinagemco to represent its interests in ruby mining and, in 1988, Vinagemco and B. H. Mining Co. of Bangkok signed a contract to develop the mining operation. A reported 1.25 million carats of ruby rough currently awaits scheduling of an auction date. KBS

GEM LOCALITIES

Die Amethyst-Vorkommen von Las Vigas, Veracruz, Mexiko (Occurrence of amethyst at Las Vigas, Veracruz, Mexico). W. Lieber and G. Frenzel, *Lapis*, Vol. 15, No. 6, June 1990, pp. 21–22, 31–38.

Although amethyst specimens from Las Vigas have found their way into gem and mineral collections all over the world, this article represents the first comprehensive report on their origin and mineralogical properties.

The amethysts occur in andesitic rocks of the Sierra Madre Oriental, in an area of several square miles near the town of Las Vigas. Lieber and Frenzel state that the crystals are found in klufts (clefts) which they believe are similar in formation to those of the Alpine klufts. The crystals usually reach 3 cm, although specimens as long as 10 cm (4 in.) have been found. The authors give a detailed analysis of the andesite and conclude that it was altered by hydrogen metasomatism and that the amethyst formed at temperatures of 150°–250°C. Milky to colorless quartz and amethyst are generally the only minerals in the pockets, but calcite, epidote, zeolites (laumontite), and lepidocrocite can sometimes be found.

Further aspects discussed are the origin and distribution of color, crystal forms (often Muzo habit, also doubly terminated crystals, rarely crystal scepters), and inclusions (negative crystals, lepidocrocite, rarely epidote). Chemical analyses of typical material are provided. The deposit is likely to produce fine specimens in the years to come, since it is only worked irregularly on a small scale and the area has not yet been prospected intensively.

The article is illustrated with many color photographs of specimens, characteristic features of the crystals, and views of the mining area.

Rolf Tatje
Duisburg, Germany

Crystallized and massive rose quartz deposits in Brazil.

J. P. Cassedanne and M. Roditi, *Journal of Gemmology*, Vol. 22, No. 5, 1991, pp. 273–286.

Rose quartz is found in a number of localities in Brazil, almost all of which involve granitic pegmatites. This article reviews many of these localities and focuses on the geology and mineralogy of the occurrences. Massive rose quartz is more common than the crystallized form, which is primarily found in Minas Gerais.

A brief description of gemological properties concludes the article. Refractive indices, birefringence, and specific gravity are typical for quartz. In more intensely colored material, a fairly strong pleochroism of dark pink/light pink can be observed. There is no distinctive absorption spectrum and no radioactivity; the color disappears when the material is heated to 575°C. Microscopic needles of rutile may provide asterism in some specimens, and macroscopic needles of rutile and tourmaline also occur in massive material. The most com-

mon internal features observed with the microscope are two-phase inclusions, milky veils, small secondary healing fractures, and fissures, sometimes with iridescence.

Color and black-and-white photographs of localities and specimens accompany the text, as does a map of localities where crystallized rose quartz is found. There is also a diagram of a typical pegmatite. CMS

Emeralds from Colombia (Part I). G. Bosshart, *Journal of Gemmology*, Vol. 22, No. 6, 1991, pp. 355–361.

Part I of three, this review article provides an introduction to Colombian emeralds that includes their history, geography, geology, genesis, and mining. The history begins with the 16th-century discovery by the Spanish of first Chivor and then Muzo. By the middle of the 17th century, emerald mining in Colombia was so productive that the Spanish sold gems all over Europe and the Middle East.

The emeralds occur in the Cordillera Oriental range of the Andes Mountains, a product of recent and ongoing tectonic movement. They are found in early Cretaceous shales and limestones (120–130 million years old). The associated mineral assemblages are summarized for the major localities. Also provided is a discussion of the predominant theories of emerald genesis, still a topic of controversy.

Part I ends with a brief description of the historic production and mining at the most significant mines – Muzo, Coscuez, Chivor, and Gachalá. Parts II and III will cover gemological properties, treatments, and identification. This promises to be an excellent review of this important gemstone, written (so far) in a lucid and readable manner that gemologists will find appealing and informative. The bibliography is one of the most complete reference lists available on the topic. One color figure of specimens accompanies part I; it is to be hoped that more illustrations and a map will be forthcoming in parts II and III. CMS

Gem thaumasite from the Black Rock Mine, South Africa. U. Henn, M. Redmann, and H. Bank, *Journal of Gemmology*, Vol. 22, No. 6, 1991, pp. 334–336.

The mineral thaumasite is usually found as aggregates of tiny needle-like crystals. Recently, however, crystals of gem quality and size (up to 1.5 cm) were found at the Black Rock mine in northern South Africa. The crystals show a distinct hexagonal prismatic habit. Refractive indices of $n_o = 1.505\text{--}1.510$ and $n_e = 1.467\text{--}1.480$, birefringence of -0.030 to 0.038 , and density of $1.88\text{--}1.90$ g/cm³ are within documented values for thaumasite from other localities. No description of color or transparency is provided, although photographs of inclusions suggest that the material is transparent. Observed microscopic features include: (1) distinct growth zoning both parallel and perpendicular to the

c-axis, (2) liquid films, (3) partially liquid-filled negative crystals with a gas bubble, and (4) bunches of needle-like crystals. CMS

'Machingwe': A new emerald deposit in Zimbabwe. J. Kanis, C. E. S. Arps, and P. C. Zwaan, *Journal of Gemmology*, Vol. 22, No. 5, 1991, pp. 264–272.

The authors describe a deposit of emeralds discovered in 1984 in the southern part of the Rhodesian Craton, approximately 12 km northeast of the original Sandawana mine in Zimbabwe. This find, known as the Machingwe mine, is claimed to be the most important emerald discovery since Sandawana.

The article includes descriptions of regional geology, emerald occurrence, mining procedures, and emerald properties. The emeralds are extracted by a combination of simple mechanization and hand methods from pits as deep as 21 m. Few well-developed crystals are encountered, but the relatively small broken pieces found are of "superb emerald green" color. The largest faceted stone to date is less than 5 ct.

Chemical data for two emerald specimens from the Machingwe mine are provided along with comparable information for samples from Sandawana and Zambia. The Machingwe material is notably higher in iron and lower in chromium than is the emerald from Sandawana. The dull red color observed for Machingwe emeralds through a Chelsea filter is consistent with such a composition.

Refractive indices and birefringence for the Machingwe emeralds are within values previously observed for emeralds from Zimbabwe. Reaction to long-wave U.V. is bright green; short-wave reaction is a weaker green. The absorption spectrum, most distinct in "samples with the finest colours," reveals chromium lines in the red and a strong band in the yellow-green region. Inclusions observed in the Machingwe emeralds are similar to those found in material from Sandawana. Four color photomicrographs – as well as maps, locality photos, and graphs – accompany the text. CMS

Gems around Australia, part 3. H. Bracewell, *Australian Gemmologist*, Vol. 17, No. 7, 1990, pp. 265–269.

This third part in a series of gem-related travelogues takes the reader to Australia's Northern Territory, beginning with a brief review of mining activities dating back to 1865. Within the Territory is the Harts Range, a 250-km² area known by such names as the "Gem Centre of Australia" and the "Jewel Box" for its wealth of gem materials.

First visited were Zircon Hill and Specimen Hill, where both zircon and apatite are found. The author next visited a garnet field, where small pieces that cut nice gems were collected. Nearby, beryl crystals were picked up at Annamurra Creek. Traveling east, a stop was made at the Disputed mine for specimens of beryl, tourmaline,

and mica "books." The author was also able to collect specimens of extremely thin, tabular ruby crystals in amphibolite at a site where commercial mining had recently ceased.

The author describes as the highlight of the trip her first sighting of a profusion of kyanite crystals scattered down the side of a mountain, having weathered from a mica schist. These crystals ranged up to 29 cm in length.

Other stops were made to collect various gem materials, including good-quality deep green epidote crystals and glassy fragments of iolite, the latter in the region of Inkamulla Bore. The final gem-collecting site described is the Plenty River mine in the Jervois Range, where gem-quality lepidolite was found. Unexpectedly, the report concludes with a number of the author's observations on the aborigines. It is regrettable that this article did not include a map of the localities visited.

RCK

Mt. Philp aventurescent iolite. G. Brown and H. Bra-cowell, *Australian Gemmologist*, Vol. 17, No. 6, 1990, pp. 231–234.

This well-illustrated report is a follow-up to a preliminary note by the authors on iolite from Australia. The deposit, previously described as being at Mt. Isa, is actually located 55 km to the southeast, in the southern foothills of Mt. Philp in northwest Queensland. It is worked by simple hand-mining procedures, with most gem-quality material being recovered from small pebbles that surround larger iolite boulders in a red soil.

Internal features noted beyond those previously described for this material are blue and yellowish masses of pinite, greenish hexagonal flakes resembling chlorite, and evidence of at least two directions of cleavage. Some specimens display an "iridescent aventurescence," which is attributed to thin-film interference from very small, thin, hexagonal platelets of possibly hematite. Other gemological properties of this phenomenal iolite are as follows: S.G. – 2.59; R.I. – $\alpha = 1.531$, $\beta = 1.534$; $\delta = 1.540$; birefringence – 0.009; optic character – B –; pleochroism – strong, $\alpha =$ pale yellow, $\beta =$ grayish, $\delta =$ violet-blue; absorption spectrum – indistinct and very directional, with strongest features being vague bands at 585, 493, and 436 nm.

RCK

INSTRUMENTS AND TECHNIQUES

Medo hand® vacuum tweezers, model MH-100 and Linicon LV-125 vacuum pump. T. Linton and G. Brown, *Australian Gemmologist*, Vol. 17, No. 7, 1990, pp. 272–273.

This Instrument Evaluation Committee report covers the use of a Japanese-manufactured vacuum pump in conjunction with an American vacuum tweezers for handling gemstones. First addressed are the technical specifications of the two components, which include the noise generated by the pump's motor (64 dbA at a

distance of 0.3 m), something the evaluators recognize as potentially annoying.

Next, the use of the system with a variety of gem sizes and shapes is described. It was found effective with stones as large as 31 ct and as small as 0.01 ct; it could handle faceted stones, cabochons with flat bases, and gems with curved surfaces (including pearls and small carvings); and it eliminated the confusing reflections gemologists often encounter when holding gems in tweezers or stoneholders for examination with magnification. Among limitations noted (in addition to the noise problem) is the fact that the hand set cannot be used effectively on either irregular or wet surfaces.

In summary, the evaluators feel the system should prove of considerable use to gemologists who regularly handle large numbers of gemstones.

RCK

The microscopic determination of structural properties for the characterization of optical uniaxial natural and synthetic gemstones. Part I: General considerations and description of the methods. L. Kiefert and K. Schmetzer, *Journal of Gemmology*, Vol. 22, No. 6, 1991, pp. 344–354.

This first article in a three-part series provides information on structural characteristics of corundum, beryl, and quartz. The angles between crystal faces for these three gem minerals are characteristic, constant within small tolerances, and well documented, making them useful for purposes of identification.

The authors describe how, with immersion and polarized light, the angles between crystal faces and/or twin planes can be determined through the use of a two-axial sample holder with a 360° dial and/or a microscope ocular with cross hairs and a 360° dial.

The application of the information determined in this way, to be discussed in parts II and III, involves the distinction between natural and synthetic specimens of corundum, beryl, and quartz. The current article is accompanied by extremely helpful diagrams, tables, and color photomicrographs. The gemologist whose crystallography has become rusty will want to bone up a bit before tackling this one.

CMS

Sodium polytungstate as a gemmological tool. W. W. Hanneman, *Journal of Gemmology*, Vol. 22, No. 6, 1991, pp. 364–365.

Dr. Hanneman describes an alternate heavy-liquid solution for determining the specific gravity of gem materials. Sodium polytungstate, an inorganic salt that comes as a powder, is reported to be less toxic than the liquids now commonly used by gemologists. Solutions of various specific gravities—from 2.4 to 3.1—can be prepared by the addition of water. Initially, a saturated solution of sodium polytungstate is prepared and adjusted slowly by adding water until an indicator stone remains suspended. The density of the solution is checked by obtaining its refractive index and comparing

it to the graph provided that correlates R.I. with density. Special considerations in the use of this heavy liquid are discussed in the note, but they appear to present no significant problems. CMS

JEWELRY MANUFACTURING ARTS

A designer/jeweler's route of investigation, learning, change, discovery. B. Greenberg, *Metalsmith*, Vol. 11, No. 2, 1991, pp. 28–33.

Mary Ann Scherr has been contributing to jewelry design for over 30 years. Trained at the Cleveland Institute of Art, she began her career as an automobile designer in 1950. Later, after she had opened her own industrial design company with her husband, she began her training in metals. She has been teaching metals and jewelry design since 1968.

Mrs. Scherr's design career took a turn when she discovered that one of her design students had a trachea tube in her throat. She proceeded to design a piece of jewelry to cover the trachea tube, and realized that others might benefit from similar devices. Since then, Mary Ann Scherr has spent a large part of her time designing jewelry to disguise life-saving devices. For example, she has worked with engineers to design pieces of "jewelry" that monitor air quality and pulse rates and even convert into an oxygen mask.

Etching is one of Scherr's other passions, and through experimentation she has become a recognized authority. In fact, she served as a technical advisor on etching to Oppi Untracht while he was putting together his jewelry encyclopedia, *Jewelry Concepts and Technology*. Since 1989, Scherr has been working on a process that uses computer silkscreening to accelerate and improve the etching of metal. The article recounts several other aspects of Scherr's interesting and varied work with metals and jewelry. Six photographs of her jewelry and sculptures accompany the article.

Glen R. Hodson

A garden of delight: Victorian flower jewelry. P. Foy, *Jewelers' Circular-Keystone*, Vol. 162, No. 2, February 1991, pp. 146–149.

The key to understanding many styles of period jewelry is in knowing the socioeconomic climate of the time in which the jewels were made. In this four-page article, the author outlines the reasons for the immense popularity of botanical jewelry during the 19th century. England under the rule of Queen Victoria was enjoying a period of prosperity and expansion. The arts and sciences, including botany, were burgeoning as well. Gardening was a pastime that had scientific as well as spiritual virtues, and it became associated with success and abundance. Flowers and fruit were used as motifs in all the decorative arts and were more often than not assigned a sentimental symbolism.

The author expands on these themes, and cites examples from literature. Six color photos provide illustrations of Victorian botanical jewels. EBM

Jewelry: New looks for a changing world. A. G. Kaplan, *Jewelers' Circular-Keystone*, Vol. 161, No. 5, May 1990, pp. 140–145.

In this very general overview, the author has managed to compress nearly eight decades of jewelry history into five pages that also include nine illustrative photos. The article is excerpted from Mr. Kaplan's forthcoming book and presents, in a nutshell, the basic characteristics of jewelry from the Arts & Crafts, Art Nouveau, Edwardian, Art Deco, and Retro periods. The lists Kaplan provides of designers for several of the periods could act as signposts for future research. (However, the text typo of *Murrie*, Bennet & Co.'s name [it should be *Murrie*, Bennet & Co.] adds confusion rather than clarity.) Although the article may be helpful as an introduction for those unacquainted with period jewelry, it presents very little new information to anyone familiar with these jewelry styles. EBM

JEWELRY RETAILING

Putting the punch behind tradition. A. Marshall, *British Jeweller*, Vol. 58, No. 9, May 1991, pp. 18–22.

The rigorous British hallmarking system may be a thing of the past after 1992. The majority of the member countries of the EEC do not have compulsory hallmarking and feel that it inhibits jewelry trade between countries, so they may vote for its demise. Most of the European countries now either hallmark on a voluntary basis or rely on self-certification by the manufacturer. The understandable concern by the British is that this results in poor quality control and increased competition from foreign competitors with substandard goods, which will inevitably lead to defrauding the public.

RT

Software review: Tracking loose stones. M. Thompson, *Jewelers' Circular-Keystone*, Vol. 162, No. 4, April 1991, pp. 122–125.

Mr. Thompson discusses three software packages designed to keep track of diamond and gemstone inventory: Loose Gem Management, Gemdata, and The Diamond Dealer. All three packages work on IBM or IBM-compatible personal computers. A detailed overview of each system is provided as well as comments by the reviewers on publisher support, user-friendliness, and problems encountered. RT

SYNTHETICS AND SIMULANTS

Biron® synthetic pink beryl. G. Brown, *Australian Gemmologist*, Vol. 17, No. 6, 1990, pp. 219–221.

Beginning with a succinct review of natural morganite,

the investigator goes on to briefly describe the hydrothermal synthesis of pink beryl by Biron International Ltd. of Perth, Australia. This is followed by information gleaned from a gemological examination of a 21.44-ct sawn crystal section and a 2.34-ct faceted specimen of the Biron product.

On the basis of this investigation, the author concludes that the identification of the Biron synthetic pink beryl "should not prove to be too difficult" because of what he feels are "considerably lower" ranges of specific gravity and refractive indices for the Biron product compared to those for natural morganite. However, an examination of the data on both the Biron product and natural morganite, conveniently presented in a table, leads this reviewer to conclude that the properties of the Biron product are too close to those of the natural to classify this as an easy separation. This is especially true when one considers that the author's conclusion was drawn after examining only two samples. The most promising distinguishing characteristic of the Biron material, should additional research prove it to be consistent, is an "apricot pink" fluorescence to long-wave U.V. that has not been observed in natural morganite. Inclusions, as usual, are also important distinguishing features. RCK

Gemmological investigation of a synthetic spinel crystal from the Soviet Union. J. I. Koivula, R. C. Kammerling, and E. Fritsch, *Journal of Gemmology*, Vol. 22, No. 5, 1991, pp. 300–304.

The authors describe a 17.19-ct flux-grown synthetic red spinel crystal reportedly manufactured in the Soviet Union. The crystal is described as a near-perfect octahedron of exceptional transparency, with a refractive index of 1.719 and a specific gravity of 3.58, both within the ranges for natural spinel. Reaction to long-wave ultraviolet radiation was strong purplish to orangy red; there was a similar but weaker reaction with a slight chalkiness along some edges to short-wave U.V. Comparison to the reactions of natural pink and red spinels revealed no significant difference. The Chelsea color filter reaction was comparable to that of similarly colored natural red spinels.

The visible-range absorption spectrum of the synthetic crystal, as viewed with a hand-held prism spectroscope, consisted of general absorption from 400 to 450 nm, a weak diffuse band between 580 and 630 nm, a strong fine line at 680 nm, and a strong fluorescent line at 690 nm. Examination with a spectrophotometer confirmed these features. The spectrum is similar to that of natural red spinel except that the two distinct "chromium lines" found around 650 nm in the natural material appear as a single broader band in the synthetic specimen.

The crystal was originally described by its supplier as hydrothermally grown, but mid-infrared spectros-

copy revealed none of the features associated with hydroxyl groups that are characteristic of hydrothermally grown synthetics. EDXRF bulk chemical analysis, moreover, revealed the presence of molybdenum, a common component of fluxes used to grow gem materials. EDXRF also revealed, in addition to the basic elements of red spinel composition, a lack of the titanium typically found in natural spinels.

Microscopic examination revealed a number of features that further confirmed the origin of the crystal to be flux growth and that can be used by gemologists to distinguish such material from natural red spinels. Deep orangy brown primary flux inclusions, with an angular to jagged profile, formed a phantom aligned with the external octahedral crystal faces. Also noted were reflective and iridescent air-filled fractures associated with strain (observed in polarized light), and semi-circular growth hillocks on octahedral faces that are quite distinct from the triangular etch pits commonly present on the crystal faces of natural spinels. Color photomicrographs clearly illustrate the features described. CMS

YAGG. G. Brown, J. Snow, and R. Brightman, *Australian Gemmologist*, Vol. 17, No. 6, 1990, pp. 239–242.

After a brief review of the crystal chemistry of garnets—including the so-called synthetic garnets YAG (yttrium aluminum garnet) and YAGG (yttrium aluminum gallium garnet)—this Gemmology Study Club report addresses the properties of the flux-grown YAGG once manufactured by J. O. Crystal Co. of California, but no longer in production.

Available information suggests that the material, which the authors consider an effective imitation of tsavorite, is crystallized from a brownish yellow flux held in a platinum crucible. The green color is caused primarily by Cr^{3+} substituting for Al^{3+} ; according to communication with the crystal grower, the addition of Ni^{3+} will superimpose a blue-green color while the addition of Fe^{3+} will result in a yellowish green hue.

The authors list the gemological properties of this YAGG and conclude that the material can be identified by its S.G. (5.05–5.08), R.I. (over the limits), red fluorescence (to long- and short-wave U.V. and white light), Cr^{3+} absorption spectrum, and inclusions (yellowish brown flux and "reflective silvery platinum"). RCK

Correction: Spring 1991 issue abstracts of the articles "Gem-quality Chrysoprase from Haneti-Itiso Area, Central Tanzania," "Role of Aluminium in the Structure of Brazilian Opals," and "Colored Pectolites, So-Called 'Larimar' from Sierrro de Baoruco, Barahona Province, Southern Dominican Republic" were erroneously attributed. Professor R. A. Howie wrote the abstracts of the articles for *Gems & Gemology*. We sincerely regret the error.