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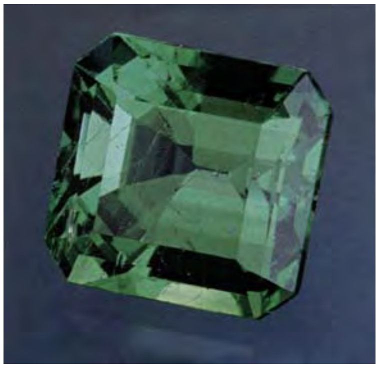

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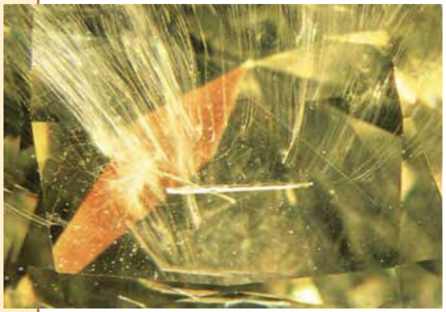

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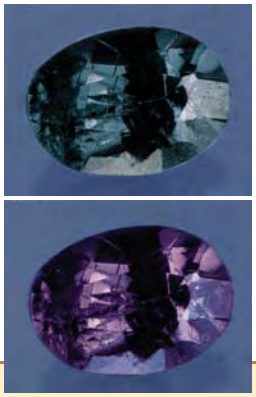

ABOUT THE COVER: In response to concerns expressed by the trade over the degree of clarity enhancement in emeralds, GIA Gem Trade Laboratory researchers have devised a methodology to establish the size, number, and position of filled fissures in an emerald, in order to classify the apparent degree of clarity enhancement achieved. The lead article in this issue reports on this research and the resulting classification system.

The 10.5 ct emerald crystal in this gold and platinum pendant is from Jos, Nigeria. The pendant was designed by Elena Villa, and manufactured by Hans Dieter Krieger; it is courtesy of Gebrüder Bank, Idar-Oberstein, Germany.

Photo © Harold & Erica Van Pelt—Photographers, Los Angeles, California.

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Gems & Gemology Turns 65

It was in 1934 that Robert M. Shipley, founder of both GIA and the American Gem Society, published the first issue of *Gems & Gemology*. The journal began as a bi-monthly, pamphlet-sized publication with three holes punched for convenient storage in a loose-leaf binder. I wish Robert Shipley could be with us now to see the full-color, 180 page, Fall 1999 *Symposium Proceedings* issue 65 years after his brainchild first appeared.

I believe (and our authors tell me) that *G&G* is the most rigorously peer-reviewed publication in gemology and allied sciences alike. We felt that such a review process was critical if gemology was to achieve the status as a science that gems and jewelry had achieved as an industry. We also recognize that, unlike the situation with most scientific journals, our readers encompass a broad range of education and experience. Through careful editing, we work to make every item as useful to the advanced researcher as it is to the new G.G. or the gemologist with 20 years of experience.

Over time, some articles have been portentous, others pretentious. I recall, for instance, a piece that Shipley and I wrote in 1941, which we titled "A Solution to Diamond Color Grading Problems." Obviously, diamond color grading problems remain to this day. Nevertheless, each article has contributed something to the body of knowledge in gemology.

Looking back, it's been an exciting, exhilarating journey. I am proud to have been part of such a dynamic evolution, and I look to the future of gemology, and *Gems & Gemology*, with anticipation and great expectations.

Richard T. Liddicoat
Editor-in-Chief

Looking Back . . .

So where will the next 65 years take us? What once seemed fantastic—a computer that fits in the palm of your hand—now seems ordinary. What once seemed impossible—the nondestructive identification of non-surface-reaching inclusions—is becoming routine. What will change in gemology over the next several decades? Let us look to the current issue for some clues.

The lead article, on emerald clarity-enhancement classification, is in response to concerns regarding the many new fillers being used to enhance emeralds. The future will see more fillers and even more-sophisticated treatments in other gem materials. The methods developed by General Electric to treat diamonds—as discusssed in Karl Schmetzer's article on possible GE POL-related patents, and updated in the Lab Notes item on the new GE-processed yellow-green diamonds—are just two examples of the resources now being devoted to enhancement and synthesis.

At the same time, gemology is becoming increasingly sensitive to world affairs. The lead Gem News entry and a special section of Gemological Abstracts address the challenges of making a country-of-origin determination for Angolan diamonds. This is in response to demands by U.S. politicians that diamonds be "identified" in an attempt to bar from the market stones that are being sold to support the atrocities committed by Angolan rebels.

We at *Gems & Gemology* will continue to work with researchers worldwide to address critical issues. Although good research takes time, we will make every effort to disseminate reliable information as quickly as possible. We plan to use our Web site (www.giaonline.gia.edu) to give regular updates on developments in gemological research, and eventually to provide real-time reports from new and important gem localities. As computing and publishing technologies coalesce to provide consistent color reproduction on screen, our vision of the future shows a fully digitized version of the journal itself.

We have a great foundation, provided by giants such as Robert M. Shipley and Richard T. Liddicoat. With our current combination of dedicated researchers and expert reviewers, we have a future as exciting and exhilarating as the past that propels us forward.

Alice S. Keller
Editor

. . . and Moving Forward

LETTERS

Comments on "Identification of Emerald Filling Substances"

First, let me congratulate the authors of the [Summer 1999] *Gems & Gemology* article on emerald filling substances. Second, I would like to raise the following points:

1. The language in Box B on page 88 is potentially confusing. Antonio Negueruela is mentioned fourth on the list of cedarwood oil distributors who replied to the authors' inquiries, and some sentences later it is reported that "Three distributors stated that the material was all natural, but the fourth acknowledged a considerable amount . . . of synthetic ingredients." Several people who have read the article believe that we are the ones using these ingredients.
2. Our answer to the authors' inquiry on January 25, 1999, was that our oil was 100% natural. In subsequent correspondence, we included a detailed list of the all-natural ingredients in our cedarwood oil.
3. In none of our laboratory's tests did we detect any greenish coloring to our cedarwood oil. (It is a colorless to pale yellow viscous liquid just after it has been purified.)

In no case is our oil "presumed natural oil," but rather it is "genuine natural oil."

Antonio Negueruela
Antonio Negueruela S.A.
Madrid, Spain

In Reply

We did not mean to imply that Mr. Negueruela's company uses synthetic ingredients; only that one of the four companies that responded had indicated that such ingredients were incorporated into its product. We regret the resulting confusion, as Mr. Negueruela had indeed told us that his company's cedarwood oil was all-natural.

On the matter of coloring, both samples we received were translucent and semi-solid when we first examined them in Carlsbad. Perhaps this material, in its pure state, was sensitive to the temperature and pressure changes involved in shipping to the United States. As a result of this letter, I asked an experienced color grader to re-examine the samples, and he thought the color should be described as a "desaturated, very light yellow-green." There is so little color in the material that I would not expect it to affect the color of an emerald.

Although we accept the statement that Mr. Negueruela's cedarwood oil is 100% natural, our point was that spectroscopic techniques cannot distinguish an all-natural cedarwood oil from one that contains synthetic ingredients. For this reason, we advise against assuming that any emerald clarity-enhanced with cedarwood oil has been treated only with natural materials. The "presumed natural" filler categories were intended both as a contrast to "artificial resins" (which cannot be natural) *and* as a reminder that GIA has no technique that proves that a filling substance is natural.

Mary Johnson, Ph.D.
GIA Gem Trade Laboratory
Carlsbad, California

Lab Notes to the Rescue

Once again, *Gems & Gemology* has come to the rescue. While reading through the Lab Notes section of the Spring 1999 issue, I noted the reference to "Imitation Tahitian Pearls."

At the time, I was taking a brief break from an appraisal I was doing on items seized by Canada Customs. One of the items I had just opened was an envelope containing a pair of black "pearl" earstuds. Imagine my surprise to find that these two 12 mm beads were identical in all respects to those you had described in the Lab Note!

By the way, the origin of the seizure was New York, but that does not pin down where these items are being manufactured.

Thanks for the guidance.

Anne Neumann
Harold Weinstein Gemmological Laboratory
Toronto, Ontario, Canada

Reflectivity Reading of Synthetic Moissanite

In the Letters section of the Summer 1999 issue (pp. 80–81), Dr. Mark Kellam of C3 described how the reflectivity reading of synthetic moissanite can be lowered by converting the outermost layers of SiC to SiO_2.

Since etching with hydrofluoric acid was the only suggested method for dealing with such a "treated" surface, it appears that this practice could have devastating consequences for those who use reflectivity meters as tools of *determinative gemology*. And they might well deserve their fates.

Reflectivity meters are neither refractometers nor infallible "black boxes." They are simply tools of *confirmative gemology*; that is, they are intended to help a knowledgeable gemologist *confirm* the identity of a gemstone (Hanneman, 1978a). The obvious higher dispersion, the typical blocky Hodgkinson Method secondary images, and/or the observation of doubled facet junctions of synthetic moissanite all "scream" that the stone is not a diamond. Therefore, the user will be seeking a confirmation for synthetic moissanite—which surface-treated stones won't be able to produce.

Before synthetic moissanite entered the marketplace, all plausible diamond simulants showed less reflectivity than diamond, and many reflectivity-meter users became complacent. Synthetic moissanite, which has a greater intrinsic reflectivity than diamond, changed that. Moreover, we now know that one can reduce the reflectivity value of synthetic moissanite to match that of diamond by oxidation or other methods.

When using a reflectivity meter to examine diamond simulants, the gemologist must make certain that the surface being examined is "clean" and well polished. Today, this entails a bit more than a wipe with a handkerchief and a glance at a light source reflected from the surface, but—contrary to Dr. Kellam's report—hydrofluoric acid is not required. One can simply obtain a sheet of 0.3 micron Al_2O_3 polishing paper from a faceter's supply house and use it to "clean" the stone before testing. The use of aluminum oxide has been recommended by Dr. K. Nassau and H. Schonhorn (1977–1978). It certainly is adequate for removing about 50 atomic layers of SiO_2 from synthetic moissanite, which has a hardness of 9.5.

Another approach is to use the water drop test (Hanneman, 1978b). Wipe the stone with a clean cloth and place a small drop of water on the table. If the water spreads (low contact angle of less than 25°), then the stone's surface probably has been altered, and its reflectivity reading could be lower than expected. If the drop "stands up" (contact angle greater than 45°), then the stone should give adequate readings.

On the other hand, if you first "clean" your samples with aluminum oxide, you will never know if the stone was altered or not, nor will you have to care.

W. Wm. Hanneman, Ph.D.
Hanneman Gemological Instruments
Poulsbo, Washington

Hanneman W. (1978a) The role of reflectivity in gemmology. *Journal of Gemmology*, Vol. 16, No. 2, pp. 109–121.

Hanneman W. (1978b) Water as a gemological tool. *Lapidary Journal*, Vol. 31, No. 12, p. 2576.

Nassau K., Schonhorn H. (1977–1978) The contact angle of water on gems. *Gems & Gemology*, Vol. 15, No. 12, pp. 354–360.

Stack Attack

Recently I had the pleasure of receiving a shipment of *Gems & Gemology* back issues. I got straight into them and found lots of things about emeralds—especially great photos of inclusions—all in time to include in the body of research I was doing on beryl varieties. Thank you.

Every quarter, when my *Gems & Gemology* turns up, I covet it all the way home from the post office and won't allow myself to open it until a big pot of tea is made—then the contents frenzy begins. Well, the real point is, what a buzz to receive a whole *stack* of them—I had the heart rate of a hummingbird!

Nancy Fraser-Lau
Bundall, Queensland, Australia

CLASSIFYING EMERALD CLARITY ENHANCEMENT AT THE GIA GEM TRADE LABORATORY

By Shane F. McClure, Thomas M. Moses, Maha Tannous, and John I. Koivula

One of the greatest concerns with emerald filling is the degree of clarity enhancement such treatment represents. Stones that appear to have excellent clarity with the unaided eye are often revealed to have an extensive network of filled fissures, or some in areas that could be easily damaged. Using the GIA diamond clarity grading system as a framework, the GIA Gem Trade Laboratory has devised a methodology to establish the size, number, and position of filled fissures in an emerald and on this basis to classify the apparent degree of clarity enhancement achieved. Each of more than 500 filled emeralds were classified by experienced gemologists to determine the usefulness and reproducibility of the methodology. Backed by this research, GIA will be offering a new emerald report on which the degree of clarity enhancement detected will be indicated as "minor," "moderate," or "significant."

ABOUT THE AUTHORS

Mr. McClure (smcclure@gia.edu) is manager of Identification Services, Ms. Tannous is senior staff gemologist, and Mr. Koivula is chief research gemologist, at the GIA Gem Trade Laboratory, Carlsbad, California. Mr. Moses is vice president of Research and Identification at the GIA Gem Trade Laboratory, New York.

Please see acknowledgments at the end of the article.

Gems & Gemology, *Vol. 35, No. 4, pp.176–185*

In response to concerns expressed by members of the gem and jewelry industry regarding the use of organic fillers to enhance emeralds, GIA and the GIA Gem Trade Laboratory have been conducting an extensive study of fillers in emeralds. This research focuses on three major areas: (1) identification of the specific filler used in an emerald; (2) determination of the extent to which an emerald has been filled; and (3) examination of the response of different fillers over time and to normal conditions of wear, care, and manufacturing. The first area was addressed in the Summer issue of *Gems & Gemology* by Johnson et al. (1999); they concluded that distinctions can be made in some cases for "pure" fillers, but that the detection of one substance in a fissure does not prove that all others are absent. While research on the third item is still in progress, the present article reports the development of a method to determine the extent to which a particular emerald has been filled as an indication of the degree of clarity enhancement.

Based on the results of this research, in early 2000 the GIA Gem Trade Laboratory will be offering a new emerald report that will describe the level of clarity enhancement in natural emeralds. We hope that this type of report will help dealer and retailer alike reestablish consumer confidence in emeralds (figure 1) by providing information needed to make an educated purchase decision. Although the GIA Gem Trade Laboratory is not the first gemological lab to offer such a report, we believe that this is the first article to reveal the materials, methodology, and results of the study on which a system for classifying the degree of enhancement in an emerald is based, as well as the general criteria used.

BACKGROUND

The vast majority of natural emeralds, regardless of their locality of origin, contain fissures that may affect the

Figure 1. Emeralds have traditionally been among the most coveted of colored stones, even though most are "filled" in some fashion with a material that reduces the visibility of surface-reaching fissures and improves their apparent clarity. In recent years, however, concerns about the nature, stability, and extent of different fillers have disrupted the emerald market. Classifying the degree of emerald enhancement should help restore the confidence of consumers and retailers alike in this important gem material. This suite contains a total of 94.02 ct of Colombian emeralds, the largest of which is approximately 20 ct. Courtesy of Ronald Ringsrud and Ronald Leon; photo © Harold & Erica Van Pelt.

appearance of the cut stone. Over the last few years, clarity enhancement in emerald (to reduce the visibility of these fissures) has caused a great deal of consternation in the jewelry industry. This was the primary focus of the International Emerald Forum (November 1996) and the First World Emerald Congress (February 1998), both held in Bogotá, Colombia. Much has been written about enhancement substances and the methods used to identify the filling materials (e.g., Hänni et al., 1996; Johnson et al., 1999; Kiefert et al., 1999). However, many emerald dealers and laboratories have also focused their attention on the amount of filler in a given emerald (i.e., whether the stone is lightly or heavily treated), as an important indication of quality (SSEF Swiss Gemmological Institute, 1998). In fact, at the First World Emerald Congress, which two of the authors (SFM and TMM) attended, the consensus among dealers and producers from around the world was that determining the relative amount of filler in an enhanced emerald was a more important issue than identifying the filler itself (Johnson and Koivula, 1998).

A few laboratories already offer such a service (see, e.g., SSEF Swiss Gemmological Institute, 1998, pp. 74–86; and reports by the AGTA Gemological

Testing Center and Gübelin Gem Lab). To our knowledge, though, the criteria used for the different categories have not been published, although we have been told that AGTA uses a weighted numerical system to arrive at their clarity-enhancement categories (K. Scarratt, pers. comm., 1999). We began to investigate how we might define these criteria in a repeatable and teachable way shortly after the February 1998 Congress. The following study was conducted to establish a systematic method of measuring the amount of filler in surface-reaching fractures in emeralds, with the goal of providing a consistent approach to determining the extent of clarity enhancement, with reproducible results.

MATERIALS AND METHODS

Study Samples. To address the issue thoroughly, we included in our research project all qualities of emeralds (from heavily included, inexpensive goods to relatively clean, high-quality material) from a variety of geographic sources. We borrowed approximately 150 filled emeralds from several dealers, and combined these with about 100 emeralds submitted to the Gem Trade Laboratory for reports and about 250 emeralds acquired for the emerald study. We believe that the approximately 500 fashioned samples studied are representative of the full range of emerald qualities offered in the gem and jewelry market. These samples weighed from less than one carat to over 20 ct. They were examined over the period March 1998 through October 1999.

The approximately 250 emerald-study samples were incorporated into the formal testing program only in their filled state. However, the authors examined them both before and after filling with various substances, to gain a better understanding of just how much the treatment was affecting the appearance of these stones. Throughout the study, we also used photographs of the stones in their unfilled state as a reference to see how much the appearance was enhanced in a particular emerald and confirm that the clarity classification it was given accurately reflected the relative degree of enhancement.

From our examination of this large group of filled emeralds, we recognized that in some cases the filler provided little if any improvement in apparent clarity—usually because of an inferior cleaning and filling process, or deterioration over time. These stones, however, were a small minority of the samples examined. In general, our observations of the emeralds that we examined both before and after the filling process confirmed that the position and size of filled fractures present in a stone correlated well with the degree of enhancement in apparent clarity.

Methodology. *Test Participants.* For this study, we used the most experienced gemologists from our laboratories in New York and Carlsbad. Each of the approximately 150 borrowed emeralds and most of the 250 study stones were examined by a minimum of five people. Because client stones are in the laboratory for such a short time, in some cases only two gemologists looked at each emerald (although three were used if there was a discrepancy in the classification given).

Locating and Measuring the Filled Fissures. First, the participants used a gemological microscope (at magnifications ranging from 10∞ to 25∞) and darkfield illumination to determine the size, extent, and location of the fissures. The procedure used requires that the gemologist first examine the stone face up (through the table facet, tweezers holding the stone girdle-to-girdle), then through the sides and ends (tweezers holding the stone table to culet). The gemologist carefully views the stone from all directions to assess the depth of the fissures and the amount of filler present. Fiber-optic lighting may be useful to establish the overall extent of fissures, which may not have been apparent with darkfield illumination. An overhead light source for examining facets in reflected light will help in determining both whether fissures reach the surface and the length of those fissures (figure 2), which may be difficult to see in a well-filled stone. (For more information on locating filled fissures in emeralds, see Kammerling et al., 1991; Johnson et al., 1998; Kiefert et al., 1999.)

Once the gemologists located the surface-reaching fissures and determined that they had been filled or partially filled, they were asked to classify the degree of apparent enhancement according to a combination of the size (length), extent (depth), number, and location of fissures, and the amount of filler present in them. The amount of filler present in the fissures was established microscopically with supplemental fiber-optic illumination (see, e.g., Koivula, 1982). For some emeralds, a distinctive ultraviolet fluorescence (which is a standard test in emerald identification) may also reveal the location, size, and extent of filled fractures (see, e.g., Johnson et al., 1999; Kiefert et al., 1999).

Figure 2. The use of reflected light (especially fiber-optic illumination) can help determine the length of a surface-reaching fissure that may be difficult to see because of the clarity enhancement. Photomicrograph by John I. Koivula; magnified 20×.

Establishment of Clarity-Enhancement Criteria. To establish the general criteria for the emerald clarity-enhancement classification system, we turned to the well-respected GIA system for clarity grading diamonds (for a description of this system, please see the *GIA Jeweler's Manual,* 1989). Although we knew from our experience with emeralds that the specific criteria would have to be very different, this system provided a good starting point for establishing general parameters. As an added benefit, we found that using the diamond grading system as a frame of reference made it easier to train our gemologists and communicate some of the key concepts. For example, we determined that the classification criteria of size, nature, and position of the filled fractures could be used in the assessment of emerald clarity enhancement in the same way that the size, nature, and position of inclusions are used in diamond clarity grading. In addition, we established the classification categories for emeralds so that they followed a flow similar to that of the graduated clarity grade ranges of diamonds.

From the beginning, however, it was made clear that the emerald clarity-enhancement classification system is distinctive. Specifically, whereas diamond clarity grading incorporates *all* inclusions, the emerald system is concerned only with filled surface-reaching features. That is, the categories in the emerald system represent a visual assessment of the size, extent, number, and location of surface-reaching features (and the amount of filling they contain) relative to: (1) the size of the emerald, and (2) the approximate appearance of the emerald in the face-up position if it were in an unfilled condition. Although number is relevant in evaluating the degree of emerald enhancement, number and color do not play the same role as they do in diamond clarity grading. Also, we could not use apparent visibility as a criterion for evaluating emerald clarity enhancement, since the goal of this treatment is to make the fissures *less* visible. Indeed, some fillers are so successful that the fissures can be very difficult to locate (again, see figure 2). For this reason, the gemologist needs to use a range of magnifications to determine the emerald clarity-enhancement classification, not strictly 10∞ as is the standard with diamond clarity grading. In some stones, too, visibility varies from fracture to fracture, and some fillers change their appearance over time.

We started with general guidelines and then had (in most cases) five or more of the most experienced gemologists from our New York and Carlsbad laboratories make independent observations. As the study progressed, we expanded the group of gemologists involved. We asked the participants to place each clarity-enhanced emerald into one of three categories. When studying our samples, we found that distinguishing among more than three categories for degree of enhancement was impractical because one could not consistently assess the effect that fine differences in amount of filler had on the visual appearance of the emerald. In addition, throughout the emerald trade, three to four categories have been suggested and applied by other organizations (see, e.g., reports issued by the SSEF Swiss Gemmological Institute, the AGTA Gemological Testing Center, and the Gübelin Gem Lab).

In general, for the purposes of this study, the presence of filled fissures that would fit into the VVS_2 through VS_2 range in the diamond clarity grading system (i.e., with regard to the size and extent of the filled fissures relative to the size of the stone and their position in it) was considered *minor* enhancement (figure 3); emeralds with filled fissures corresponding to the SI_1–SI_2 range were *moderately* enhanced (figure 4); and those that would fall in I_1 and below were *significantly* enhanced (figure 5).

We reviewed the results for the different gemologists on each stone to (1) determine the degree of consistency in the individual classifications, and (2) ensure that the "boundaries" that marked a move from one category to the next were adequately defined. Minor adjustments were made in the course of the study to resolve boundary discrepancies.

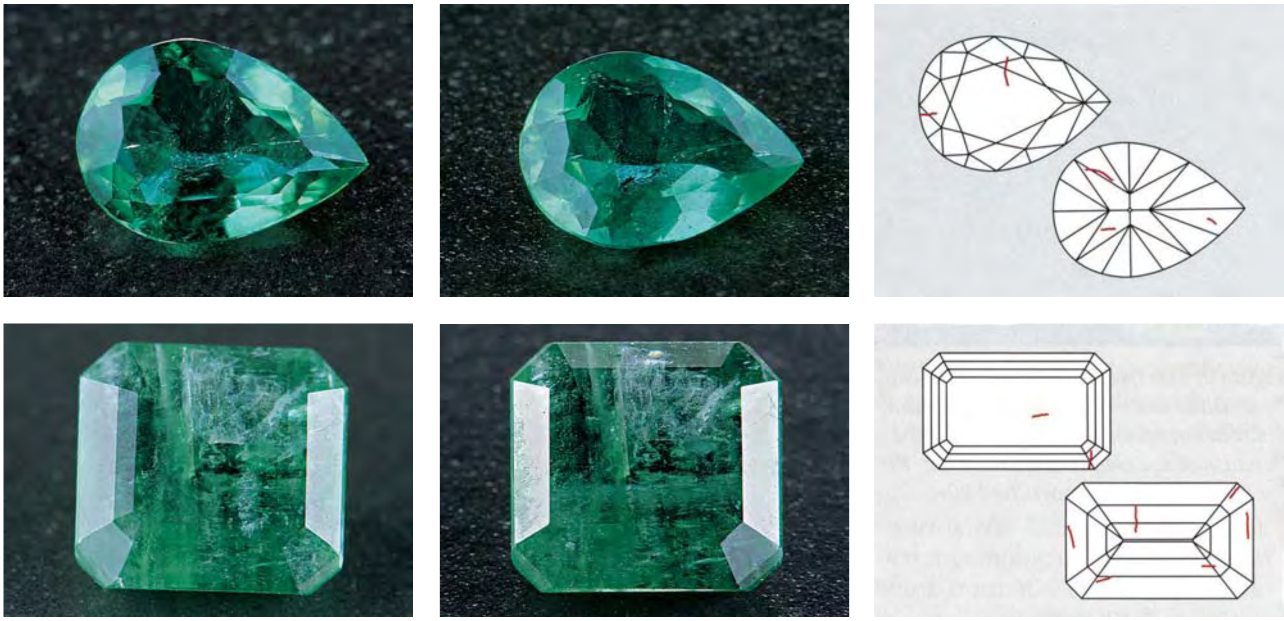


Figure 3. These images represent two examples of emeralds that would be placed in the "minor" category of the clarity-enhancement classification system. The "minor" category reflects the fact that the clarity enhancement has had only a slight effect on their face-up appearance. The images on the left show the emeralds before they were filled, and the images in the center show them after filling. The diagrams on the far right are plots of the fissures in these two emeralds as they reach the crown and pavilion surfaces. Note, however, that the depth of a fissure is not indicated on any of the plots shown in this article (which are for information purposes only here, and will not be included in the redesigned emerald report). Photos by Maha Tannous.

RESULTS AND DISCUSSION

Given our gemologists' knowledge of the clarity grading system for diamonds, and their experience with emeralds, we found this system to be easily teachable to them. Although, as noted above, some fine tuning of the three categories was done throughout the study to make sure the boundaries were adequately demarcated, for the most part the original categories established worked well: From the beginning of the research project, for the vast majority of stones, most of the gemologists were consistent in their clarity-enhancement classification calls on the same stones.

It cannot be stressed enough, however, that whereas diamond clarity grading incorporates all internal features, the categories in the emerald clarity-enhancement classification system address *only* the filled fissures and other surface-reaching features in a stone—their number, size, and extent relative to the size of the stone, and where they are located. Consequently, this classification system is used solely to evaluate the degree of apparent enhancement that these filled features represent; the system does not constitute an overall "clarity grade" of the emerald. Nor does it take into account inherent inclusions, such as mineral crystals, or primary and secondary fluid inclusions. Likewise, inclusions that do not reach the surface of the emerald cannot be filled and therefore are not properly considered in a system that only evaluates the filled fissures in a stone.

Since, in our view, the presence of filled fissures of VVS$_1$ size (that is, extremely small relative to the size of the stone) would not noticeably affect the appearance of an emerald, we include such stones under the category of "No evidence of clarity enhancement was detected." We based this on the premise that if the appearance of an emerald is not affected, then the presence of a minuscule amount of filler does not constitute an enhancement.

It is important to remember that with this clarity-enhancement classification system, as with the system for clarity grading diamonds, all of the relevant factors must be taken into consideration to

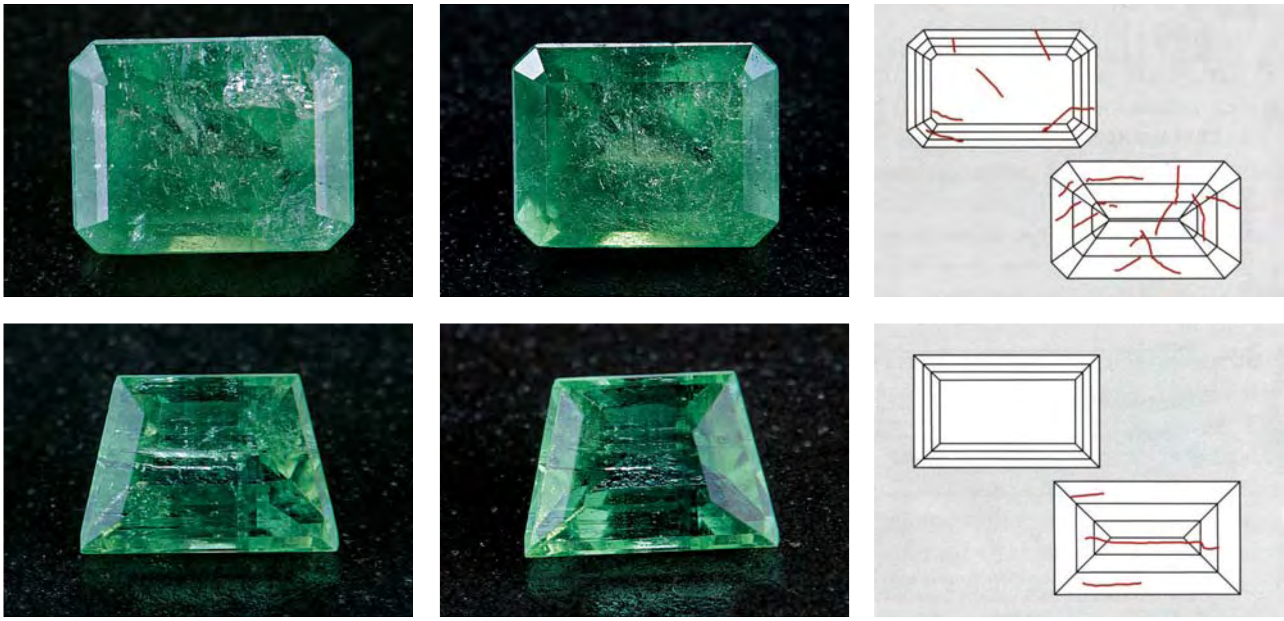
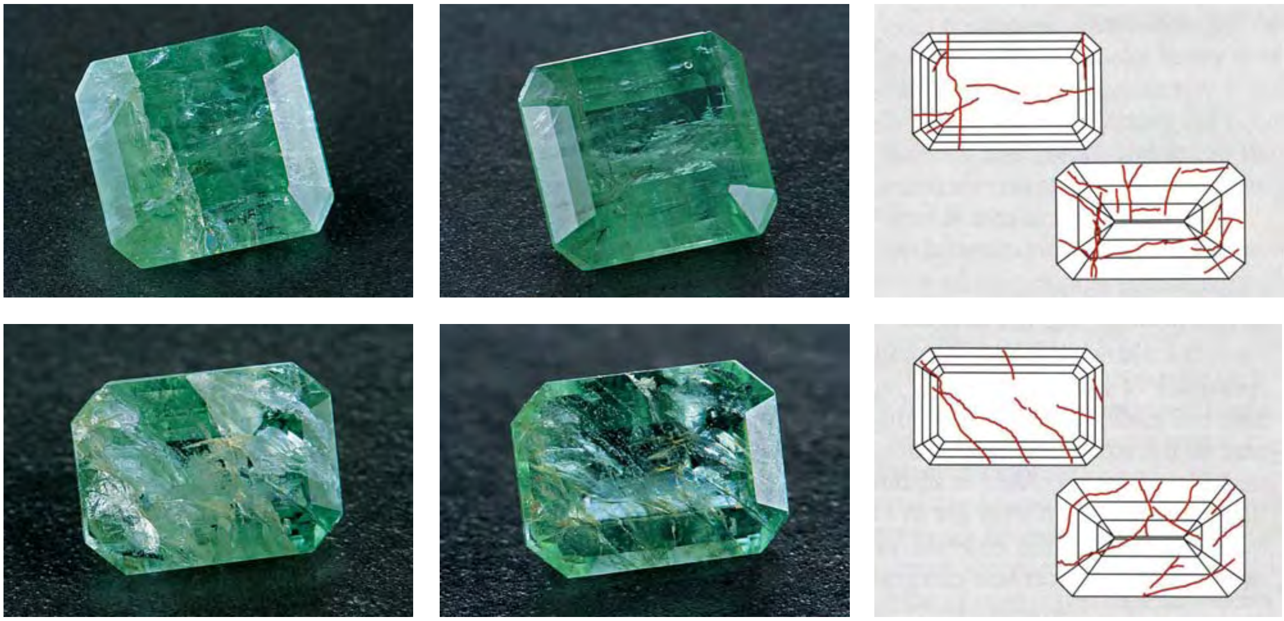


Figure 4. These two emeralds would be classified as "moderate" in the clarity-enhancement classification system. This category indicates that the fissures present have a noticeable, but not extreme, effect on the face-up appearance of the emeralds. The images on the left show the stones before they were filled, and the images in the center show them after filling. The diagrams on the far right are plots of the fissures in these two emeralds as they reach the crown and pavilion surfaces. Photos by Maha Tannous.

Figure 5. A clarity-enhancement classification of "significant" would be given to each of these two emeralds. This category indicates that the clarity enhancement has had an obvious effect on the face-up appearance of the emeralds. The images on the left show the stones before they were filled, and the images in the center show them after filling. The diagrams on the far right are plots of the fissures in these two emeralds as they reach the crown and pavilion surfaces. Photos by Maha Tannous.



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EMERALD REPORT

GIA REPORT 10348435

62495002

January 05, 2000

Shape and Cutting Style .... EMERALD CUT
Measurements .... 7.86 x 7.35 x 5.51 mm
Weight .... 2.15 carat
Transparency .... TRANSPARENT
Color .... GREEN

Clarity Enhancement .... EVIDENCE IS PRESENT
Degree .... MODERATE

Conclusion .... **NATURAL EMERALD**

Comments:

Due to their growth conditions in nature and recovery methods , most emeralds contain surface reaching features. For this reason, clarity enhancement is a common trade practice.

This Report is not a guarantee, valuation or appraisal. This Report contains only the characteristics of the item(s) described herein after it has been tested, examined and analyzed by GIA Gem Trade Laboratory, and/or has been inscribed, using the techniques and equipment available to GIA Gem Trade Laboratory at the time of the examination and/or at the time of being inscribed, including magnification, standardized viewing environment and light source, electronic carat balance, synthetic diamond screening device, high intensity short wave fluorescence imaging system, optical measuring device, micro laser inscribing device, ultraviolet lamps, millimeter gauge, color comparators, spectroscope, Illuminator Polariscope®, immersion liquids, ultraviolet-visible and infrared spectrometers, X-ray fluorescence spectrometer, gamma-ray spectroscopy systems, beta radiation scintillation detector, radiation survey meter, X-ray luminescence equipment, refractometer, dichroscope, hydrostatic balance, laser Raman microspectrometer, X-ray powder diffraction equipment, X-radiographic equipment, and ancillary instruments as necessary. The recipient of this Report may wish to consult a credentialed Jeweler or Gemologist about the information contained herein.

IMPORTANT DOCUMENT, STORE SAFELY

NOTICE: IMPORTANT LIMITATIONS ON BACK

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Figure 6. This is a prototype of the new, redesigned GIA Gem Trade Laboratory Emerald Report. It will incorporate a tabular format, a digitally produced color image, a removable tab that can be placed in a parcel paper, and state-of-the-art document security features.

place the emerald in a specific category. For example, a small filled fissure directly beneath the table of an emerald would have a greater impact on the appearance of the stone than a larger filled fissure along the girdle, and thus the smaller fissure could result in the stone receiving a more severe enhancement classification. Also, a stone may have fewer filled fractures, but if they are in an area where risk of damage is high, the emerald will be placed in a lower clarity-enhancement category.

The quality of the filler is not a primary consideration when classifying the *degree* of enhancement of emeralds. Typically, a whitish or deteriorated filler is not interpreted any differently from a uniformly transparent filler. The guiding premise in classifying the degree of clarity enhancement is the presumed appearance of the emerald before it was filled.

It is also important to point out that the emerald clarity-enhancement classification system, just as with the diamond grading system, is subjective by nature and can only be learned with practice and experience. One cannot expect to be proficient at such a system by simply reading about it or taking a class. From our experience with the laboratory gemologists who participated in this study, however, we believe that the tens of thousands of graduates trained in the GIA diamond grading system will readily understand the basic criteria used.

THE NEW GIA GEM TRADE LABORATORY EMERALD REPORT

On the basis of these results, in early 2000 GIA will be offering a new emerald clarity-enhancement classification service that will coincide with a complete redesign of the GIA Gem Trade Laboratory identification report. The report information for single unmounted stones will now be presented in a tabular format on a document that incorporates many document security features and a detachable reference tab small enough to fit inside a parcel paper. The Emerald Report (figure 6) will also include a digitally generated color image, to illustrate the appearance of the stone *at the time it was examined* in the laboratory. We believe that this will help protect the user of the report in those situations where the emerald is enhanced or the filler deteriorates after the report has been issued.

We chose the terms *minor, moderate,* and *significant* to describe the level of clarity enhancement because they are already in use by several other laboratories and, as was discussed at an international meeting of laboratories held in Bern, Switzerland, on May 7, 1999, the harmonization of word terms between laboratories should help alleviate confusion both in the trade and with consumers (Wade, 1999). Again, this classification system is used solely to evaluate the level of enhancement that filled surface-reaching features represent in an emerald, and not to offer an overall "clarity grade" for the emerald.

Emerald clarity-enhancement classification reports will be issued for loose *natural* emeralds only. Therefore, it will be necessary to identify the gemstone before providing a report. This identification will be included as part of the new report. If a stone turns out to be anything other than a natural emerald, if an emerald is mounted, and for clients who want an identification only, a standard gemological identification report will be provided along with a statement as to whether any enhancement was present. If filled fissures are observed, the identification report will include the statement that "Evidence of clarity enhancement was detected," but no quantification will be given.

DEGREE OF ENHANCEMENT VERSUS VALUE

Although it is tempting to correlate the degree to which an emerald has been clarity enhanced to the value of that stone, the extent of filler present is only one part of the value equation, which also includes color and weight (Drucker, 1999). "Significant enhancement" does not necessarily mean low value, just as "minor enhancement" or "no evidence of enhancement" does not necessarily mean high value (figure 7).

Clearly, the amount of internal non-surface-reaching inclusions present in a given emerald will have a major effect on the value of that stone. The value of a low-quality emerald that is heavily included will not be improved at all by a report that says it has only minor enhancement. Conversely, an "eye-clean" emerald that gets a report stating that it is significantly enhanced will probably see a negative impact on its value when compared to an eye-clean stone with less enhancement.

Most consumers and dealers alike would probably agree that color is the single most important factor in determining the value of a colored stone. Clarity enhancement cannot change the *inherent* color of a stone. A poorly colored emerald will always be poorly colored unless artificial coloring agents such as dyes are added. However, clarity enhancement can change the *appearance* of a stone's color. By changing the visibility of fissures in a stone, clarity enhancement reduces the amount of light scattered or reflected by those fissures, so the color of the stone may *appear* better than it was before.

That is what gem treatment is all about: changing the appearance of a stone so it looks better than it did before it was treated. Consequently, if we have two emeralds where all other factors are equal (e.g., internal inclusions and color), the stone that shows only minor enhancement will be more desirable than the one that is significantly enhanced.

This correlation between treatment and value is true for many types of stones and treatments. A good example would be the effect of heat treatment on corundum. A non-heat-treated sapphire will still not be valuable if, for instance, it is too pale or too dark. However, a heat-treated sapphire with good color and clarity will not have the same value as a similar-quality untreated sapphire.

Of course, there are several critical differences between the treatments in emerald and sapphire. With heat treatment of sapphires, the stone itself is being changed and the change is permanent, whereas

Figure 7. Degree of enhancement is only one factor that may affect a stone's value. The emerald on the left has many inclusions that are highly visible, yet it merits only a "minor" enhancement call because it has relatively few filled surface-reaching fissures. The eye-clean stone on the right appears to be of very high quality. However, the clarity enhancement is masking several large fractures. The emerald would look much worse if it were not filled, so it deserves a "significant" classification. Photo by Maha Tannous.

with the filling of emeralds it is only an apparent change and the change is not permanent. The clarity enhancement of emeralds also masks the presence of fissures that may affect the durability of the stone, particularly if the fractures are large and are located where risk of damage is high, such as in a corner of an emerald-cut stone.

CONCLUSION

We have devised a system for classifying the degree of apparent clarity enhancement in a particular emerald as *minor, moderate,* and *significant*. The extent of enhancement is based primarily on a visual assessment of the total amount of filling in surface-reaching fractures as determined with microscopic examination. A combination of factors such as the size of the filled features, where they occur within the emerald, and their quantity relative to the size of the stone also affect the final classification. To confirm the consistency of this classification system and refine the boundaries between categories, we conducted a study whereby approximately 500 emeralds were examined (and placed in one of the three categories) by several experienced gemologists. This clarity-enhancement classification system is planned for introduction into the new GIA Gem Trade Laboratory Emerald Report in early 2000.

Although the degree of clarity enhancement may be an important consideration for evaluating natural emeralds, it should not be used alone to judge the quality or value of an emerald. However, when two stones that are otherwise similar in all aspects are compared, the emerald with less clarity enhancement may require less care and be less susceptible to damage. The presence of surface-reaching fissures does not necessarily mean that an emerald has been enhanced. In situations where large fissures or fractures are present in the stone and there is only a small amount of foreign substance present, the enhancement will be classified as "minor." Likewise, a minute amount of foreign substance may be detected, but if it is determined that it does not significantly affect the appearance of the stone, the report might read "No evidence of clarity enhancement was detected."

If one were to take a heavily fractured emerald that has not been filled and obtain a report with the "no evidence" conclusion, and then subsequently treat the stone, the image on the report should show that the appearance of the stone has been altered. Note, however, that such changes may not be apparent for emeralds in which the enhancement is only visible with a microscope.

We believe that additional information such as this, which will ultimately go to the final consumer, will help educate the buying public and make them feel more comfortable when purchasing emeralds and other colored stones, thus restoring the consumer confidence that has wavered over the last few years.

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CLUES TO THE PROCESS USED BY GENERAL ELECTRIC TO ENHANCE THE GE POL DIAMONDS

By Karl Schmetzer

The specific details of the process used to enhance color and clarity in GE POL diamonds have not been disclosed. However, a survey of U.S. patents and European patent applications reveals that General Electric has developed a variety of high-temperature annealing techniques at different pressures for enhancing the optical properties of polycrystalline synthetic diamond films and single-crystal synthetic diamond. These methods may provide important clues to the process being used to decolorize natural type IIa (GE POL) diamonds, that is, by reducing the structural defects associated with their brown coloration.

In March 1999, a new type of enhanced diamond was announced by Pegasus Overseas Limited (POL) of Antwerp, Belgium, a subsidiary of Lazare Kaplan International (LKI) Inc. (*Rapaport NewsFlash,* March 19, 1999; see figure 1). This new method, which was developed by the General Electric Company (GE), reportedly changes both the color and clarity appearance of certain diamonds (see Tempelsman, 1999). The faceted diamonds are referred to as GE POL, Pegasus, and most recently at retail, Monarch™ diamonds (Heeger, 1999). Almost immediately after the GE process was announced, numerous questions were raised about the identification of these enhanced natural diamonds (see, e.g., *Rapaport NewsFlash,* 1999; Even-Zohar, 1999).

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Although GE has confirmed that it is using a high-pressure, high-temperature (HPHT) process, details of the treatment conditions so far have not been disclosed (see, e.g., Johnson et al., 1999; Moses et al., 1999; Shigley et al., 1999). Consequently, the exact enhancement mechanism still is unknown. However, a statement made by Bill Woodburn, General Electric's vice president of Superabrasives, provides some insight into GE's approach (Woodburn, 1999): "In nature the diamond's color is disturbed by normal geological factors such as changes in heat and pressure or contamination that disturbs the conditions that allow the stones to reach their colorless potential. The GE process,

Figure 1. These three GE POL diamonds (4.11–5.34 ct) were all decolorized by a high-pressure, high-temperature process developed by General Electric. Photo by Elizabeth Schrader.

through high temperature and pressure, attempts to recreate the earth's geological process and allows the diamond to reach its optimal colorless potential." That is, GE proposes that its process simulates the conditions of heat and pressure to which the diamond might have been exposed naturally in the earth's mantle.

Given this situation, the present author conducted a search of diamond treatment patents to find any reference to a process that might provide better understanding of the method applied. It is hoped that better knowledge of the enhancement mechanism will help in the development of identification criteria.

BACKGROUND

Primarily on the basis of their nitrogen or boron contents, diamonds are classified as types I (a and b) and II (a and b). The vast majority of natural diamonds are type I, which contain different forms of nitrogen. Type IIa diamonds lack nitrogen and boron (as detectable by standard infrared spectroscopy), whereas type IIb diamonds typically contain boron (for more on diamond types, see Fritsch and Scarratt, 1992; Weldon, 1999). In a sample of more than 800 GE POL diamonds examined by the GIA Gem Trade Laboratory, 99% of the stones were determined to be type IIa (i.e., low-nitrogen) natural diamonds (Moses et al., 1999). Because type IIa diamonds do not absorb visible light unless they contain structural defects, they are usually colorless; if such defects are present, however, type IIa diamonds may be gray, brown, or even pink (Fritsch, 1998; Lu et al., 1998). LKI president Leon Tempelsman has stated that the starting material for the GE process consists primarily of "top brown" to brown diamonds (see Donahue, 1999; compare Even-Zohar, 1999; Levy, 1999). Thus, the color alteration in natural brown type IIa diamonds could be caused by healing the structural defects within the diamond by means of plastic flow (also called plastic deformation).

Color improvement by high-pressure, high-temperature annealing processes was independently developed and patented in the late 1970s by GE (Strong et al., 1978, 1979) and the De Beers Industrial Diamond Division (Evans and Allen, 1983). Both procedures were based on the transformation of type Ib nitrogen to type Ia nitrogen, thereby reducing the saturation of a yellow or brownish yellow color in diamonds (Schmetzer, 1999). Although this mechanism may be involved in a few of the Pegasus diamonds examined so far, it cannot be the main mechanism for color and clarity improvement of these type IIa diamonds because they lack significant amounts of nitrogen.

GE has announced that it has not patented the process to "whiten" the diamonds sold by POL (Barnard, 1999; Donahue, 1999; Weldon, 1999). The reasons for this may be that: (1) GE wishes to keep details of the process proprietary, (2) the process is already patented, or (3) the process is already considered public domain and thus can no longer be patented. The following review of related patents suggests that all of these reasons may apply to some extent.

RELATED PATENTS

The synthetic diamond treatments described in a series of patent applications filed originally in 1994 by General Electric may help shed some light on the present treatment process of Pegasus diamonds. All involved enhancing the "toughness" of, and "reducing crystalline defects" in, chemical vapor deposited (CVD) synthetic diamond. (In the following, the terminology used in these patent documents has been adopted as closely as possible, so some of the wording may seem a little awkward.) The original patent application was filed March 11, 1994, in the U.S., but was later abandoned and so never resulted in a U.S. patent. This same application was refused by the European Patent Office in 1998 in the course of the European examination process, but by 1995 it had already entered the public domain (Anthony et al., 1995a).

Subsequent to the March 1994 application, four related patent applications were filed by GE in May and June of 1994. Three of these received U.S. patents (No. 5,672,395; No. 5,451,430; and No. 5,468,934). The methods described in these patents reveal improvements that bring us even closer to understanding the high-pressure, high-temperature technique being used to enhance color and clarity in the Pegasus diamonds.

The Original March 1994 Patent Application. As described in the European application that was subsequently abandoned (Anthony et al., 1995a), this HPHT treatment of CVD synthetic diamond can be applied to single crystals or polycrystalline diamond material up to 10 mm thick that contains grain boundaries, growth defects, dislocations, plastic strain, or other sources of density fluctuation (concentrations of inhomogeneities or voids) that reduce the quality of the optical properties.

In the process described, the synthetic CVD diamond is brought into the high-pressure, high-temperature conditions under which diamond is the thermodynamically stable phase of carbon for a prescribed period of time. The starting material is placed in inert pressure-transmitting fluids or solids, including salts (e.g., sodium chloride or potassium chloride), oxides, or graphite, and subjected to (preferably) pressures of 50–70 kilobars and temperatures of 1400°C–1700°C. In this region of the diamond stability field (see figure 2), both plastic flow (deformation) and atomic diffusion of carbon occur. The synthetic diamond may be held under these conditions for a period that ranges from minutes to several days, but typically is from 1 to 24 hours. Subsequent to cooling and release of pressure, the result is a diamond with fewer defects, reduced density gradients, and lower stress—that is, with improved optical properties. If color centers related to defects are responsible for a brown coloration, and such defects are present, one can also assume that the removal of such defects will "remove" or lighten the original color.

This HPHT method appears to use pressures and temperatures that are similar to those used in the earlier technique developed and patented by GE at the end of the 1970s for transformation of type Ib to type Ia nitrogen in natural and synthetic diamonds (again, see Strong et al., 1978, 1979). The new GE POL method, however, must use a completely different mechanism for color and clarity enhancement, because of the absence of nitrogen in the type IIa diamonds treated.

The Subsequent GE Patents. Whereas the procedure described in the 1994 patent application involved treatment in the diamond stability field (very high pressure), the later GE patents describe diamond treatments under conditions within the graphite stability field (lower pressure), but with almost identical results.

In U.S. patent 5,672,395, Anthony et al. (1997) describe an HPHT treatment (again, with specific reference to CVD synthetic diamond) that uses plastic deformation to improve diamond properties by reducing strain and decreasing the size of voids. Typical pressures of 5 kilobars were applied at temperatures between 1600°C and 1900°C. These conditions are above the plastic yield limit line but below the diamond-graphite boundary; that is, they are within the graphite stability field (again, see figure 2). To prevent graphitization of diamond while plastic flow is occurring during the high-temperature annealing, hydrogen gas or a mixture of hydrogen and methane plus other nonoxidizing media can be used as graphitization suppressors. Also to prevent graphitization, the annealing time at 1800°C is kept below 60 minutes, and at 1900°C it is below 15 minutes. This method is less expensive than that mentioned above simply because a lower-pressure apparatus can be used.

In U.S. patent 5,451,430, Anthony et al. (1995b) used temperatures between 1600°C and 1900°C, but at even lower pressures, to improve the toughness of CVD synthetic diamond. Graphitization suppressors again were used (e.g., hydrogen gas or a mixture

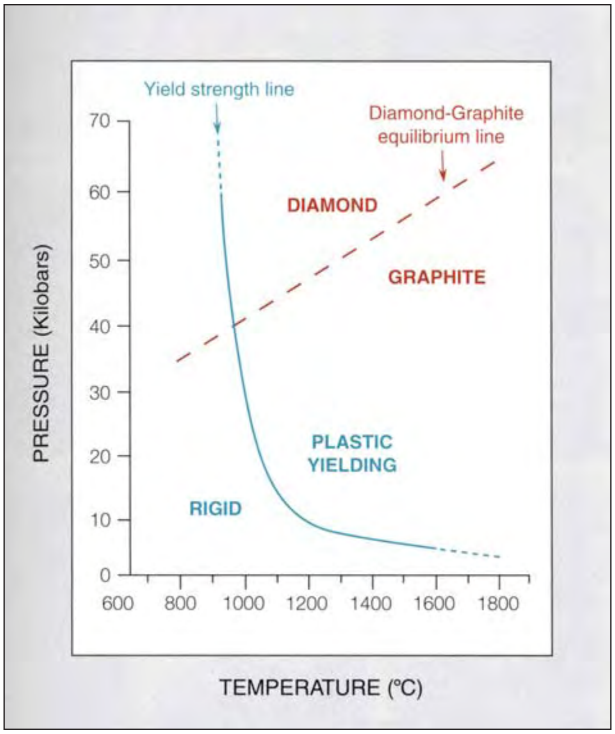

Figure 2. This pressure-temperature diagram illustrates the diamond-graphite stability field (defined by the dashed equilibrium line) and the plastic yield limit of diamond (solid line). Diamond is the stable form of carbon above the diamond-graphite equilibrium line, whereas graphite is stable below this line. Diamond is rigid to the left of the yield-strength line, whereas it can plastically deform under conditions corresponding to those to the right of this line. Modified from DeVries (1975); see also Anthony et al. (1995a and b, 1997).

of hydrogen and methane—or, alternatively, inert atmospheres such as argon, helium, or neon), and pressures could vary between 1 torr and 5 atmospheres (i.e., significantly less than one kilobar). Under these conditions, the annealing time is further reduced, to prevent graphitization, to less than 6 minutes at 1800°C and less than 15 seconds at 1900°C. Again, plastic deformation that occurs at high temperatures eliminates stress in the synthetic diamond (single crystals or polycrystalline material) and improves the optical properties. In U.S. patent 5,468,934, Anthony and Fleischer (1995) describe an apparatus designed to perform the technique discussed in this paragraph.

CONCLUSION

Information as to the exact pressures, temperatures, and annealing times applied by General Electric to produce the Pegasus diamonds, as well as which pressure-transmitting media and/or graphitization suppressors actually are used, is still proprietary. However, at least part of the mechanism of color (and clarity) enhancement may be better understood by the information cited in the GE patent applications and patents discussed above, which are probably precursors of the current GE POL process.

The different high-temperature annealing techniques at variable pressures described in these documents for polycrystalline synthetic diamond films and single-crystal synthetic diamond also can be applied to natural diamonds. It also should be possible to reduce the structural defects associated with the brown coloration of some natural diamonds (again, see Fritsch, 1998; Lu et al., 1998) by carefully controlled plastic deformation at temperatures above 1600°C. The observation of strain patterns and of graphite in cleavages in Pegasus diamonds (Shigley et al., 1999; Moses et al., 1999) also may be explained by plastic deformation during treatment and by graphitization along cleavages. However, it must be kept in mind that new methods and new discoveries are always possible, and GE still has not revealed the details of the actual conditions being used for its Pegasus diamonds.

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DIOPSIDE NEEDLES AS INCLUSIONS IN DEMANTOID GARNET FROM RUSSIA: A RAMAN MICROSPECTROMETRIC STUDY

By Michael S. Krzemnicki

Straight, acicular, colorless solid inclusions in demantoid garnet from the Ural Mountains of Russia were investigated by laser Raman microspectrometry. These "needles," which occur in association with "horsetail" inclusions (curved, fibrous chrysotile), were identified as diopside. This study also demonstrated that Raman analysis is a highly sensitive method for distinguishing even between isomorphous mineral inclusions in gems, that is, minerals with similar crystal structures but different chemical compositions.

Studies of the inclusions in demantoid garnet from Russia's Ural Mountains have focused mainly on the "horsetail" fibers that historically were referred to as *byssolite*—an obsolete name for fibrous amphibole—in the literature (see, e.g., Gübelin and Koivula, 1986; Webster, 1994). Recent investigations by A. Peretti, however, identified these fibers as chrysotile, a serpentine mineral (Phillips and Talantsev, 1996). Similar horsetail inclusions have been seen in demantoid garnets from Val Malenco, Italy. However, only very few stones from this locality have been cut and have appeared in the gem trade.

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Please see acknowledgments at the end of the article.

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In recent years, the historic demantoid deposits have been reworked and new deposits have been uncovered in the Urals. Demantoid garnets recently mined from these Russian deposits have been observed to contain distinctive acicular inclusions (see, e.g., figure 15 of Phillips and Talantsev, 1996), sometimes accompanied by horsetails. The goal of the present study was to identify these acicular inclusions by means of laser Raman microspectrometry.

Although Raman analysis has been used in mineralogical research for many years (see, e.g., Moore et al., 1971; Griffith, 1987), it is a relatively new technique in most gemological laboratories. Nevertheless, several authors have described gemological applications of Raman microspectrometry, which is an excellent tool for the nondestructive analysis of inclusions in gemstones (see, e.g., Delé-Dubois et al., 1980; Hänni et al., 1998; Koivula and Elen, 1998).

The Raman-shift effect measured by the instrument is due to the molecular vibrations within a substance during its exposure to an intense monochromatic light source, usually a visible laser (Long, 1977; McMillan and Hofmeister, 1988). Minerals that have different crystal structures can be distinguished by different peak positions in their respective Raman spectra (Maestrati, 1989). However, even isomorphous minerals (i.e., those that have similar crystal structures but different chemical compositions) may be distinguished from one another by Raman analysis (see, e.g., Pinet and Smith, 1993, 1994; Mernagh and Hoatson, 1996).

MATERIALS AND METHODS

Recently, the author had the opportunity to investigate the inclusions in 11 demantoid garnets from Russia's Ural Mountains, which were sent to the SSEF Swiss Gemmological Institute for certification. The origin of the samples was determined by SSEF on the basis of their inclusions and chemical compositions. All of the samples were faceted, most as round brilliants. They ranged from 0.55 to 3.06 ct, and from yellowish green to intense green (figure 1). Similar demantoid garnets from Russia have been reported on the market since the mid-1990s (Phillips and Talantsev, 1996; ICA Gazette, 1998).

Each stone was examined with a gemological microscope and darkfield illumination at 10×–50× magnification. The inclusions were analyzed with a Renishaw Raman system, using a 514 nm argon laser and an Olympus gemological microscope at 20× magnification to focus the laser on the inclusion. For each analysis, 20 scans (5 seconds/scan) were accumulated. On the basis of a preliminary computerized identification, the spectra were compared to reference samples to make a positive identification.

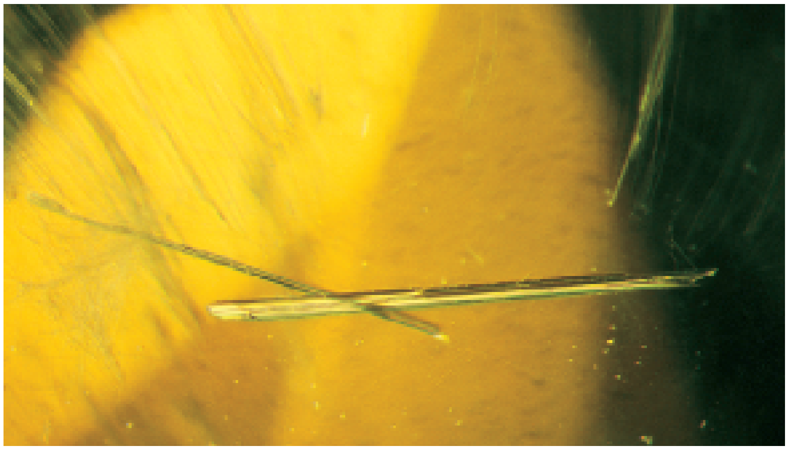
Figure 1. These demantoid garnets (0.55 to 3.06 ct) from the Ural Mountains of Russia were among those studied for this article. Photo by Henry A. Hänni.

RESULTS

Microscopic Investigations. In all 11 samples, the long, thin, curved chrysotile fibers (horsetails) characteristic of Russian demantoid were present. Three samples also contained colorless acicular inclusions that were accompanied by horsetail inclusions (figure 2). The acicular inclusions showed no specific orientation relative to the garnet structure or to the horsetails. They were characterized by a rhombic cross-section and distinct striations parallel to the long axis (figure 3). In two of the three demantoid

Figure 2. When observed with magnification, the straight, colorless diopside needles appeared very different from the curved chrysotile fibers ("horsetails") typically seen in Russian demantoid garnet. Photomicrograph by Henry A. Hänni; magnified 30×.

Figure 3. The acicular inclusions, which appeared rhombic in cross-section, revealed striations parallel to the long axis. Photomicrograph by Henry A. Hänni; magnified 50×.

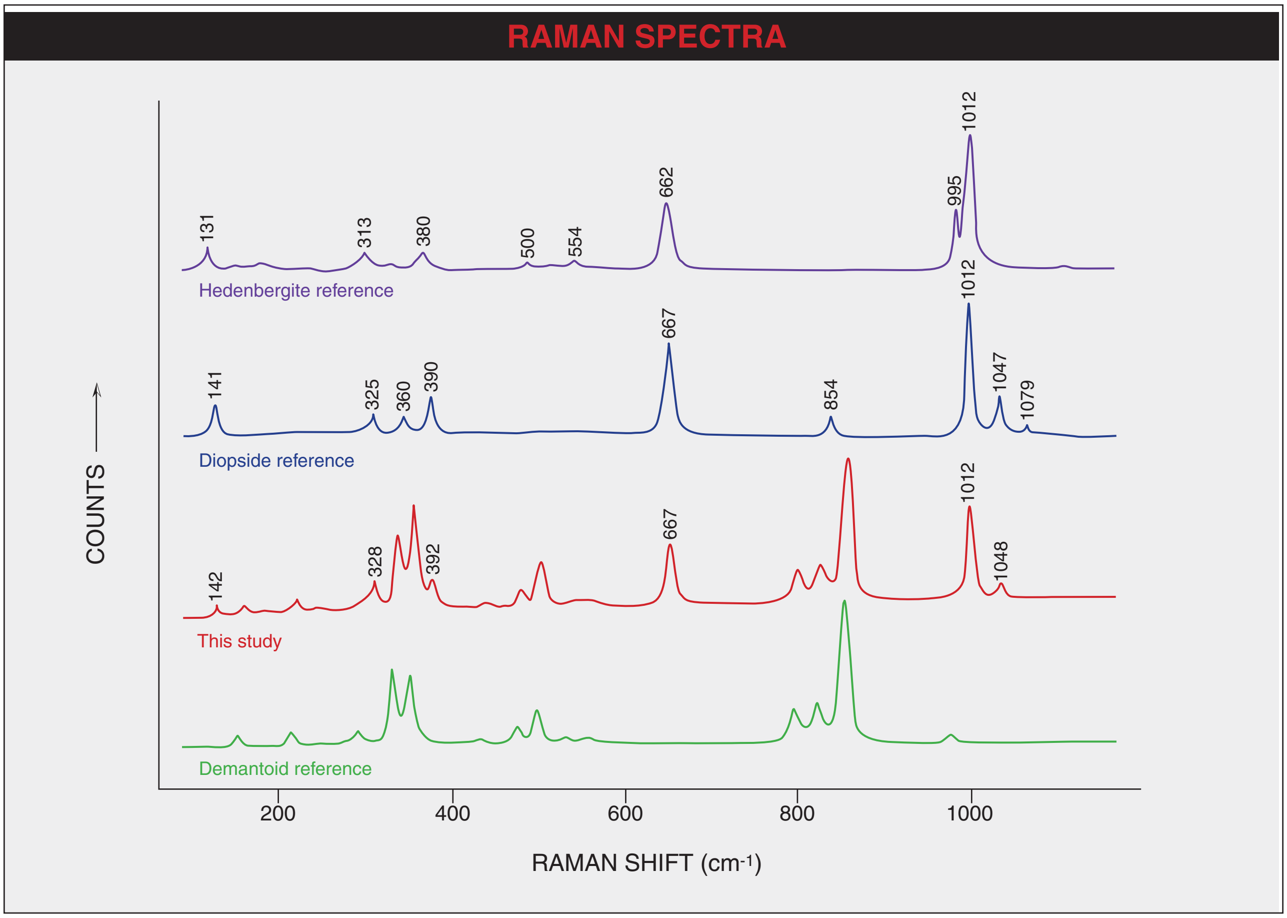


samples, the acicular inclusions were accompanied by hollow tubes that appeared to have the same shape. Where they reached the surface, these tubes were partly filled with residues of the polishing compound.

Identification of Inclusions by Raman Analysis. The Raman spectra of the acicular inclusions analyzed in the three samples showed only slight differences in peak intensity, due to the anisotropy of the crystal structure (Ostertag, 1996). They were always superimposed over the peaks of the host demantoid (figure 4). A careful subtraction of the spectra (Ostertag, 1996; Hänni et al., 1997) was required to avoid any misinterpretation. When the Raman spectra of the acicular inclusions were compared with the spectra in the digital SSEF Raman library (Hänni et al., 1997), they were identified as diopside (again, see figure 4).

Diopside, a Ca-Mg pyroxene, forms an isomorphous series with hedenbergite (a Ca-Fe pyroxene; Deer et al., 1992). The general patterns of the peak positions in the Raman spectra of diopside and hedenbergite are similar. This is not surprising, as both have the same crystal structure (monoclinic C2/c) and thus have similar vibrational spectra in Raman microspectrometry. However, the two similar structures contain slightly different molecules, which results in slightly higher wavenumbers for diopside than for hedenbergite. Thus, Raman analysis can distinguish between members of an isomorphous series, even if the size of the ions involved in

Figure 4. When a representative Raman spectrum of the acicular inclusions was compared to reference spectra for diopside, hedenbergite, and demantoid garnet, it was evident that the study sample correlated well with diopside (Ca-Mg pyroxene). The peaks that are not labeled correspond to demantoid.



the exchange mechanism (0.72 Å for Mg^{2+} in diopside versus 0.78 Å for Fe^{2+} in hedenbergite) is not significantly different. The literature reveals similar results, for example, for clino- and orthopyroxenes (Mernagh and Hoatson, 1996) and for garnets (see, e.g., for andradite-uvarovite-grossular: Pinet and Smith, 1993; for spessartine-almandine-pyrope: Pinet and Smith, 1994).

In the mineralogical literature, Deer et al. (1982) mention the presence of relics of an unspecified pyroxene in demantoid garnet from the western Carpathian Mountains of central Europe. With the current study, however, diopside is identified for the first time as an inclusion in gem-quality demantoid garnet.

CONCLUSIONS

Colorless acicular inclusions of diopside were identified in demantoid garnet from Russia's Ural Mountains. In the samples examined, these colorless acicular inclusions occurred together with classic horsetail inclusions. Consequently, they may provide further microscopic evidence for the Russian origin of a demantoid garnet.

This study also represents the successful use of Laser Raman microspectrometry in gemology to differentiate between isomorphous minerals of the pyroxene group (diopside and hedenbergite), by revealing slight general shifts in the peaks of their respective Raman spectra.

Acknowledgments: For lending several demantoid samples for this investigation, the author thanks Gemcut S.A., Geneva, Switzerland; Mr. A. Baybars, Erlinsbach, Switzerland; and Winflow Pacific Ltd., Hong Kong. Prof. Dr. C. de Capitani (Geochemical Laboratory, Basel University, Switzerland) kindly provided electron microprobe reference samples for Raman analysis. Dr. A. Peretti, Lucerne, Switzerland, provided information about the identity of "horsetail" inclusions. Further thanks to Prof. Dr. H. A. Hänni, Dr. L. Kiefert, and J.-P. Chalain (all from the SSEF Swiss Gemmological Institute) for their careful review of the manuscript.

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GARNETS FROM MADAGASCAR WITH A COLOR CHANGE OF BLUE-GREEN TO PURPLE

By Karl Schmetzer and Heinz-Jürgen Bernhardt

Gemological, chemical, spectroscopic, and microscopic properties of blue-green color-change garnets from a new deposit near Bekily, Madagascar, are given. The samples are members of the pyrope-spessartine solid-solution series, with smaller constituents of almandine and grossular. The alexandrite-like color change from blue-green in daylight to purple in incandescent light is mainly caused by relatively high amounts of vanadium (about 1 wt.% V_2O_3). These garnets are particularly noteworthy because they represent the first commercially available "blue" garnets.

Although gem-quality color-change garnets have been known from Sri Lanka and Tanzania, interest in this phenomenal material has grown rapidly with the discovery of new deposits near Tunduru (Tanzania) and especially Madagascar. In particular, the discovery in Madagascar of commercial quantities of color-change garnets that are greenish blue to blue-green in daylight represents the first "blue" garnets to enter the gem market (figure 1). Although cut stones are usually small (0.1–0.8 ct), many stones over 1 ct have been reported. The largest faceted top-quality blue-green color-change garnet seen to date is 9.5 ct (T. Hainschwang, pers. comm., 1999).

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In general, garnets that show a distinct color change from green to bluish green in day (or fluorescent) light and red to reddish purple in incandescent light are subdivided into two groups according to their chemical composition. The first group consists of chromium-rich pyropes with chromium contents above 3 wt.% Cr_2O_3. Chemical properties of samples from this first group have been reviewed by Schmetzer et al. (1980), but faceted gem material has been seen only rarely in the trade. Occasionally, garnet inclusions in diamond (see Fryer, 1982) reveal this chemical composition.

The second group of color-change garnets is more commonly seen as faceted gem material. This group is formed by members of the pyrope-spessartine solid-solution series that also contain minor molecular percentages of almandine and grossular. The color change in these garnets always is associated with small amounts of V_2O_3 and/or Cr_2O_3 (Schmetzer and Ottemann, 1979; Schmetzer et al., 1980; Stockton,

Figure 1. This 1.00 ct color-change garnet is from a new source near Bekily, Madagascar. The vanadium-rich pyrope-spessartine garnet is blue-green in day or fluorescent light (left) and purple in incandescent light (right). Photo by Maha Tannous.

1982; Gübelin and Schmetzer, 1982; Manson and Stockton, 1984; and Stockton and Manson, 1985; for a recent colorimetric study of various color-change gem materials, see Liu et al., 1999). Historically, most samples of this second type of color-change garnet have originated from different localities in only two countries: Embilipitiya and Athiliwewa, in Sri Lanka; or Umba and Tunduru, in Tanzania (see references given above as well as Koivula and Kammerling, 1988; Johnson and Koivula, 1996a and b, 1998a).

In 1998, the first color-change pyrope-spessartine garnets from Madagascar were mentioned (Johnson and Koivula, 1998b). These samples were greenish yellow in daylight and intense pink to red in incandescent light. Recently, a second variety of color-change pyrope-spessartine from Madagascar was made available to one of the authors (KS). The color of this material varies from bluish green to greenish blue (almost pure blue) in daylight, with a distinct color change to intense purple in incandescent light (figure 1). The present study was undertaken to characterize this new material, the daylight color of which is very unusual compared to that of other garnets, both single color and color change, that have entered the marketplace thus far (see again Johnson and Koivula, 1996a and b). For convenience, the color-change garnets discussed in this article will be referred to hereafter as "blue-green," their predominant daylight color.

MATERIALS AND METHODS

For the present study, about 60 faceted blue-green garnets ranging from 0.1 to 2 ct were available. We also examined more than 100 rough samples up to 5 ct. All samples were said to originate from a recently discovered mine near the town of Bekily in southern Madagascar (T. Cushman, J. Henn, H. Hogemann, E. Petsch, and M. Sevdermish, all pers. comm., 1999).

For comparison, we also studied two greenish yellow/pink color-change garnets (1.95 and 0.44 ct) that had recently come from Madagascar. As was the case for the three garnets of similar color change described in Johnson and Koivula (1998b), these two new samples were purchased at a local gem market in Madagascar, so the exact locality for this material is still unknown. However, these samples probably also originate from the Bekily area (T. Hainschwang and M. Sevdermish, pers. comm., 1999).

We tested more than 20 of the larger faceted blue-green samples and the two greenish yellow ones by standard gemological methods for refractive index, fluorescence to long- and short-wave ultraviolet radiation, and density. We examined all of the available samples (both rough and cut) for inclusions and internal structure by standard microscopic techniques using different microscopes and lighting conditions both with and without immersion in methylene iodide.

Chemical properties were determined for eight blue-green samples (designated A to H) that represented the full range of refractive indices and densities measured. In addition, we also analyzed the smaller (0.44 ct) greenish yellow sample (designated X). For quantitative chemical analyses of all nine faceted samples, a Cameca Camebax SX 50 electron microprobe was used, with traverses of 15 point analyses across the table of each sample.

For 30 rough and faceted (approximately half each) blue-green garnets and for the two greenish yellow stones, we recorded spectroscopic data with a Leitz-Unicam SP 800 spectrophotometer for the visible-to-UV range.

To identify the needle-like inclusions observed in the blue-green garnets, we used the electron microprobe described above. For this examination, we analyzed several faceted stones in which the needles reached the surface, as well as a few samples of rough material on which we had faces specially polished. Inclusions in three of these rough samples were also analyzed by laser Raman microspectrometry using the Renishaw system.

TABLE 1. Physical and chemical properties of color-change garnets from Madagascar.

Physical and chemical properties	Blue-green (daylight) /purple (incandescent light) samples								Greenish yellow/pink sample
	A	B	C	D	E	F	G	H	X
Refractive index	1.759	1.760	1.760	1.761	1.763	1.765	1.766	1.767	1.764
Density (g/cm^3)	3.87	3.87	3.88	3.89	3.90	3.92	3.92	3.93	3.91
Microprobe analyses (wt.%)[a]									
MgO	14.02	13.23	13.03	12.91	11.58	11.66	11.42	11.53	10.02
CaO	2.09	2.46	2.27	2.28	2.13	2.39	2.71	2.21	4.21
MnO	17.22	18.02	18.02	18.33	20.17	20.09	20.58	20.61	22.07
FeO[b]	3.44	2.55	3.14	3.44	3.19	3.10	2.86	3.14	1.80
V_2O_3	0.95	0.98	1.25	1.22	0.89	1.21	1.16	1.22	0.21
Cr_2O_3	0.15	0.23	0.25	0.24	0.14	0.24	0.36	0.20	0.18
Al_2O_3	22.88	21.96	21.81	22.28	21.95	21.78	21.87	22.00	22.27
SiO_2	40.64	39.24	39.34	40.05	38.96	39.12	39.61	39.38	39.43
TiO_2	0.06	0.06	0.06	0.06	0.05	0.07	0.05	0.07	0.09
Total	101.45	98.74	99.19	100.81	99.08	99.64	100.63	100.36	100.27
Cations[c]									
Mg	1.532	1.492	1.468	1.431	1.317	1.319	1.281	1.296	1.131
Ca	0.165	0.200	0.184	0.181	0.174	0.194	0.218	0.179	0.342
Mn	1.069	1.155	1.153	1.155	1.303	1.291	1.312	1.317	1.416
Fe	0.211	0.161	0.198	0.214	0.204	0.197	0.180	0.198	0.114
V	0.056	0.060	0.076	0.073	0.054	0.074	0.070	0.074	0.013
Cr	0.009	0.014	0.015	0.014	0.009	0.014	0.021	0.012	0.011
Al	1.977	1.958	1.942	1.953	1.974	1.949	1.939	1.956	1.988
Si	2.979	2.970	2.972	2.978	2.972	2.970	2.980	2.971	2.986
Ti	0.003	0.004	0.003	0.003	0.003	0.004	0.003	0.004	0.005
Mol.% end-members[d]									
Pyrope ($Mg_3Al_2Si_3O_{12}$)	51.46	49.61	48.88	47.99	43.93	43.95	42.83	43.34	37.67
Grossular ($Ca_3Al_2Si_3O_{12}$)	2.37	3.06	1.64	1.84	2.72	2.16	2.80	1.77	10.21
Spessartine ($Mn_3Al_2Si_3O_{12}$)	35.93	38.40	38.40	38.74	43.47	43.03	43.85	44.05	47.16
Almandine ($Fe^{2+}_3Al_2Si_3O_{12}$)	7.08	5.36	6.60	7.18	6.79	6.55	6.02	6.64	3.79
Goldmanite ($Ca_3V^{3+}_2Si_3O_{12}$)	2.72	2.93	3.73	3.56	2.67	3.61	3.46	3.62	0.64
Uvarovite ($Ca_3Cr_2Si_3O_{12}$)	0.44	0.64	0.75	0.69	0.42	0.70	1.04	0.58	0.53

[a] *Average composition of 15 analyses each.*
[b] *Total iron as FeO.*
[c] *Calculated on the basis of 12 oxygens.*
[d] *Pure end-member formulas are from Deer et al. (1992)*

RESULTS FOR THE BLUE-GREEN COLOR-CHANGE GARNETS

Visual Appearance and Gemological Properties. All the rough samples were irregular fragments of originally larger crystals. No external crystal faces were observed.

All samples, faceted and rough, revealed a homogenous bluish green, blue-green, or greenish blue color in daylight, with a distinct change to purple in incandescent light (again, see figure 1). The color of this new material under both lighting conditions is close to that seen in the natural alexandrite from Russia's Ural Mountains that is currently available in the trade. The variation in color from one sample to another was small. Refractive indices were found to vary within a small range, from 1.759 to 1.767. The densities ranged from 3.87 to 3.93 g/cm^3 (table 1). All the blue-green garnets were inert to both long- and short-wave UV radiation.

Chemical Properties. All eight blue-green garnets analyzed were relatively homogeneous in composition, without any distinct chemical zoning. All were members of the pyrope-spessartine solid-solution series, with pyrope contents from 43 to 51 mol.% and spessartine contents from 36 to 44 mol.% (table 1). All also contained minor percentages of almandine and grossular. In addition, these blue-green color-change samples revealed unusually high amounts of vanadium (0.89–1.25 wt.% V_2O_3) and distinctly smaller percentages of Cr_2O_3 (0.14–0.36 wt.%; see table 1).

Spectroscopic Properties. The absorption spectrum of the blue-green samples consists of one strong, broad absorption band with a maximum at 571 nm, and a second strong band in the blue-to-violet range with three distinct maxima at 408, 422, and 429 nm (figure 2). Between these two major absorption bands, we always observed four somewhat weaker maxima at 459, 483, 503, and 518 nm.

This type of spectrum is consistent with the data reported in the literature for vanadium-bearing pyrope-spessartines (see, e.g., Schmetzer and Ottemann, 1979; Schmetzer et al., 1980); the absorption bands were assigned to V^{3+} (571 nm), Mn^{2+} (408, 422, and 483 nm), Fe^{3+} (429 nm), and Fe^{2+} (459, 503, and 518 nm). The absorption bands of Cr^{3+} in garnets occur at positions (about 570 nm) almost identical to those of vanadium and, thus, the two superimposed absorptions cannot be separated. Because of the high intensity of the V^{3+} (plus Cr^{3+}) absorption band in the yellow region, an absorption minimum always is found in the blue-green range, at about 474 to 476 nm.

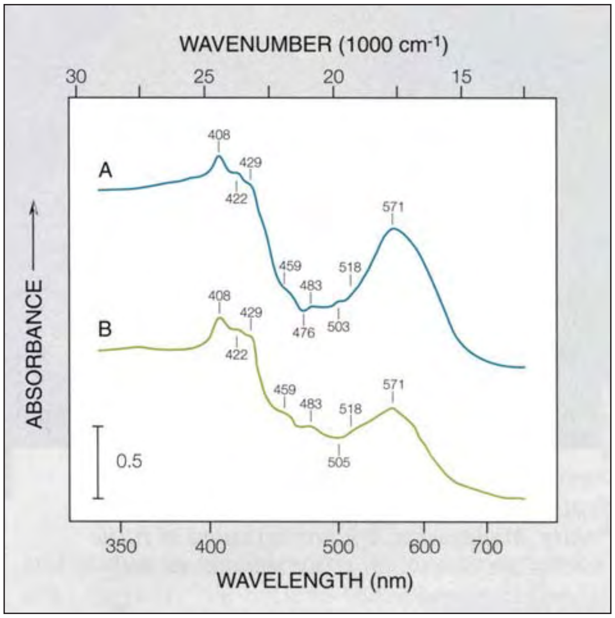

Figure 2. These visible-range absorption spectra are representative of two types of vanadium-rich and chromium-bearing color-change garnets from Madagascar: (A) blue-green and (B) greenish yellow. Absorption maxima were assigned to V^{3+} (plus Cr^{3+}), Mn^{2+}, Fe^{3+}, and Fe^{2+}; absorption minima (which are responsible for the different colors in day and incandescent light) are found in the blue-green (around 476 nm) and green (around 505 nm) areas of the visible range, respectively.

Properties Observed with the Microscope. When examined with crossed polarizers, all samples revealed strong anomalous double refraction (figure 3); growth patterns were rare. In most of the blue-green garnets, needle-like inclusions were present in four orientations (again, see figure 3). The angle between any two sets of these inclusions always measured 70°. With one set parallel to the direction of view in the microscope, we always saw a network of the three remaining sets of needles (figure 4), but the axes of these other needles were never oriented perpendicular to the plane of view. From these observations, it is evident that the needles were oriented parallel to the four [111] axes of the garnet.

Electron microprobe analysis of the needle-like inclusions in some of the blue-green garnets

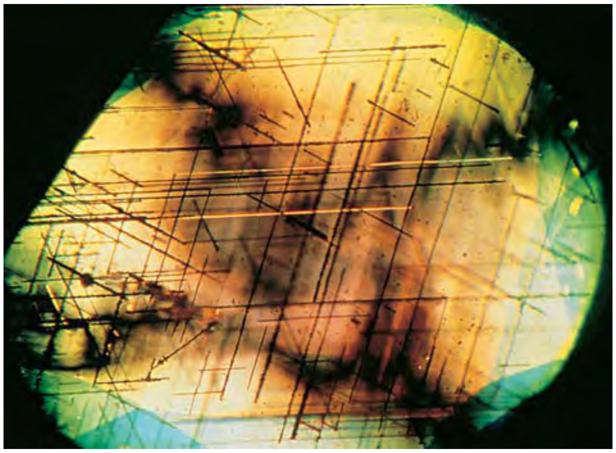

Figure 3. Anomalous double refraction is evident in this blue-green color-change garnet from Bekily, Madagascar. Four orientations of rutile needles are also present. Immersion, crossed polarizers, magnified 30×.

revealed that they were rutile, which was confirmed by Raman analysis. The diameter of these rutile needles was in the range of 3 μm.

In a few samples, we also saw small, rounded mineral inclusions. However, these have not yet been identified.

DISCUSSION

Comparison with the Greenish Yellow Color-Change Garnets. As also is evident in table 1, the densities and refractive indices of the two greenish yellow samples from Madagascar were within the ranges of density and R.I. for the blue-green samples. Chemical analysis, however, revealed that the greenish yellow sample contained somewhat less pyrope and almandine, and more spessartine, with distinctly more grossular. The microprobe analyses also revealed a chromium content in the same range as for the blue-green material, but there was distinctly less vanadium in the greenish yellow sample. The most prominent internal features were dense groups of small, thin "needles" in different orientations.

The lower percentages of V_2O_3 and FeO in the greenish yellow garnet result in the day- and incandescent-light colors that differ from those of the blue-green material (figure 5). Although absorption bands of V^{3+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, and Fe^{2+} in the spectrum (again, see figure 2) of the greenish yellow garnet resemble those of the blue-green garnets, the former has an absorption minimum in the green range near 505 nm. Also contributing to the different colors of the greenish yellow material are the lower intensity of the vanadium-chromium band in the yellow range and of the iron bands in the green region.

Comparison with Other Vanadium-Bearing Garnets. Subsequent to the description of a vanadium-bearing green gem grossular from southern Madagascar (Mercier et al., 1997), we now have examined two types of vanadium-bearing garnets from this island nation, in this case color-change members of the pyrope-spessartine solid-solution series. The chemical properties and colors of the greenish yellow sample were similar to color-change garnets from Sri Lanka and Tanzania that have been known for about 20 years (Schmetzer and Ottemann, 1979; Schmetzer et al., 1980; Stockton, 1982; Gübelin and Schmetzer, 1982; Manson and Stockton, 1984; Stockton and Manson, 1985).

The unusual blue-green color of the new color-change garnets from Bekily is due mainly to an extremely high vanadium content. A similar high amount of V_2O_3 for pyrope-spessartine garnet has been mentioned previously only once, for material from East Africa (Koivula and Kammerling, 1988). Recently described samples from Sri Lanka (Johnson and Koivula, 1996a and b, 1998a) are even closer in color to the new blue-green material from Madagascar, but chemical analyses for these garnets have not been published.

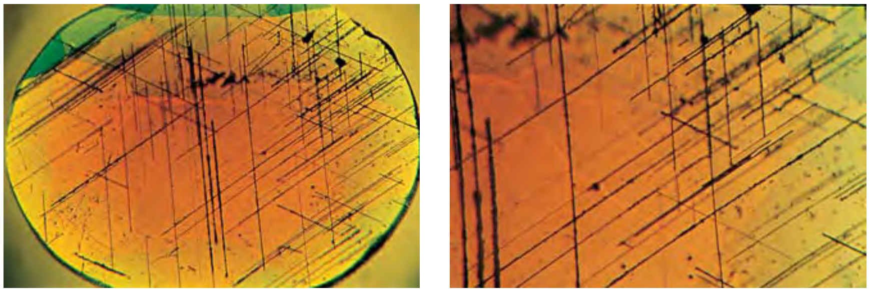

Figure 4. As seen with immersion at different magnifications in the same stone (30×, left; 50×, right), three sets of oriented rutile needles are visible in this blue-green color-change garnet from Bekily, in a view parallel to one of the [111] directions of the garnet. Each set is oriented at 70° to an adjacent set.

Figure 5. The two types of color-change garnets from Madagascar are shown here as they appear in day or fluorescent light (left) and incandescent light (right). The 0.35 ct blue-green sample is rich in vanadium, with some chromium. The 0.44 ct greenish yellow sample has less vanadium and comparable amounts of chromium. Photo by Maha Tannous.

An unusual pyrope-spessartine with even higher contents of vanadium and chromium (2.08 wt.% V_2O_3, 1.05 wt.% Cr_2O_3), which came from Sri Lanka, was bluish green in daylight but did not show much of a color change (Schmetzer and Ottemann, 1979). The absorption maximum of its V^{3+} (plus Cr^{3+}) absorption band occurred in the yellowish orange region at 588 nm. This value is below the small range (562–578 nm) within which an alexandrite-like color change can be seen in gem materials.

CONCLUSION

Commercial quantities of a pyrope-spessartine garnet that is bluish green to greenish blue in daylight and purple in incandescent light have entered the gem market. We believe that these are the first commercially available (almost) blue garnets. The blue-green color is caused by unusually high amounts of vanadium. Microscopic examination revealed the presence of four sets of needle-like inclusions, with each set at an angle of 70° to the others. Analysis of these inclusions in some of the samples showed that they were rutile. A greenish yellow color-change garnet, also from Madagascar, contained less pyrope and almandine, more spessartine, and distinctly more grossular. This material also revealed significantly less vanadium than the blue-green color-change garnets.

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GIA GEM TRADE LAB NOTES

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BERYL with Unusual Eye

The West Coast lab recently examined what at first appeared to be a brown chatoyant cabochon. The refractive indices of 1.577–1.583, uniaxial negative optic character, and specific gravity of 2.72 (measured hydrostatically) identified the material as beryl. In transmitted light, the overall brown color of the 8.80 ct cabochon was clearly banded with thin brown layers oriented parallel to the length of the cabochon (figure 1). The stone showed no spectrum (when viewed with a desk-model spectroscope) or fluorescence; its pleochroic colors were brown and black.

Observation with magnification revealed finely laminated twinning planes throughout the stone (figure 2). Because of dense layers of brown inclusions along these planes, they appeared dark and translucent; however, the areas between the planes were colorless and transparent. These growth structures and inclusions not only proved that the beryl cabochon was natural, but they also were responsible for its unusual appearance.

When viewed through the flat back of the cabochon, the stone looked almost completely colorless; the refraction caused by the curved surface of the cabochon created the brown face-up appearance. The only area where the colorless layers could be seen through the top was at the apex of the cabochon. At this point, the vertical orientation of the twinning planes created a transmission "window" that allowed the viewer to see through the stone (again see figure 1). The colorless band along the top of the brown stone gave the appearance of an eye. However, this "eye" moved across the cabochon only to a limited degree as the stone was rocked. This phenomenon would have to be referred to as a "pseudo-eye," since *chatoyancy* is defined as a product of reflection from oriented inclusions (see the *GIA Jeweler's Manual*, 3rd ed., 1989).

Because the "eye" was actually a zone where one could see through the stone, it assumed the color of the background over which it was placed. When the cabochon was viewed from the side, perpendicular to the twin planes, it showed a very weak diffused star. *SFM*

Figure 1. This 8.80 ct brown cabochon is natural beryl. Vertically oriented, densely included twinning planes with colorless zones in between form the apparent "eye." Transmitted light, magnified 10×.

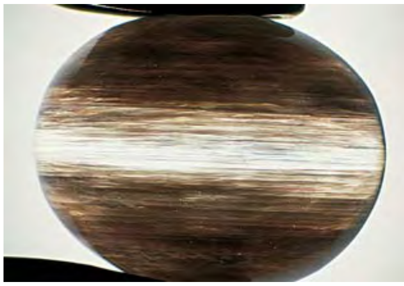

Figure 2. Dense layers of brown inclusions along lamellar twinning planes give this beryl its brown color. Magnified 15×.

DIAMOND

Exhibiting Much Fire

A friend of the East Coast lab recently showed us a 2.31 ct round brilliant (figure 3), which this diamantaire described as a "fireball," for possible use in our ongoing research into how cutting proportions affect the face-up appearance of a round brilliant cut diamond. The diamond exhibited a great deal of fire (the face-up expression of how a diamond disperses white light into its component colors) and showed strong contrasts of bright and dark

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Figure 3. This 2.31 ct round brilliant diamond appeared very fiery when rocked in ordinary room light, or, as here, when illuminated with a narrow incandescent light source.

areas, especially when it was rocked from side to side. We recorded the following proportions: 34.1° crown angle, 42.4° pavilion angle (45.6% pavilion depth), 55% table size, 59.7% star-facet length, 85.3% lower-girdle-facet length, a fully faceted girdle varying from medium to slightly thick, and a small culet. The symmetry was very good; the primary faults were two flat spots in an otherwise round outline, and a slightly uneven crown height (i.e., the table was not parallel to the girdle). These proportions would receive a cut grade of 5 from AGS, midway between their best grade of 0 and their worst one of 10, and this combination produces a "typical" WLR value of 0.277. (For an explanation of WLR, see T. S. Hemphill et al., "Modeling the appearance of the round brilliant cut diamond: An analysis of brilliance," *Gems & Gemology*, Fall 1998, pp. 158–183.) *IR*

Identifying Treated-Color Rough with the Spectroscope

The GIA Gem Trade Laboratory has issued reports distinguishing between natural-color and treated-color yellow diamonds since the 1950s. The spectroscope is a necessary tool for this identification, as discussed in two landmark 1957 *Gems & Gemology* articles by G. R. Crowningshield ("An introduction to spectroscopy in gem testing," Summer 1957, pp. 46–55; and "Spectroscopic recognition of yellow bombarded diamonds and bibliography of diamond treatment," Winter 1957, pp. 99–104). Despite technological advances in treatment methods, and the common use of spectrophotometers in today's gem testing labs, the spectroscope remains invaluable. This was clearly demonstrated by the case of the yellow octahedron shown in figure 4, which was submitted to the East Coast lab for color-origin determination.

Figure 4. Examination with a desk-model spectroscope proved that this 13.12 ct diamond crystal was treated to enhance its yellow color.

The 13.12 ct crystal showed a variety of etched features, striations, trigons, channels, and cavities (see Yu. L. Orlov, *The Mineralogy of the Diamond*, John Wiley & Sons, New York, 1973, for illustrations), which were shiny and transparent, indicating that this was a natural diamond crystal. When the crystal was examined over diffused light, the bodycolor looked quite pale, and careful comparison of the appearance viewed from all sides showed one face to be somewhat more yellow than the other seven. A desk-model spectroscope showed a strong line at 415 nm, but no band at 478 nm; the latter is the most easily observed part of the "Cape" series spectrum that produces yellow in strongly colored yellow diamonds. Instead, there were strong lines at 496 and 503 nm, and a weak line at 595 nm. The diamond fluoresced a moderate chalky green-yellow to long-wave UV radiation; this was localized at the face that appeared darker in color. Weak orange fluorescence was observed with short-wave UV. This diamond crystal did not show any green luminescence to strong transmitted visible light.

A pair of lines in the hand spectroscope at 495 and 503 in a yellow diamond can indicate natural color, when the pair is associated with green "transmission" luminescence, but in the absence of this property they suggest laboratory treatment. Such treated-color diamonds usually also show a line at 595 nm and/or a pair of lines in the near-infrared region (A. T. Collins et al., "Spectroscopic studies of the H1b and H1c absorption lines in irradiated, annealed type-Ia diamonds," *Journal of Physics C: Solid State Physics*, Vol. 19, 1986, pp. 3933–3944). We checked the visible-range spectrum with a Hitachi U-4001 UV-visible spectrophotometer, and verified that the pair of lines seen in the hand spectroscope corresponded to the well-known bands associated with the H3 (503 nm) and H4 (496 nm) color centers. We also obtained both mid- and near-infrared spectra, which revealed a weak H1b line (4935 cm^{-1}) and a very weak H1c line (5164 cm^{-1}), and confirmed what the desk-model spectroscope had indicated (and the color and fluorescence zoning had suggested): The yellow color of this diamond crystal was due to laboratory irradiation and annealing.

IR

Yellow to Yellow-Green Diamonds Treated by HPHT, from GE and Others

Researchers from the Superabrasives division of General Electric Company (GE) recently announced a new product they have developed: strongly luminescent greenish yellow to yellow-green diamonds, or saturated yellow diamonds, that have been transformed from natural type I brown diamonds (J. Casey, pers. comm., 1999).

GE has indicated that, unlike most earlier treated-color diamonds in this hue range, the stones are not exposed to laboratory radiation; rather, GE uses

Figure 5. These representative greenish yellow to yellow-green diamonds, each approximately half a carat, were treated by a high-temperature, high-pressure process at GE Superabrasives.

high-pressure, high-temperature (HPHT) treatment. These are the same general conditions that GE researchers described in the Fall 1999 issue of *Gems & Gemology* (see the box titled "Research on diamonds at the General Electric Company," by T. Anthony and J. Casey, on page 15 of the article "Observations on GE-Processed diamonds: A photographic record," by T. M. Moses et al.). Although the exact conditions to which these colored diamonds are exposed have not been divulged, we believe that they are roughly similar to those used to remove color from type IIa diamonds.

Figure 5 shows the color range of this new product. These diamonds are quite similar in appearance and gemological properties to the luminescent "green transmitters" that we observed in the fall of 1996 and reported in the Summer 1997 Lab Notes section (p. 136). We thought at that time that the treatment was probably being done in Russia with the presses that are used to grow synthetic diamonds, a suspicion that was later confirmed through conversations with a client.

Over the last several months, GIA researchers have also examined similar colored diamonds, also with strong green luminescence, that were loaned to us by Novatek Company (Provo, Utah). Novatek has recently begun to market this product under the name Novadiamond and plans a formal announcement to the trade at the February Tucson show. Novatek representatives have told us that these diamonds, too, are subjected to an HPHT process, for which a patent is pending. More recently, a New York client brought us yet another selection of similar treated-color diamonds from the Far East, reportedly treated in China (figure 6).

We have had the opportunity to test samples from each group—General Electric, Novatek, and reported Chinese—and our preliminary results for 47 of these diamonds show that their properties are similar to those described in the 1997 Lab Note mentioned above. The treated diamonds fluoresce a strong greenish yellow to long-wave UV, and generally a weaker greenish yellow to short-wave UV, with some localized chalkiness to both. For all three groups, the mid-infrared spectra showed that these were type I diamonds, with moderate to high amounts of nitrogen, and typically with more B aggregates than A aggregates (see, e.g., E. Fritsch and K. Scarratt, "Natural-color nonconductive gray-to-blue diamonds," *Gems & Gemology*, Spring 1992, especially pp. 38–39). Many of these diamonds showed well-defined color zoning, with brown to yellow octahedral graining observed when examined with diffused light. Excitation with a strong light source such as a fiber-optic illuminator causes these colored graining planes to luminesce bright green; this luminescence strongly contributes to their characteristic overall face-up greenish color.

Typical features observed with a handheld spectroscope in these HPHT treated-color diamonds are a weak absorption line at 415 nm, a pair of lines at 495 nm and 503 nm (which vary in strength from stone to stone), and emission lines at about 513 and 518 nm. This spectrum is not indicative of treatment for this color range, but it implies that the diamond requires further inspection. UV-Vis-NIR spectroscopy corroborated these absorption features, and showed the H2 peak (at 985 nm) in all of the samples that had a green component to the color. Magnification revealed that, like the treated-color diamonds described in 1997, a number of the samples from each source showed evidence of high-temperature exposure, such as frosted naturals, frosted feathers, or faceted girdles with bearding.

TM and IR

PEARLS

Freshwater Natural

The West Coast lab received two pearls, each approximately 13 mm in diameter, that a client had purchased some time ago in Hawaii. The client

Figure 6. This group of brownish yellow to greenish yellow diamonds, ranging from 0.22 to 0.39 ct, were reportedly treated by an HPHT process in China.

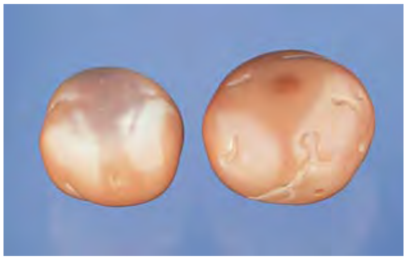


Figure 7. These brownish pink baroque pearls, each approximately 13 mm, proved to be of freshwater origin.

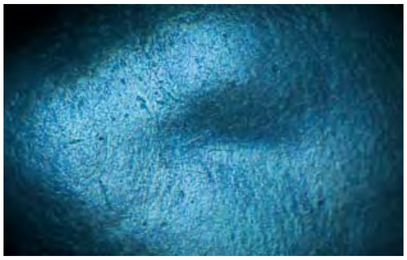


*Figure 8. The fine suture lines on the side with high luster of each of the pearls in figure 7 indicated natural pearl formation. Magnified 20*x*.*

*Figure 9. The honeycomb structure of the dull side on each of the pearls in figure 7 is typical of the prismatic calcite layer seen in shells. Magnified 30*x*.*

had been told that the pearls originated from the South Seas. A preliminary examination showed an appearance unlike the lustrous pearls that are commonly found in South Sea waters, but rather like that of calcareous concretions, or nonnacreous pearls. As can be seen in figure 7, they were uneven brownish pink in color and slightly baroque in shape.

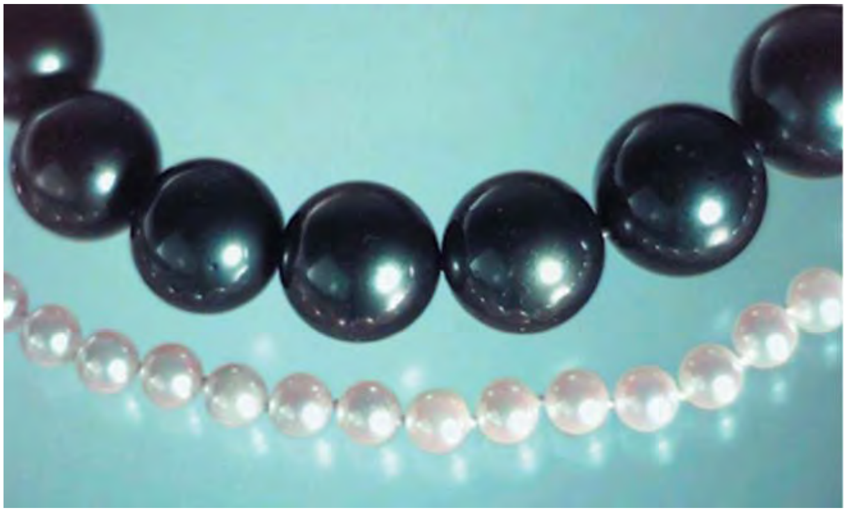
It also was obvious to the unaided eye that each showed quite a range of luster: One side had a fairly high luster, and the opposite side was rather dull. Examination with magnification in reflected light revealed the fine suture lines (mottled surface texture) that are indicative of pearl formation (figure 8), whereas the duller area had the honeycomb structure usually seen in the prismatic calcite layer of shells (figure 9). The X-radiograph also showed structural features that indicate natural pearl formation. Much to our surprise, the pearls luminesced a weak yellowish white to X-rays. This confirmed that these natural pearls were of freshwater rather than saltwater origin. Even though we cannot prove their provenance, it is interesting to note that contributing editor G. Robert Crowningshield recalled having examined similar brownish pink natural pearls that had been brought from Pakistan for the New York World's Fair in 1964 (B. Anton, "Pink pearls of Pakistan," *Gems & Gemology*, Vol. 11, No. 6, 1964, pp. 175–179, 191). *KH*

Notable Strand of Large Black Cultured Pearls

The East Coast lab recently received a strand of 23 round cultured pearls that graduated in size from 19.18 mm to 15.68 mm (figure 10). While we have tested larger individual black cultured pearls (Gem Trade Lab Notes, Winter 1987, pp. 234–235), these cultured pearls are notable for their consistently large size throughout the strand. The X-radiograph showed that they were bead nucleated, with nacre of varying thickness. Examination with long-wave UV radiation revealed a weak reddish brown fluorescence in all of the cultured pearls, which proved that they were of natural color.

When we observed the strand in standardized lighting and viewing conditions, we described all of the cultured pearls as black using the Pearl Description System in GIA's 1999 *Pearls* course. Note that the GIA color description system represents a range of color sensations. Therefore, even though some of the cultured pearls in the strand displayed a subtle increase in saturation from neutral

Figure 10. Pictured next to a strand of typical-size 6.5–7.0 mm pearls, this strand of black cultured pearls, which graduate from 19.18 to 15.68 mm, is one of the largest we have encountered.



black toward greenish black, all of them still corresponded to the range described as black. The most noticeable variation in appearance within the strand was due to the presence of a pink overtone on some of the cultured pearls. *Akira Hyatt*

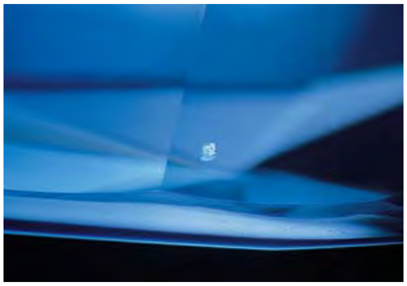
SAPPHIRE

With a Valuable Inclusion

Many jewelers and gem dealers still tend to regard inclusions as mistakes of nature that diminish the quality of what otherwise might be a perfect gem. Now that the vast majority of rubies and sapphires are heat treated, a little inclusion can go a long way toward insuring that a fine gemstone is of natural color. Such was the case with a transparent 3.02 ct oval mixed-cut blue sapphire that was submitted to the East Coast lab for identification.

With near-monochromatic sodium-equivalent light, the stone showed refractive indices of 1.761–1.769. No fluoresence reaction was observed to either long- or short-wave UV radiation. A typical iron absorption spectrum was noted through a desk-model spectroscope. The presence of angular growth and color zoning, seen with a microscope, made it easy to determine that this sapphire was natural. The more difficult part of the identification was establishing whether the blue color was of natural origin or the result of heat treatment. There was no evidence of heat treatment present, but the color zoning alone was not enough to prove natural color either.

Figure 11. Measuring only 0.09 mm in largest dimension, this tiny carbonate inclusion proved that the host, a natural sapphire, had not been heat treated.



A careful facet-by-facet search finally resulted in the discovery of a tiny (only 0.09 mm) transparent crystal. It was situated near the girdle edge on the pavilion side. When examined with polarized light, the inclusion exhibited birefringence (figure 11). There were no signs of any heat damage associated with this inclusion. It was so small, however, that its reaction to polarized light might have been anomalous. Only by identifying this inclusion could we determine conclusively if the host sapphire had been heat treated (from the expected reaction of the mineral to heat treatment).

Because the crystal was very close to the surface, we used laser Raman microspectrometry. We were able to obtain a clear Raman spectrum, which most closely matched the pattern shown by the mineral calcite, although other carbonates such as dolomite could not be ruled out. The identification of this transparent mineral inclusion as a carbonate proved that the host sapphire had not been heat treated to improve its color, because a carbonate such as calcite or dolomite would not have survived the high temperatures (□1500°C) commonly used to effect a color change in corundum.

In the case of this sapphire, an inclusion was an extremely valuable asset, because it enabled us to state on the report that the stone was of natural color. *John I. Koivula*

With High Refractive Indices

A semi-transparent, brownish orange, rectangular cushion-shaped mixed-cut stone set in a yellow metal ring was recently submitted to the East Coast lab for identification (figure 12). The stone measured approximately 8×12 mm. With the microscope, we observed abundant "rust" red to dark brown and black tiny, skeletal crystal inclusions. These inclusions (figure 13) contributed to the bodycolor of their host as well as to its slight turbidity; they looked very much like the exsolution crystals of ilmenite and hematite often seen in similarly colored sapphires from the Umba River region in Tanzania. The simultaneous reflectance and iridescence of the inclusions showed that they were oriented in distinct

Figure 12. This 8×12 mm brownish orange stone proved to be a natural sapphire, but with unusually high refractive indices.

Figure 13. The numerous skeletal inclusions in this sapphire appeared to be responsible for at least part of the bodycolor of their host. Magnified 40×.

planes, which supported the possibility that these inclusions had exsolved from their host. After this initial phase of the examination, it seemed that the identification would be relatively straightforward, and we moved on to the next step, obtaining a refractive index reading.

The table facet was well polished, and raised above the mounting, so we anticipated no difficulty in measuring the R.I.'s accurately. Using a near-monochromatic sodium-equivalent light source, we obtained a reading of 1.770–1.779—a complete surprise. This is higher than any reading previously obtained in the Gem Trade Laboratory from any faceted sapphire of any color, with the exception of the diffusion-treated red corundum reported by S. McClure et al. ("Update on diffusion-treated corundum: Red and other colors," *Gems & Gemology*, Spring 1993, pp. 16–28). First we checked the refractometer carefully for damage to the hemicylinder contact surface, and then we inspected the table of the sapphire for cleanliness. Nevertheless, even with fresh R.I. contact liquid, the reading was the same. We next tested two faceted flame-fusion synthetic sapphires from our reference collection, one blue and one orange, on the same instrument as controls. These samples showed refractive indices in the expected range of 1.762–1.770, confirming that the refractometer readings were accurate.

The mounted sapphire was inert to both long- and short-wave UV radiation. Using a Beck desk-top prism spectroscope, we saw an absorption band between 520 and 580 nm, a cutoff in the blue from 490 nm down, and another cutoff in the red from 660 nm up. While this spectrum is consistent with the brownish red color of the gemstone, it is not diagnostic. Laser Raman microspectrometry confirmed the identification of this stone as sapphire; no unusual features were noted in the Raman spectrum.

We next turned to energy-dispersive X-ray fluorescence (EDXRF) analysis to see if the chemistry offered any clues as to why the R.I. readings were unusually high. We analyzed the sapphire for both major and trace elements using an EDXRF Spectrace 5000 instrument. In addition to the expected aluminum, the analysis showed iron, chromium, titanium, gallium, and vanadium. The strength of the iron peak as compared to the others suggested as much as 2 wt.% FeO. This amount of iron could account for the lack of fluorescence even with the presence of chromium and vanadium, as iron tends to quench fluorescence. The iron might also be responsible for the elevated R.I.'s. In *Gems* (4th ed., Butterworths, London, 1983, especially p. 91), Webster reports that some iron-rich green sapphires show elevated refractive indices of 1.77 and 1.78. While we have seen similar-appearing sapphires in the past with slightly elevated refractive indices, this is the first one we have encountered with this extreme reading.

John I. Koivula and Shane Elen

PHOTO CREDITS

Shane McClure took figures 1 and 2. Vincent Cracco and Elizabeth Schrader took figure 3. Elizabeth Schrader was the photographer for figures 4 and 6. Maha Tannous provided figures 5, 7, and 12. John Koivula photographed figures 8, 9, 11, and 13. John M. King supplied figure 10.

GEM N·E·W·S

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DIAMONDS

Can Angolan diamonds be identified by country of origin?

There have been a number of reports recently on the sale of diamonds to fund long-running civil wars in Africa, particularly in Angola and Sierra Leone (see, e.g., P. Hawthorne, "Diamonds in the rough," *Time*, December 6, 1999, pp. 64–65). After visiting these troubled areas in December, two U.S. Congressmen, Tony Hall (D–Ohio) and Frank Wolf (R–Virginia), have sponsored legislation (H.R. 3188) requiring disclosure of where diamonds are mined, so that a ban on diamond trade with the rebels in these areas can be enforced. Considering the geology of the Angolan diamond deposits, and of diamond deposits in general, how accurate could such an origin determination be? What scientific tests might be used to establish where a diamond is mined? How practical would it be to attempt such an identification?

Some indications can be gathered from the world of colored stones, where country-of-origin determination has become a popular laboratory service for important rubies and sapphires. In a recent lecture, Ken Scarratt of the AGTA Gemological Testing Center described the many kinds of data his lab needs to determine conclusively the origin for, at most, 90% of the gemstones they are asked to test (T. Novellino, "AGTA lab explains gem origin determinations," *National Jeweler*, December 1, 1999, p. 22). He went on to explain that the gathered data must then be compared to a large database made from observations of rubies or sapphires known by other means to be from a specific location in order to reach a conclusion. Such testing can take hours to days per stone.

A large database of diamond properties applicable to geographic origin determination does not exist. However, on a statistical basis, diamonds from certain countries and specific mines do have distinctive features. For example, cubic diamonds are common from the Democratic Republic of Congo (formerly Zaire) but relatively rare elsewhere; a high proportion of the world's rare type IIa diamonds come from South Africa (the Premier mine); diamonds with a green skin are abundant in Botswana (the Jwaneng mine); Australia's Argyle mine yields diamonds with highly saturated pink and dark brown colors; and gem diamonds from Russia are commonly flat-faced octahedra with sharp edges. However, many of these characteristics are not applicable to faceted diamonds, and none of these features is exclusive to a specific locality when the stones are considered on an individual basis. Tests such as analysis of the inclusions or physical properties of the diamond (e.g., with cathodoluminescence or infrared spectroscopy) also fail to yield results that are specific, conclusive, or unequivocal with regard to origin determination.

Some reasons for the lack of diagnostic inclusions or physical properties are found in the geologic origin of diamonds. Because diamonds form deep in the earth's mantle (at about 125–150 km) and are transported to the surface by volcanic processes (kimberlite or lamproite magmas), stones that crystallized in the same area of the mantle conceivably can be found in diverse geographic localities. Such diamonds could contain similar inclusions and other characteristics, regardless of where they were ultimately emplaced at the earth's surface. Further, the diamond-bearing magmas might have sampled more than one mantle source area during their rise toward the earth's surface, so a single source area can contain diamonds with

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different formation characteristics. The situation is further complicated in Angola by the fact that most of the diamonds are being mined from alluvial deposits; that is, they were transported from kimberlite pipes elsewhere in Angola or nearby countries in Africa.

Because mineral inclusions in diamonds tend to fall into one of two broad groups (eclogitic and peridotitic), reflecting their mantle source region, it is not likely that such inclusions would be diagnostic regarding the country of origin, even with a study of their trace elements, isotopic signatures, or other characteristics. With current technology, such studies require direct access to the inclusion within the diamond, which is inevitably destructive for stones with non-surface-reaching inclusions. Furthermore, many gem diamonds do not contain mineral inclusions at all. Trace elements in diamond itself have been studied by neutron activation, but this method produces some residual radioactivity in the diamond so that, after measurement, it must be held at a licensed facility before it "cools" enough to be released for sale. Other potentially relevant geochemical methods are also problematic. For example, measuring carbon or nitrogen isotopes to indicate a geographic source has not been shown to yield definitive answers.

Assuming that a database of characteristics for diamonds from different deposits was created, and that some diagnostic properties were identified for the deposits of interest, testing diamonds quickly enough would still be a Sisyphean task. Approximately 10 million diamonds of 0.50 ct or more, of all qualities, are cut annually worldwide. Even with multiple graders in multiple venues, a massive and expensive effort would be required. Given these constraints, it is unlikely that analytical testing of diamonds to determine their place of origin can be made practical—either immediately, as Congressmen Hall and Wolf are proposing, or in the foreseeable future.

Dr. A. A. Levinson
University of Calgary, Calgary, Alberta, Canada
Dr. Ilene Reinitz
GIA Gem Trade Laboratory, New York

A visit to Venezuelan diamond mines. While traveling in Venezuela in late 1998, GIA Distance Education instructor Ric Taylor had an opportunity to visit the alluvial diamond mining region of Guaniamo, in the state of Bolivar in central Venezuela. The following report is based on this visit.

Miners in Guaniamo use water cannons to wash the soil from the hillsides into pits (figure 1), from which it is pumped into rocker boxes or sieves. After washing, the gravel remaining in the bottom of each box is hand-sifted to recover the diamonds. The rough diamonds typically weigh 0.20–0.70 ct; they range from near colorless to intense yellow, with some brown and reddish brown (figure 2). About 20% of the diamonds are suitable for faceting.

Figure 1. Water cannons are used to mine diamonds near the Quebrada River in the Guaniamo region of Venezuela. Photo by Ric Taylor.

According to Venezuelan government records, in 1980 the Guaniamo area produced more than 75% of the country's rough diamonds. The neighboring towns of La Salvación and Milagro are in the center of the diamond-mining area. The towns lie along the Quebrada River, the alluvial distribution system in Guaniamo. In La Salvación, the miners have washed away the ground right up to the edges of buildings; in a few areas, buildings have been undermined and are falling into the artificial lakes created by the diamond-mining operation.

Diamond production appears to have decreased significantly in recent years. For example, according to engineer

Figure 2. These well-formed diamond crystals from Venezuela weigh 0.07–1.03 ct. Courtesy of Ric Taylor; photo by Maha Tannous.

Tiso Campo of the Associación Cooperativa Mixta La Salvación (which manages the mining area of La Salvación), the cooperative produced 9,930 carats in 1997, down from 32,393 carats in 1994. After watching several miners walk away from the cooperative's official buyer, unhappy with the prices they were offered, one might suspect that the diamonds are being sold through other, more profitable channels; this would account for the decrease in official production figures. During my visit to La Salvación and Milagro, however, I saw evidence that the population of the two towns had dwindled. Some stores had closed and others, although still open with sparsely stacked shelves, were for sale. This observation was reinforced when I talked to long-time residents of the two towns. Apparently, there was wealth at one time, but now everything seems to be a struggle. Nevertheless, new miners move into the area regularly, with the ever-present dream of waking up poor and going to bed rich.

An international mining concern, Cantreras el Toco, has been surveying and exploring in La Salvación for more than 10 years. More information on diamond mining in Venezuela can be found on the Web site http://ganoksin.com/orchid/archive/9711/msg00333.htm.

Ric Taylor, GIA Education

Figure 3. These "Aggos"—thin slices of matte-finished Montana agates—were fashioned to bring out their colors and patterns. The shield shapes measure 24 x 22 x 0.8 mm. Courtesy of LS Enterprises/Montag Mfg.; photo by Maha Tannous.

Figure 4. These two slices of Montana agate (27 x 13 x 0.9 mm) have been set with similarly colored Montana sapphires. Courtesy of LS Enterprises/Montag Mfg.; photo by Maha Tannous.

COLORED STONES AND ORGANIC MATERIALS

Matte-finished Montana agates. Nature is an artist, as beautifully evidenced by the patterns and colors of many agates. To showcase Nature's talent, Montana photographer John Schlosser has fashioned agates from the Yellowstone River in eastern Montana into thin slices called "Aggos" that are cut to maximize the artistry of the patterns (figure 3). The slices are polished to a satin (low-luster matte) finish to bring out the color and patterns; they are fashioned with a "radiused" edge (a semicircular cross-section) for better edge-strength than a conventional cabochon would achieve. The agates are cut in thin slices so the patterns are sharper, and so pieces can be matched for use in suites of jewelry. Montana sapphires are set into some "Aggos" as accent stones (figure 4).

"Aggos" are marketed by LS Enterprises/Montag Manufacturing of Billings, Montana. We have seen them in the trade since the 1997 Tucson show, when *Gems & Gemology* technical editor Carol M. Stockton first called them to our attention.

Dickite: Consider the odds. There are currently more than 3,500 known minerals, and the list continues to grow. Although some minerals occur as isolated single crystals (as is the case with most gem rough), the majority occur only as components of rocks. When rocks are used as ornamental materials, they generally are carved or fashioned into beads.

As a gift, GIA graduate Kelly Huang, an octogenarian gem carver and jewelry designer in Malaysia, sent GIA chairman Richard T. Liddicoat a printing block carved with Mr. Liddicoat's likeness (figure 5). The approximately 61 x 41 x 11 mm block was composed of a semitranslucent white to very light brown aggregate material. The contours of the carving were highlighted with black dye or ink. There were also red ink stains on the surface, which were the result of previous inking of the block before it was sent to GIA. When Mr. Liddicoat transferred the piece to GIA's gem collection, curator Jo Ellen Cole asked the Gem Trade Laboratory to identify the material for archival purposes.

The surface was too rough to obtain a refractive index. Since the block did not appear to be porous, a specific gravity of 2.61 was determined hydrostatically. No other gemological properties useful for identification could be obtained. Now that GIA has ready access to laser Raman microspectrometry, we turned to that technique for a possible identification. In preparation for analysis, the surface of the block was cleaned with alcohol to remove any grease. Using the 514 nm argon ion laser, we obtained spectra from three spots on the front and three on the back. All matched that of the mineral dickite in the Renishaw digital spectral library.

Named for British mineralogist A. B. Dick in 1930, dickite is a monoclinic mineral in the kaolinite-serpentine group. It has the chemical formula $Al_2Si_2O_5(OH)_4$, and is polymorphous with three other minerals (halloysite, kaolinite, and nacrite). For this reason, and because the Raman library does not contain spectra for all of the members of this large group, we have only tentatively identified this printing block as a rock composed of massive member(s) of the kaolinite-serpentine group, which has the Raman spectrum of the end-member mineral dickite.

Note, however, that this is not the first time that we have encountered dickite in a gemological sample. It was previously identified as a component of the Chinese carving material known as "chicken-blood stone" (see Wang Fuquan and Guo Jingfeng, "Chicken-blood stone from China," *Gems & Gemology*, Fall 1989, pp. 168–170).

To many of his friends, Richard Liddicoat goes by the nickname "Dick." What are the odds that, out of all of the possible known minerals and rocks, a printing block carved in his likeness would turn out to give us a Raman spectrum for dickite?

Figure 5. Raman spectra taken on this printing block "stone" carving of GIA Chairman Richard T. (Dick) Liddicoat, Jr. matched that of the mineral dickite. Photo by Maha Tannous.

Star ekanite. Recently, a 161 ct cabochon of dark green ekanite from Sri Lanka was loaned to this editor (KS) for examination. This unusual cabochon displayed an eight-rayed star that consisted of two four-rayed stars, one of which was more intense than the other (figure 6). (For a similar case of a double-rayed star, see the Summer 1999 Gem News item "Twelve-rayed star sapphire from Madagascar," p. 148.)

A rare mineral, ekanite is one of the few species that was first described as a gemstone (taaffeite is another). It was discovered in 1953 and described as a new mineral

Figure 6. This 161 ct (33 x 25 x 20 mm) oval cabochon is an eight-rayed star ekanite from Sri Lanka. Photo by M. Glas.

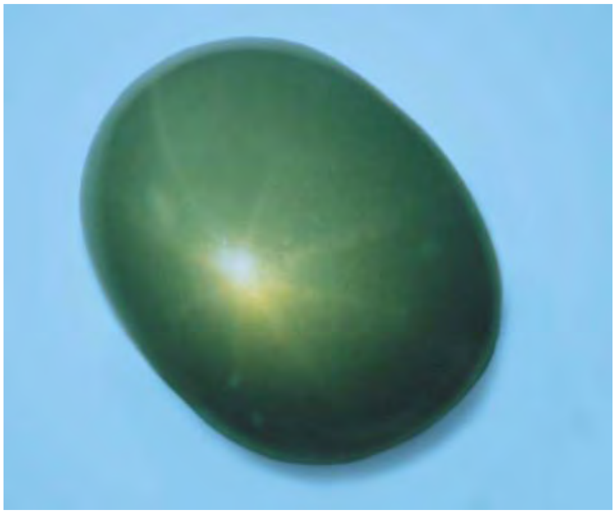


Figure 7. These five yellow and orangy yellow opals are from Nevada. The cabochons weigh 1.36 ct (yellow) and 1.73 ct (orangy yellow). The largest piece of rough weighs 4.57 ct. Courtesy of Richard Shull; photo by Maha Tannous.

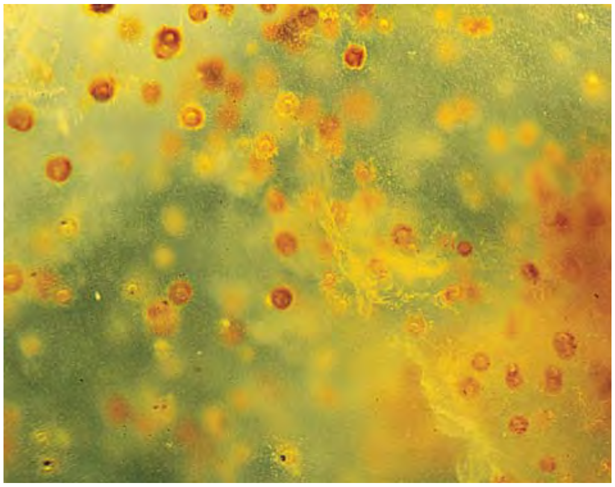


*Figure 8. The iron-stained spherical inclusions in this 1.73 ct opal cabochon resemble fish eggs. Photomicrograph by John I. Koivula; magnified 20*x.

in 1961 (B. W. Anderson et al., "Ekanite, a new metamict mineral from Ceylon," *Nature*, Vol. 190, No. 4780, p. 997). Today, gem-quality ekanite occasionally is found at Eheliyagoda, Sri Lanka. It still is considered quite rare, and four-rayed star ekanite is among the rarest of gemstones (see, e.g., J. E. Arem, *Color Encyclopedia of Gemstones*, 2nd ed., Van Nostrand Reinhold, New York, 1987, p. 86; M. Sevdermish and A. Mashia, *The Dealer's Book of Gems and Diamonds*, Kal Printing House, Israel, 1996, p. 284).

Chemically, ekanite is a thorium-bearing silicate that also may contain significant amounts of uranium; the original analysis by Anderson et al. revealed 2.1 wt.% UO_2. Ekanite from Sri Lanka is commonly metamict due to lattice damage by natural radioactivity. (A metamict mineral is one that has become virtually amorphous due to the breakdown of the original crystal structure by internal bombardment with alpha particles emitted by radioactive atoms within the mineral.) Asteriated ekanite from Sri Lanka typically reveals a weak four-rayed star, which echoes the tetragonal symmetry of the mineral prior to metamictization. The inclusions in asteriated ekanite were described by E. Gübelin ("Ekanite, another new metamict gem from Ceylon," *Gems & Gemology*, Vol. 10, No. 6, 1961, pp. 163–179, 191; and *Gemmologist*, Vol. 31, No. 373, 1962, pp. 142–157, and No. 374, 1962, pp. 165–169).

Microscopic examination of the eight-rayed star ekanite revealed a network of tiny elongated particles. At present, the nature of these inclusions, which are undoubtedly responsible for the unusual star pattern, is unknown. The only other reference to eight-rayed star ekanite is a recent review by W. L. D. R. A. Kumaratilake ("Gems of Sri Lanka: A list of cat's-eyes and stars," *Journal of Gemmology*, Vol. 25, No. 7, 1997, pp. 474–482), in which it was noted that the eight-rayed stars were associated with four sets of oriented inclusions intersecting at 45° to one other. *KS*

"American Golden opal" from Nevada. Richard Shull of Out of Our Mines, Arcata, California, provided the Gem News editors with several samples of rough and cabochon opal (figure 7) from a deposit in Nevada. The material is yellow in bodycolor and transparent to translucent. When we examined the more transparent material with a microscope, we saw round inclusions, some of which were iron stained (figure 8). In a number of samples, the iron-stained inclusions were so prevalent that the overall appearance was reminiscent of amber rather than opal (again, see figure 7). The two cabochons (1.36 and 1.73 ct) had refractive indices of 1.475 and 1.465, respectively; the five samples (rough and cut) had specific gravity values (measured hydrostatically) between 2.11 and 2.17. All were inert to both short- and long-wave UV radiation. None of the opals showed any play-of-color.

The formation of white zones in Mexican opals during fashioning. Natural opal can be frustrating for both the lapidary and the jeweler, as some opal is not stable during fashioning and normal conditions of wear and care. Often the surface develops fine cracks, a condition known as "crazing." In the case of some Mexican fire opals recently seen by this editor (EF), a different type of degeneration occurred.

The five opals examined ranged from 2.00 to 6.58 ct. Two independent cutters—Alexandre Wolkonsky of Paris and Denis Gravier of Le Minéral Brut, St. Jean le Vieux, France—mentioned that during or immediately following cutting (within one day), these opals developed somewhat spherical, opaque whitish internal zones that rendered the material inappropriate for gem use (figure 9). Thus, the alteration in these fire opals was quite fast and dramatic in contrast to crazing, which typically develops over months (sometimes years) in some opals (G. Tombs and M. Duncan, "Australian opal—stable or unstable," *Transactions of the 26th International Gemological Congress*, Paris, France, 1993, pp. 257–259).

The shape of the white zones roughly followed the shape of the fashioned pieces—that is, the zone looked elongated in the pear shape, round in the round stone, and triangular in the triangular piece. This suggests that the mechanical strain introduced by cobbing, preforming, or faceting is a major factor in the development of this type of alteration.

Both cutters pointed out that, with careful examination of the rough using intense fiber-optic illumination, they could identify pieces that might alter in this way by the presence of a roughly egg-shaped, slightly white area approximately in the center of the piece (figure 10). It was not visible with typical transmitted ambient lighting. According to Gem News editor John Koivula, opals with such zones also are found *in situ* in the mines; the zones occur in all degrees of transparency, from barely discernible with transmitted sunlight to opaque. The opals in which these zones are obvious probably are rejected at the source.

Mr. Wolkonsky told us that, in his experience, a small percentage of the fire opal rough delivered to him in the last 20 years has changed with time or fashioning. In addition to the white zones described above, he has also seen the development of a spherical fracture, or of a white outer area surrounding a transparent gem nodule in the center. In at least one case, he observed the development of a white zone in a piece of Mexican opal that showed play-of-color. *EF*

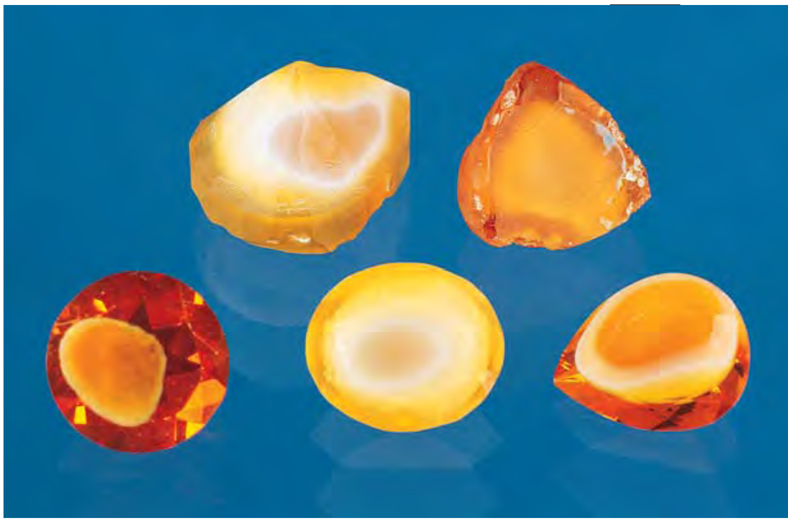
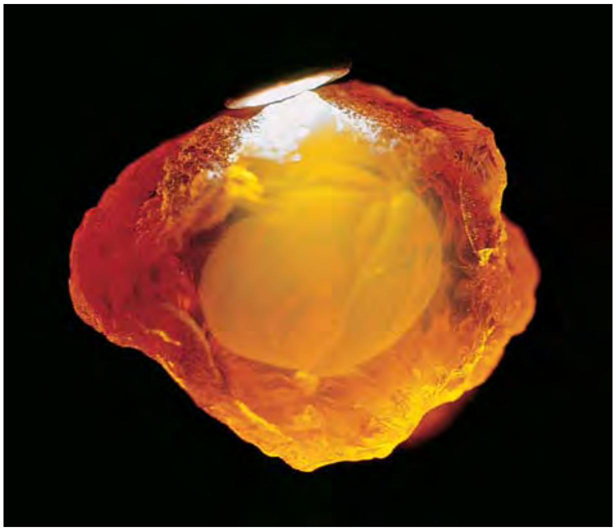


Figure 9. In these five Mexican opals (preformed or fashioned; 2.00–6.58 ct), white zones formed after fashioning had begun. Photo by Alain Cossard.

An update on the John Saul ruby mine. Dr. John Emmett provided the following update on mining and production at the famous John Saul ruby mine in Kenya, which was reopened by Rockland Kenya Ltd. in August 1995. The mine is located in the Tsavo West National Park in southern Kenya, on a flat, semi-arid plain. The history of this mine is perhaps as colorful as the gems it produces. Discovered in 1973 by two geologists, John Saul and Tim Miller, it rapidly became coveted by the family and friends of Jomo Kenyatta, then president of Kenya. The predictable result was that the two geologists lost control of the mine. For the next 20 years, mining was sporadic at best. In 1989, mining operations in the national parks were terminated by Richard Leakey, Kenya's director of Wildlife Conservation at that time. It seems that poachers of elephant and rhinoceros in the game parks were posing as miners to avoid discovery. By 1991, ownership, mining rights, and permits had finally been secured by Rockland Kenya Ltd., led by Johnson Muthama. Mining at the site resumed in 1995.

According to Cedric Simonet, chief geologist for Rockland Kenya, the ruby deposits at the John Saul mine are associated with the contact zone of a rounded ultrabasic body within the Kurase Group of country rock. In this locality, the Kurase Group consists primarily of metasediments such as marbles, graphite gneisses, and quartzites. The ultrabasic body appears almost white in color and is composed of magnesium-pyroxenes, magnesium-amphiboles, carbonates, and talc. Although several types of ruby mineralization are exhibited in different

Figure 10. A roughly egg-shaped white area, visible only with intense fiber-optic lighting, may be seen in the center of some Mexican opals that will later develop opaque white zones. This example weighs 2.09 g; photo by Alain Cossard.



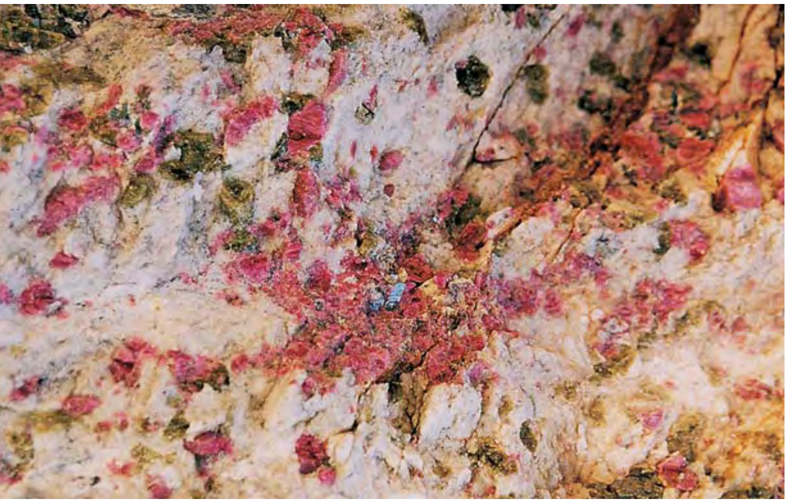


Figure 11. Note the high concentration of ruby in this 45 cm (18 inch) long portion of the ruby-bearing vein in the Kimbo pit. Photo © John L. Emmett.

Figure 12. These cabochons (8.67–17.85 ct) were fashioned from ruby that was recovered from the Kimbo pit. Photo by Maha Tannous.

portions of the John Saul mine, only two are responsible for significant ruby production. In the "Main pit," which was the first portion mined in the 1970s and 1980s, ruby was recovered from pegmatite-like veins inside the ultrabasic body. These veins are comprised of mica, tourmaline, and ruby. In the "Kimbo pit," ruby occurs at the interface of the ultrabasic body with the country rock. This interface is comprised of plagioclase, magnesian muscovite, green tourmaline, ruby, and minor amounts of graphite and monazite. The vein averages 1.2 m thick, although in some areas it reaches 2.5 m thick. A portion of that vein is shown in figure 11.

Today, Rockland Kenya is exploiting the Kimbo pit as their primary ruby production source. The broad ruby-bearing zone is mined by open-cast methods, as mineralization is present close to the surface. The removal of the barren host rock is a highly mechanized operation. Security at the mine is extremely tight and very professionally managed. At present, the pit is approximately 30 m deep. The mineralized zone, which was exposed to about 60 m from the surface, has widened to about 90 m at depth, extending southward. With increasing depth, both the color and clarity of the ruby improves, along with some changes in the mineralogical characteristics of the vein.

Much of the facet-quality ruby is recovered from eluvial gravels on the surface. The gravels are passed through a trommel to remove the fine-grained material and then are processed with a heavy-media concentrator. The specific gravity cut is made at about 2.9 so that chrome tourmaline—which is also present in the gravels—can be recovered as well.

Since the opening of the Kimbo pit in 1995, production at the John Saul mine has averaged well in excess of 100 kg of ruby per month. Of this, about 60% is cuttable, with 5%–10% representing top-quality material. The great majority of the ruby produced is of cabochon quality (figure 12); only rarely is facetable rough recovered. Some crystals are quite uniform in color, while others exhibit strong color zoning (see figure 13). The lack of transparency is due primarily to the large number of "fingerprint" inclusions and feathers. Polysynthetic twinning also is very common. Fine rutile needles, presumably exsolved during cooling, are typical and of sufficient density in some pieces to produce good stars. Among the other inclusions are large rutile grains and various micas including fuchsite (chromium-rich muscovite), although a definitive inclusion study remains to be done.

The iron content of the John Saul rubies is very low, typically 0.01% as Fe_2O_3. As a result, they fluoresce a very strong red, much like the famous rubies from the Mogok district of Myanmar. While the color of much of the material is also reminiscent of Mogok rubies, heat treatment is often used to improve it further by reducing or eliminating a slight blue hue to produce a purer red.

Figure 13. Strong color zoning is common in the rubies from the John Saul mine, as this basal section of a stone from the Kimbo pit illustrates. Photo © John L. Emmett.

Heat treatment of John Saul ruby also melts any micaceous inclusions, which sometimes flow to the surface of a stone. The glassy melt droplets that result may be easily confused with the residual flux inclusions typically observed in heat-treated Mong Hsu rubies (see, e.g., figure 1 on p. 90 of the Fall 1999 issue of *Gems & Gemology*).

While the John Saul ruby mine is already the stuff of legends, it would appear that it is only beginning its productive life.

Dr. John L. Emmett, JLE Associates
Brush Prairie, Washington

Ruby from Songea, Tanzania. In mid-1998, Randy Wiese of Michael Couch and Associates, Fort Wayne, Indiana, sent us a parcel of seven faceted rubies and three ruby slabs (figure 14), which are representative of material recently mined near Songea, Tanzania. He reported that most of the ruby rough from that area would cut half-carat stones, but some pieces were as large as 4–5 ct. The stones were recovered from an alluvial deposit about 30 km south of the city of Songea, along the Ruvuma River.

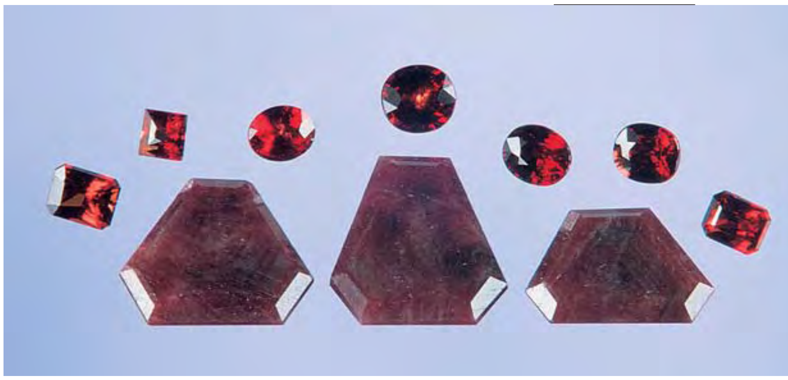


Figure 14. These 10 ruby samples came from the Songea area in Tanzania. The slabs weigh 5.73–8.11 ct; the faceted stones are 0.37–1.17 ct. Courtesy of Randy Wiese; photo by Maha Tannous.

The seven faceted stones were transparent and somewhat brownish red to purplish red. They ranged from 0.37 to 1.17 ct, with the largest measuring 6.47 x 5.96 x 3.68 mm. The stones were pleochroic in yellow-brown and brownish red. Refractive index values ranged from 1.763 to 1.772, and specific gravity (measured hydrostatically) ranged from 4.00 to 4.01. A handheld spectroscope revealed features representative of both chromium and iron in corundum. The seven stones were inert or fluoresced very faint red to long-wave UV radiation, and were inert to short-wave UV. With magnification, we observed the following inclusions in the faceted stones: transparent dark brownish red rounded crystals, probably rutile; one metallic crystal with a large metallic halo, probably pyrite; and some black rounded and melted-appearing inclusions. Some of the inclusions had associated partially healed fractures (fingerprints).

The three flat, semi-translucent slabs weighed 5.73, 6.80, and 8.11 ct, with the longest 17.13 mm in maximum dimension. The gemological properties, where measurable, were comparable to those of the transparent stones, with a slightly lower R.I. (1.762–1.770) and broader S.G. range (3.99–4.01). With magnification, we again saw pyrite and rutile crystals; in addition, we could see distinct, eye-visible, hexagonal zoning.

Because we had not yet documented rubies from this locality, we asked GIA Gem Trade Laboratory research associate Sam Muhlmeister to measure the chemical compositions of three of the faceted samples (0.65, 0.70, and 1.04 ct) using energy-dispersive x-ray fluorescence (EDXRF). The three rubies contained 0.24–0.42 wt.% Cr_2O_3, 0.99–1.23 wt.% FeO, and up to 0.94 wt.% CaO (possibly due to apatite inclusions, since phosphorus also was detected in each sample and EDXRF is a bulk method of analysis). Small amounts of titanium (0.01–0.05 wt.% TiO_2) also were detected and may have been due to rutile inclusions.

Because of recent trade concerns about radioactivity (see, e.g., "Radioactive rubies," Fall 1998 Gem News, pp. 227–228), we checked all 10 stones with a handheld Geiger-Muller counter. None showed any evidence of radioactivity.

Another source for bicolored sapphire: Tunduru, Tanzania. Bicolored corundum (pink sapphire or ruby on one side, blue sapphire on the other) has been reported in *Gems & Gemology* from two sources: Nepal (C. P. Smith et al., "Rubies and fancy-color sapphires from Nepal," Spring 1997, pp. 24–41) and Vietnam (Spring 1998 Gem News, pp. 51–52). Last year, Stephen Avery, a gem dealer in Lakewood, Colorado, showed us six bicolored sapphires obtained in 1995 that reportedly came from Tanzania's Tunduru region: two fashioned gems (0.64 and 1.97 ct; figure 15); three preforms weighing 0.73, 1.41, and 2.07 ct; and a 4.16 ct crystal. The crystal and the 1.41 ct preform showed potential for cutting bicolored corundums with blue sapphire as well as ruby zones, but the other samples were pink-to-purple in their reddest areas. Along with these sapphires was a 4.01 ct pale purplish pink spinel crystal with a dark blue rim that also could be fashioned into a bicolored gem.

Gemological properties of the two fashioned gems were measured by staff gemologist Maha Tannous and Gem News editors John Koivula and Dino DeGhionno. These were as follows (for the smaller stone first, where different): color—roughly half purplish pink (purple-pink) and half dark violetish blue; optic character—uniaxial; Chelsea color filter reaction—orangy red in the pink areas, inert in the blue areas; R.I.—1.760–1.769 and 1.760–1.768; S.G. (measured hydrostatically)—4.05 and 4.02; typical ruby absorption spectrum seen with a handheld spectroscope. The two stones fluoresced moderate-to-strong orange, with uneven distribution and medium chalkiness, to long-wave UV radiation; they were inert to short-wave UV. The 0.64 ct stone contained small transparent birefringent crystals

Figure 15. These two fashioned bicolored purplish pink to purple-pink and blue sapphires are reportedly from Tunduru, Tanzania; they weigh 1.97 and 0.64 ct. Courtesy of Stephen M. Avery; photo by Maha Tannous.

(possibly zircon); the 1.97 ct stone contained exsolved rutile and (probably) ilmenite "silk" in distinct zones. Both showed color zoning with sharp-edged regions; there was no sign of diffusion of color. The fact that the crystals and silk were intact, together with the sharp-edged color zoning, provided evidence that these sapphires had not been subjected to heat treatment.

Although mining at Tunduru has diminished greatly this year (as workers moved to the new tsavorite workings in Tanzania; see, e.g., Summer 1999 Gem News, pp. 151–152), in the past its gem gravels have produced a broad range of exciting material (see, e.g., the Gem News items in Summer 1995, pp. 133–134, and Spring 1996, pp. 58–59). The gem potential of this region is probably far from being exhausted.

Figure 16. These spessartine garnets are from a new deposit in Nigeria, near the village of Iseyin. The spessartine rough sometimes occurs as well-formed crystals up to 2 cm in diameter, as shown here. Photo by Joachim Zang.

Spessartine from Nigeria. In April 1999, some highly saturated orange-yellow spessartine garnets appeared on the market in Idar-Oberstein, Germany, reports Dr. Joachim Zang and colleagues. By mid-summer, several dozen kilograms of rough spessartine from this source, mostly of lower quality, had arrived in Idar-Oberstein. African dealers reported the source as a mining area near the village of Iseyin, a three-hour drive northwest of Ibadan, Nigeria.

From a study of both crystals and fashioned stones (see, e.g., figures 16 and 17), we determined refractive index (measured with a Topcon refractometer) values of greater than 1.790 and specific gravity (measured hydrostatically) values ranging from 4.19 to 4.23. These measurements are consistent with near-end-member spessartine, which has an R.I. of 1.800 and an S.G. of 4.19. Absorption spectra exhibited typical spessartine features, plus local maxima at 469 nm and 527 nm (due to Fe^{2+}) and at 482 nm (due to Mn^{2+}). Most of the rough occurs in rounded shapes, although we saw a few crystals up to 2 cm in diameter (again, see figure 16). The largest clean faceted stone examined weighed more than 23 ct (again, see figure 17).

Semi-quantitative chemical analysis with a scanning electron microscope (EDAX system) gave the following composition (weight percent, normalized to 100%, all Fe reported as Fe^{2+}; values for pure spessartine are given in brackets for comparison): SiO_2 = 36.1 [36.41], Al_2O_3=21.4 [20.60], FeO = 0.64 [0.00], MnO = 40.6 [42.99], MgO = 0.94 [0.00], CaO = 0.27 [0.00]. With a combination of physical and chemical techniques, the samples were determined to be nearly pure spessartine (up to 94 mol.%), with lower contents of almandine (from 1.5 to 11 mol.%) and pyrope (around 3.5 mol.%).

Dr. Joachim Zang, Klaus Schoder,
and Dr. Michael Luhn
Idar-Oberstein, Germany

Figure 17. These faceted spessartines are also from the new Nigerian deposit. The spessartine on the left weighs more than 23 ct. Photo by Joachim Zang.

Figure 18. These five spessartine garnets (2.15–11.03 ct) come from the Lundazi area of Zambia. Courtesy of Marc Sarosi; photo by Maha Tannous.

Spessartine from Zambia. At the 1999 Tucson shows, we saw orange spessartine from many sources, including several localities in Brazil (see, e.g., Spring 1999 Gem News, p. 55) and some sources in Africa. Marc Sarosi of the Marc Sarosi Company, Mill Valley, California, kindly loaned us five fashioned spessartines from the Lundazi region in Zambia (figure 18). According to Mr. Sarosi, a fair amount of orange garnet has been found in the country rock (decomposed granite) in the area, but very little of it is clean (less than 1 kg so far). The largest fashioned garnets weigh over 10 ct.

All five stones (2.09–11.03 ct) we examined were orange with even color. None showed any reaction to a Chelsea color filter. Refractive indices were in the narrow range of 1.799 to 1.800, but specific gravity values (measured hydrostatically) extended from 4.20 to 4.25, an unusually high value. All five were inert to both long- and short-wave UV radiation. They had a typical spessartine absorption spectrum when viewed with a handheld spectroscope, with a lower wavelength cutoff at 435 nm; bands at 460, 480, and 530 nm; and a weak 504 nm line. When viewed with a microscope, they showed typical garnet growth bands and fluid-filled "fingerprint" inclusions (figure 19). Based on these gemological properties, this is also nearly pure end-member spessartine.

Because some of the samples had high S.G. values, we analyzed two of them using EDXRF spectroscopy. Although these two samples had different S.G.'s (4.20 for the 11.03 ct stone and 4.23 for the 2.15 ct stone), research associate Sam Muhlmeister found similar chemical compositions for both samples, with major amounts of aluminum, silicon, and manganese, and trace quantities of iron, zinc, calcium, and gallium.

The Lundazi area also produces tourmaline (see, e.g., "Multicolored bismuth-bearing tourmaline from Lundazi, Zambia," by M. L. Johnson et al., *Gems & Gemology*, Fall 1997, pp. 204–211) and aquamarine. Mr. Sarosi believes that this area shows considerable promise as a source for gems.

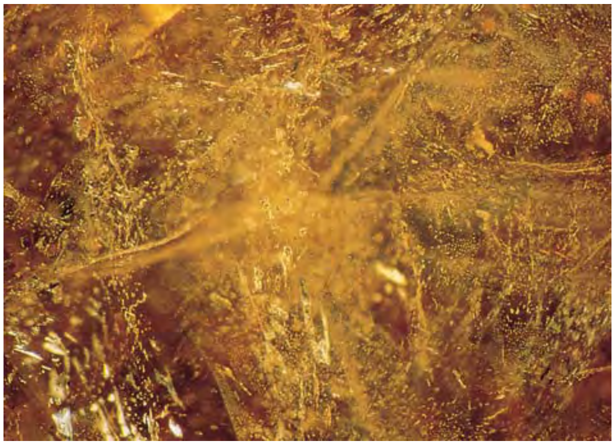


Figure 19. The Zambian spessartines typically had fluid-filled "fingerprint" inclusions, as seen here in the 11.03 ct modified triangular brilliant. Photomicrograph by John I. Koivula; magnified 30×.

Tremolite rock from China, represented as "Longxi Jade." Professor Zhang Ru bo of the Department of Geological Science, Chengdu Institute of Technology in Chengdu, Sichuan Province, China, sent the following information to Dr. James E. Shigley of GIA Research. Professor Zhang and colleagues Zhang Yu Yu and Yang Da Xiong had examined a deposit of tremolite rock near Longxi Village, Wenchuan, in Sichuan Province, about 230 km north of Chengdu. The material was first discovered by villagers in the 1940s; based on its presence, the Guanxi Jade Carving Factory was founded, and the tremolite was marketed as "Guanxi Jade." This source of carving material was no longer economic by the early 1980s, so the factory carved other materials (i.e., "Nanyang Jade" and "Xu Jade"). (The reader is reminded that *jade* is an inexact translation of the Chinese term *yu*, which refers to any hard stone that can be carved. In

Figure 20. A semi-transparent tremolite rock forms stratified layers in the metamorphosed limestone at Longxi. Photo courtesy of Zhang Ru bo.

contrast, Western usage restricts the term *jade* to jadeite and nephrite. For more on this, see "Standards issued for the jewelry industry in China," Fall 1997 Gem News, pp. 229–230.)

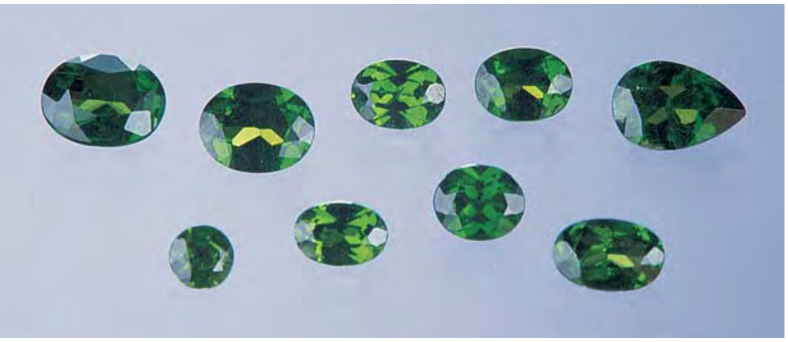
The Chinese team visited the locality in summer 1997, and determined that the source was not yet depleted. The mine is actually located several kilometers from Longxi, near the hamlet of MaJia, at an altitude of 2,500 feet (760 m). At the time of their visit, there was a horizontal adit about 9 m deep and a 15-m-square open area for stacking the ore blocks.

The massive tremolite formed as layers up to 2 m thick (although typically 10 to 50 cm; figure 20), within an anticline. The material in the mine pit was yellow, "golden" yellow, green, and yellow-green. The tremolite apparently formed by metamorphism of dolomitic limestones, with no evidence of metasomatic fluids; the tremolite only occurred in specific layers in the metamorphosed rock. Consequently, the authors predicted that large reserves of "Longxi Jade" will not be found at this deposit.

Professor Zhang and his colleagues determined the following gemological properties on representative samples of "Longxi Jade": color—gray-white, light yellow, and yellow-green; diaphaneity—semi-transparent to opaque; hardness—5.5 to 6 on the Mohs scale; specific gravity—2.95 to 3.01. In thin section, the rock appeared to be composed of fibrous tremolite with small amounts of talc and carbonates. R.I. values of 1.595 and 1.625 were determined on the tremolite in the thin section. Chemical analysis revealed a composition that is quite close to end-member tremolite.

The finest-quality tremolite rock from the deposit is suitable for fashioning into cabochons. Some cabochons show a cat's-eye effect and resemble cat's-eye chrysoberyl.

Figure 21. These nine tsavorite garnets (0.15–0.67 ct) are reportedly from a new deposit in southwestern Madagascar. Courtesy of Allerton Cushman & Co.; photo by Maha Tannous.



Tsavorite from Madagascar. Tsavorite garnet from Madagascar was first called to our attention by Samir-Pierre Kanaan of Paris in mid-1997. In March 1999, Tom Cushman of Allerton Cushman & Co., Sun Valley, Idaho, showed us a suite of nine green garnets (0.15 to 0.67 ct) from southwestern Madagascar (figure 21), which also proved to be tsavorite; to the best of our knowledge, this is the first location outside of Kenya or Tanzania to produce commercial quantities of tsavorite. The parcel also included six chrome tourmalines that had been represented as tsavorite, and Mr. Cushman reported that green diopside also is recovered from the same area. The tsavorite is mined from a primary deposit; "intermittent production" typically yields faceted stones that do not exceed 1 ct.

Gemological properties of the garnets were as follows: color—green; optic character—singly refractive with weak anomalous double refraction; Chelsea color filter reaction—weak orange; refractive index—1.740 to 1.742; birefringence—none; specific gravity (measured hydrostatically)—3.63 to 3.66. The stones were inert to both long- and short-wave UV radiation. When viewed through a handheld spectroscope, they showed a typical tsavorite spectrum: 470 nm cutoff, absorption band between 580 and 620 nm, and vague absorption between 620 and 700 nm. With magnification, needles, small crystal inclusions, and "fingerprints" were seen. EDXRF analysis of two stones by research associate Sam Muhlmeister revealed major aluminum, calcium, and silicon, with traces of titanium, vanadium, chromium, manganese, iron, yttrium, and zirconium. All these properties are consistent with the tsavorite variety of grossular garnet.

TREATMENTS

The chemistry of emerald fillers. In the course of GIA's ongoing study of emerald treatments (see M. L. Johnson et al., "On the identification of various emerald filling substances," Summer 1999 *Gems & Gemology*, pp. 82–107), we investigated the possibility of using trace elements to identify fillers by means of energy-dispersive X-ray fluorescence (EDXRF) spectroscopy, using a Tracor Northern Spectrace 5000 instrument. A limitation of this system is that elements lighter than sodium cannot be detected; this includes the main constituents of the organic fillers (i.e., carbon, hydrogen, and oxygen). However, many of the 26 fillers we studied with this technique did contain heavier elements.

We examined fillers in the following substance categories: eight essential oils/natural resins, four other oils, seven epoxy prepolymers, two UV-setting prepolymers, and five solid polymers. The liquids were poured into the EDXRF sample holders for analysis, and the solid fillers were examined as blocks. Each sample was run at 15 and 20 kV (at 0.35 mA) in a vacuum, and at 30 kV (at 0.35 mA) in air.

Results are presented in the table. Only one essential oil (synthetic cinnamon oil) showed a distinct "heavy" element peak (zinc [Zn]). Of the other oils, Joban oil contained iron (Fe), copper (Cu), and calcium (Ca); azeite de dende (palm tree oil) contained chlorine. Six out of seven epoxy prepolymers (all except Epo Tek 314) contained chlorine (Cl), and all the solid polymers contained Cl. The two UV-setting artificial resins, in both liquid and solid form, contained many discernible elements: Epo Tek UVO114 contained silicon (Si), phosphorus (P), sulfur (S), Cl, and antimony (Sb); and the Norland Optical adhesive contained S and tin (Sn).

EDXRF results for 26 possible emerald fillers.

Substance category	Filler[a]	Elements identified with EDXRF[b]
"PRESUMED NATURAL" SUBSTANCES		
Essential oils		
Essential oils or natural resins	Cedarwood oil for clearing (Merck)	None
	Cedarwood oil for immersion (Baker)	Ca (?), Fe (?)
	Cedarwood oil for immersion (Merck)	W (?)
	Canada balsam (natural resin)	Zn (?)
	Clove bud oil	None
	Clove oil	None
	Cinnamon oil (synthetic)	Zn, Fe (?)
	Cinnamon oil (cassia)	None
Other oils		
Mineral oils	Mineral oil	None
	Paraffin oil	None
Vegetable oil	Azeite de Dende	Cl, K (?), Ca (?)
Mineral (?) oil plus vegetable (?) dye	Joban oil	Ca, Fe, Cu, Cl (?),K (?)
ARTIFICIAL RESINS		
Epoxy prepolymers	Araldite 506	Cl
	Araldite 502	Cl
	Araldite 6005	Cl
	Araldite 6010	Cl, K (?)
	Epo Tek 301	Cl
	Epo Tek 302-3M	Cl
	Epo Tek 314	None
Other prepolymers		
UV-setting	Epo Tek UVO114	Si, P, S, Cl, Sb
	Norland Optical Adhesive type 65	S, Sn
Polymers	Opticon Resin 224 (cured)	Cl, Fe (?)
	Permasafe	Cl, Ca (?)
	Super Tres	Cl, Ca (?)
UV-setting	Epo Tek UVO114 (cured)	Si, P, S, Cl, Sb
	Norland Optical Adhesive type 65 (cured)	S, Sn

[a] *For sources, see M. L. Johnson et al., "On the identification of various emerald filling substances,"* Gems & Gemology, *Vol. 35, No. 2, pp. 82–107.*

[b] *All EDXRF analyses were performed on the loose fillers (i.e., as "pure" substances, not in an emerald). "None" means that no element heavier than neon was detected. Peaks definitely identified (trace level) are given as, for example, "Fe"; those that were tentatively identified (i.e., a small peak was seen, but its signal was not significantly above the background level) are given as, for example, "Fe (?)."*

The next question was: How useful is this information for the identification of substances *within* emeralds? Most of the elements we identified also could be found naturally within an emerald, given the gem's common inclusion of brines (Cl and perhaps P) and sulfides (Fe, S, and perhaps Cu and Zn); so the best "test cases" to see if fillers produced elemental signatures were Sb or Sn. We therefore compared the EDXRF spectrum of a known natural emerald from Muzo, Colombia, with that of a 1.12 ct emerald that—after cleaning—we had filled with a significant amount of Norland Optical Adhesive type 65. The 5.01 ct unfilled emerald revealed major amounts of Si and aluminum, as well as trace amounts of S, Cl, K, Ca, titanium, vanadium, chromium, Fe, and gallium. The 1.12 ct emerald filled with Norland 65 contained the same elements (except gallium), and did not reveal detectable amounts of Sn. As other experiments described in the above-mentioned *Gems & Gemology* article found that less than 0.001 ct of filler is needed in an emerald of this size, the inability to detect the tin was not surprising. This research shows that it is not feasible at this time to identify the filler in an emerald with EDXRF.

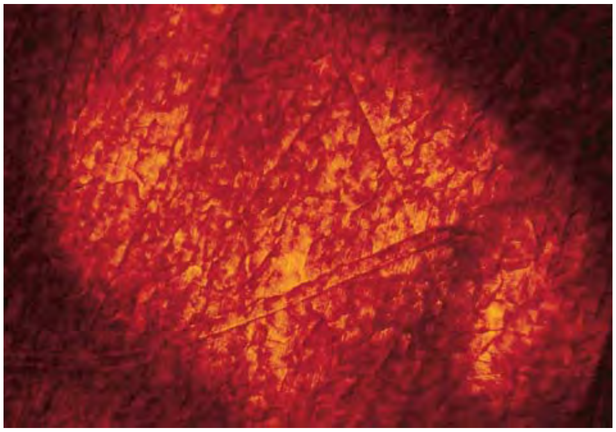
MLJ and Sam Muhlmeister,
GIA Gem Trade Laboratory
Shane Elen, GIA Research

Figure 22. The heat-treated portion of this 5.60 ct almandine-spessartine garnet (left) developed a dark gray metallic coating that was identified as hematite. Photo by Maha Tannous.

Hematite coating on heat-treated garnet. After publishing the Winter 1997 Gem News item "Heat treatment of garnets" (p. 308), the Gem News editors carried out an experiment to determine the nature of the metallic coating that develops on certain garnets with heating. Such a coating has been noted when iron-bearing garnets (such as almandine) are heated in air to temperatures above 900°C, as previously determined by Gerhard Becker of Idar-Oberstein, Germany.

For our experiment, we chose a 5.60 ct transparent, dark orange-brown, oval modified brilliant cut. It was reportedly from Orissa, India, and contained only minimal inclusions (so few that they were unlikely to cause damage during heating). The garnet had an R.I. of 1.756, an S.G. of 3.91, and a mixed almandine-spessartine absorption spectrum. EDXRF analysis of the stone prior to heating showed the presence of aluminum, calcium, iron, magnesium, manganese, and silicon, with iron appearing to be slightly more abundant than magnesium, manganese, or calcium. The stone's bodycolor, relative elemental peak heights, and the strength of the almandine visible-light absorption spectrum, suggested that there was more almandine component than spessartine.

Figure 23. The semi-transparency and mottled, uneven appearance of the hematite coating on the heat-treated garnet is visible in strong transmitted light. Photomicrograph by John I. Koivula; magnified 40x.



For the experiment, the garnet was cut into two pieces, so that half the stone could be retained as an untreated (control) sample. The other half was placed in a muffle furnace, heated in air to 920°C, and then allowed to cool slowly. As expected for this iron-bearing garnet, the heat treatment produced an obvious dark gray metallic coating on the surface (figure 22).

We then retested the gemological properties on the heated half. Because of the metallic coating, we could not obtain an R.I. value. The 3.93 S.G. was slightly higher than that obtained before heating. Once again, the absorption spectrum was mixed almandine-spessartine, although it was much darker because the metallic coating interfered with the stone's transparency. When examined with magnification in strong transmitted light, the coating was semi-transparent and had a mottled, uneven appearance (figure 23).

Using Raman analysis on the treated half, we identified the coating as hematite. This was not surprising, considering the high iron content of the garnet. We believe that iron at the surface of the garnet oxidized to form hematite (Fe_2O_3).

Factors in the heat treatment of corundum. At the 25th International Gemmological Congress (October 1995) in Rayong, Thailand, Dr. Varunee Thiramongkol of the Department of Science Service, Bangkok, gave a presentation on corundum heat treatment. She kindly provided the Gem News editors with the following update on her research in this area at the Third International Gemological Symposium last June.

Dr. Thiramongkol discussed oxidation conditions as an important factor in the heat treatment of corundum varieties. Corundum is oxidized in oxygen-rich environments, and reduced in hydrogen-rich, organic-rich, or inert environments. Oxidizing conditions cause rubies from Mong Hsu, Trat (Thailand), and Africa to become "purer" red; greenish blue sapphires to turn green; and dark blue-to-black sapphires to lighten. Reducing conditions make rubies from Mong Hsu, Trat, and Africa become more purple; and cause silky, milky, or yellowish blue sapphires to become blue. Pale yellow sapphires from Sri Lanka and Kanchanaburi turn intense yellow when heated in oxidizing conditions, but they become light blue when heated in nitrogen gas; the same stone can have its color "reversed" several times by changing the atmosphere in which it is heated.

Another factor that is sometimes important in heat treatment is the local "micro-environment" during heating: Light-colored stones may be stained blue in patches by proximity to dark blue or black sapphires, or they may be stained pink to brownish red if they are heated with rubies.

SYNTHETICS AND SIMULANTS

Manufactured products imitating charoite. One would not consider charoite a likely candidate for imitation, although a possible charoite (or sugilite) simulant (a dyed rock consisting of massive beryl and quartz) was described in the Summer 1992 Gem News section (p. 135). In the past three years, however, we have come across two manufactured products intended to simulate charoite. The first, marketed in 1996 as "Royal Russianite" by Marchant Enterprises of Anchorage, Alaska, was obtained as a bracelet of 20 round beads averaging 8.1 mm in diameter (figure 24). The second imitation, obtained in Tucson in 1999 by GIA Education product manager Philip York, consisted of a 2.90 ct rectangular bead.

Both samples were purple, opaque, and unevenly colored; both had a (spot) refractive index value of 1.55; and both burned, giving off an acrid odor, when exposed to a thermal reaction tester (hot point). (These properties were sufficient to identify these beads as manufactured products, probably comprised of or containing a significant amount of plastic.) It was not possible to measure the specific gravity of the round beads without dismantling the bracelet; however, the rectangular sample revealed an S.G., measured hydrostatically, of 2.67. The round beads were inert to long- and short-wave UV radiation, but the rectangular bead fluoresced uneven faint blue to long-wave UV radiation and uneven faint yellow to short-wave UV.

Figure 24. This bracelet of 8 mm imitation charoite beads was purchased in Alaska. Photo by Maha Tannous.

When examined with magnification, the two imitations looked quite different. The surface of each round bead showed a swirled mass of opaque purple layers in light and dark tones (figure 25), with no white or colorless areas. In contrast, the rectangular bead consisted of many translucent to opaque white blobs held together by purple, black, or even blue dye/bonding agents (figure 26). Through the microscope, the second was therefore the more convincing imitation of a charoite-bearing rock, but the first was more convincing to the naked eye.

In the course of editor MLJ's trip to Alaska, she saw other interesting imitations, including "Arctic Opal" (not an opal, but malachite/azurite or an imitation of it), "Glacier Pearle" (abalone shell, not pearl), and the familiar

Figure 25. The "Royal Russianite" imitation charoite was mottled in light and dark tones of purple when viewed with magnification. Photomicrograph by John I. Koivula; magnified 15x.

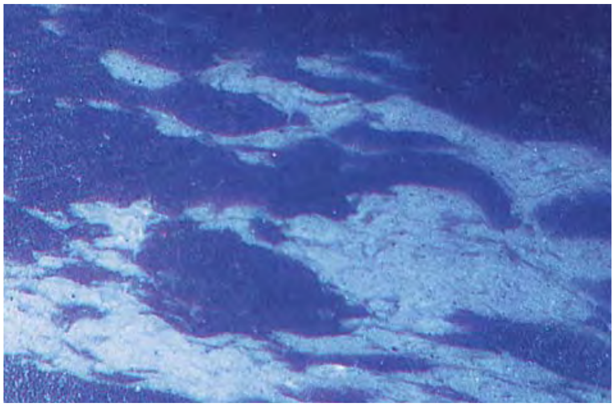


Figure 26. The rectangular bead imitation of charoite was composed of white blocks and swirls of varying concentrations of purple (or blue, or black) colored matter. Photomicrograph by John I. Koivula; magnified 10x.

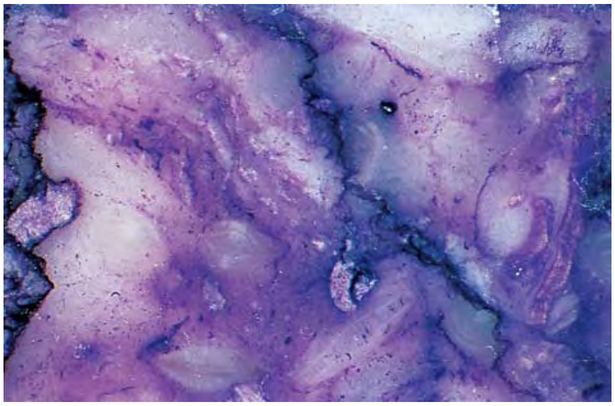


Figure 27. The words in this 42-mm-long synthetic quartz crystal were inscribed completely internally by a laser technique. Photo by Maha Tannous.

"Alaska Black Diamond" (hematite or a hematite imitation, but not diamond). Tourist beware!

MISCELLANEOUS

More on "internal" carving: Now done to synthetic and natural quartz. We first reported on the use of lasers to produce three-dimensional images inside of glass in the Winter 1996 Gem News section ("Completely internal 'carving' of glass," p. 292). In that entry, we mentioned that we saw no impediment to applying this technology to isotropic gem materials (such as CZ or diamond). This year, we discovered that this technology has gone beyond our predictions, as the uniaxial mineral quartz also is being internally inscribed in this fashion.

Utah Mineral and Fossil, of Bountiful, Utah, markets hydrothermal synthetic quartz crystals that have been laser inscribed near the surface (figure 27). We looked through the microscope at a sample inscribed beneath one prism face and observed sharp parallel fractures, such as those seen in the glass sample we observed in the Winter 1996 Gem News entry. We looked for evidence of dispersion of the laser beam, such as a broadening of the fissures in the deepest part of the inscription that might have been due to splitting of the beam by quartz's two refractive indices; however, we saw no such evidence.

Another firm has taken quartz carving a step further. At Tucson in 1999, Tom Harrelson of The Gemologist, Bellevue, Washington, showed *Gems & Gemology* senior editor Brendan Laurs a partially polished piece of natural quartz in which a stag had been internally engraved using a laser technique (figure 28). By March 1999, his firm had experimented with 17 quartz samples, including the varieties rock crystal, ametrine, rose quartz, and amethyst. Six of these samples sustained moderate to heavy damage from stress cracking by the laser process, but designs were successfully produced in the other 11 with, reportedly, "good to excellent" image resolution. The laser inscriptions were produced in the U.S. using a proprietary computer software program that reduces the internal stress on the gem material caused by the laser. Mr. Harrelson also noted that any stress cracking in the gem material is produced at the time of inscription; no cracking has been observed to form later.

Several firms in Russia currently produce internal laser inscriptions, mainly in glass but also (reportedly) in cubic zirconia. The engravings are made with computer-controlled lasers and CAD-CAM programs; the images still consist of series of dots inscribed at specified positions in three dimensions. As the resolution gets finer (i.e., the number of "pixels" increases), the image quality improves.

ANNOUNCEMENTS

Basel 2000. The World Watch, Clock and Jewellery Show will be held March 23–30 in Basel, Switzerland. In conjunction with Basel 2000, on March 25 GIA will host GemFest Basel 2000 and the GIA Reception and Alumni Reunion, both sponsored by Messe Basel. GemFest, which is open to the public, will highlight critical issues in the gem and jewelry trade and host an open forum similar to the popular "War Rooms" at the 3rd International Gemological Symposium last June. For more information on Basel 2000, call 41-61-686-2020 or visit the Web site www.messebasel.ch. For details on GemFest, e-mail Cindy Campman at ccampman@gia.edu or call 760-603-4150. *Gems & Gemology* representatives will be available at the GIA booth in Hall 201, Stand 311.

International Rough Diamond Conference. The Israeli diamond industry and government will co-host the 2nd International Rough Diamond Conference March 21–23, 2000, at the Hilton Hotel in Tel Aviv. The conference will serve as a strategic forum between corporations involved in diamond mining, exploration, manufacturing, and financing, as well as government delegates from producing countries. Attendance will be free of charge to qualified members of the international rough diamond community, but space is limited. For details, contact the conference secretariat at 972-3-5410004 (phone), 972-3-5140044 (fax), or visit the Web site www.diamonds.org.il.

ISA personal property appraisal courses. The International Society of Appraisers (ISA) will offer its Core Course in Appraisal Studies February 26 through March 5, 2000, in Los Angeles, California. The course will focus on the broad issues of appraisal principles, including valuation theory, market research and analysis, identification and authentication, ethical standards, tax regulations, report writing, legal issues, basic appraisal techniques, and the Uniform Standards of Professional Appraisal Practice (USPAP). For more information, contact ISA at 888-472-

Figure 28. The stag was engraved completely within this natural quartz sample using laser technology. Courtesy of Tom Harrelson; photo by Maha Tannous.

4732, e-mail ISAHQ@isa-appraisers.org, or visit the Web site www.isa-appraisers.org.

Kremlin Gold at the Houston Museum of Natural Science. Presenting more than 140 gold relics, jeweled masterpieces, and precious art objects, *Kremlin Gold: 1000 Years of Russian Gems and Jewels* will be featured at the Houston (Texas) Museum of Natural Science from April 15 to September 4, 2000. On display will be works by Russian master goldsmiths dating back to the 4th century, a select number of Fabergé Imperial Easter Eggs crafted at the turn of the century, and award-winning contemporary works from the last half of the 20th century. For more information, call 713-639-4629 or visit the Web site www.hmns.org/hmns/kremlin.

Treasures from Topkapi Palace. Istanbul's Topkapi Palace has for centuries housed imperial jewels and other treasures from the Ottoman Empire. More than 200 objects from this palace will be on display in a new exhibition, *Palace of Gold & Light: Treasures from the Topkapi, Istanbul*. The exhibition will debut at the Corcoran Gallery of Art in Washington, DC, March 1–June 15, 2000, and will later appear at the San Diego Museum of Art July 14–September 24, 2000, before completing its tour at the Museum of Art in Fort Lauderdale, Florida, October 15, 2000–January 14, 2001. To contact the Corcoran Gallery, call 202-639-1700; for the San Diego Museum of Art, call Mindy Riesenberg at 619-696-1946.

West Coast Antique & Period Jewelry Seminar 2000. This second annual seminar will be presented by the Center for Jewelry Studies on April 14–16 at the Sheraton Suites Fairplex in Pomona, California. Elise Misiorowski, Ginger Moro, Peter Shemonsky, Janet Zapata, and Christie Romero will lecture on topics ranging from turn-of-the-century and later jewelry styles, American jewelers, diamonds and colored gemstones, the American crafts movement, and costume jewelry. To request a brochure, or for further information, call 714-778-1828 or e-mail CR4jewelry@aol.com.

Gemstones at upcoming scientific meetings. Special sections applying to gemstones will be offered at these upcoming meetings:

- A session on *Gemstones of the Pacific Rim* will take place at the Geological Society of America 96th Annual Meeting, Cordilleran Section, in Vancouver, British Columbia, Canada, April 27–29, 2000. For more information, visit the Web site www.eos.ubc.ca/cordgsa2000.
- A thematic session on *Diamond-Host Rocks: New Exploration Targets and Scientific Insights* and a one-day short course on *Kimberlites and Their Indicator Minerals* will be held at the joint meeting of the Canadian Geophysical Union and GeoCanada 2000 in Banff, Alberta, Canada, May 23–27, 2000. For details, visit the Web site www.acs.ucalgary.ca/~cguconf/main.html.
- Symposia on the *Geology of Gemstone Deposits, Applied Mineralogy: Ceramics and Gem Materials, Synthetic and Treated Gem Materials*, and *Petrogenesis of Carbonatite, Kimberlites, Lamproites and Related Rocks* will be included in the 31st International Geological Congress on August 6–17, 2000, at the Riocentro Convention Center in Rio de Janeiro, Brazil. Field trips to colored gemstone deposits of Minas Gerais and to diamond placers in the southern Espinhaço Mountain Range are also planned. For more information, contact FAGGA Eventos (phone 5521-537-4338, fax 5521-537-7991, e-mail geoexpo@fagga.com.br), or visit the Web site www.31igc.org.

Book Reviews

Susan B. Johnson & Jana E. Miyahira-Smith, Editors

ROCK CRYSTAL TREASURES FROM ANTIQUITY TO TODAY

By Sylvie Raulet, 240 pp., illus., publ. by Vendome Press, New York, 1999. US$75.00

Journalist and historian Sylvie Raulet has graced our jewelry literature with several fine works, among them her sumptuous *Art Deco Jewelry* (1990). Here is another splendid book from her pen, this time a unique study of ornamental applications of rock crystal quartz. From this material, artisans have fashioned an array of beautiful objects ranging from small gems to impressively large vessels and figure carvings. Only a brief scan of this book is needed to convince one that it is of permanent reference value. In scope it covers objects produced in the Mediterranean countries and Europe from Roman times up to the present (the considerable production of similar objects in India and China is not considered).

Ms. Raulet provides an introductory chapter on the scientific and technological aspects of rock crystal, and another on the symbolic and medicinal lore. These are followed by chapters that describe many types of objects, with meticulous histories furnished for the major examples as preserved in museum and private collections. They cover the period from ancient Roman times to Fatimid Egypt (roughly 100 BC to 1170 AD); then, in the Western world, from Merovingian times to the Renaissance (about 1400 to 1600 AD); and, last, the 19th and 20th centuries. One of the most intriguing chapters is devoted to the formation of "curiosity cabinets" in the courts of Europe from about 1400 to 1600 AD, which notes especially that of Rudolph II in Prague. Rudolph's curator of gems and royal physician was Boetius De Boodt, the author of one of the greatest gemological books, the *Gemmarum et Lapidum Historia* (1609). This chapter is especially rich in sharp color photographs of rock crystal vases, most of which are embellished with precious-metal fittings studded with gems.

In contrast to earlier forms of ornament that used rock crystal, modern applications seem extremely simple and dependent more on form than on detail to fulfill the artist's conception. Ms. Raulet describes numerous objects here: a great chandelier with rock crystal "lights;" various boxes and other containers; cigarette cases; abstract sculptures; jewelry; and small figurines, some of exquisite beauty that are marvels of the lapidary/jeweler's arts.

On the negative side, it is evident from the errors in the chapter dealing with the technical aspects of quartz that it could have used a careful reading by a qualified mineralogist. A grievous error appears in the caption to the quartz crystal drawings on page 13, which are claimed to be "diagrams showing techniques for cutting rock crystal." In fact, these are crystal drawings apparently copied from those on pages 54–55 of C. Frondel's *Silica Minerals,* volume 3 of *Dana's Seventh System of Mineralogy* (1962). Other errors include the claim that rock crystal quartz shows "distinct dichroism," is "extremely resistant to oxidation," and contains inclusions of "titanium" (presumably meaning rutile). A particularly annoying lapse is the failure to give dimensions or magnification factors for most of the objects. While the bibliography is helpful, it could have been enhanced by incorporating the many works mentioned in the text but absent from either footnote or bibliography.

Nevertheless, the book is a satisfying intellectual as well as visual treat. It is strongly recommended reading.

JOHN SINKANKAS
Peri Lithon Books
San Diego, California

BEYOND PRICE—PEARLS AND PEARL-FISHING: ORIGINS TO THE AGE OF DISCOVERIES

By R.A. Donkin, 448 pp., illus., publ. by the American Philosophical Society, Philadelphia, PA, 1998. US$45.00

One cannot help but admire the expertise and dedication that R. A. Donkin, Fellow of Jesus College, Cambridge University, demonstrates in this treatise, which was published as part of the *Memoirs* series of the American Philosophical Society. The book was widely acclaimed as an outstanding scholarly achievement, one that will remain the standard for the future. Regrettably, this review can give only a brief summary of the vast amount of information contained in *Beyond Price.*

Over the course of the book's 10 chapters, the author documents the origins and historical geography of pearls up to the Age of Discoveries (18th century), chronologically and by region, with extensive archaeological and philological perspectives. Notes and references supplement each chapter.

Starting with folklore and leading to the advent of scientific inquiry, the first chapter chronicles the vast literature on the origins of pearls. It includes indigenous writings and historical atlases, which have been translated by various linguists worldwide.

The next chapter deals with the biology, distribution, and ecology of freshwater and marine [saltwater] pearls. Mr. Donkin also elaborates on existing nomenclature and taxonomy problems of the marine pearl-bearing mollusks. Nine maps show the world distribution of the principal sources of freshwater and marine pearls, following G. Ranson's widely accepted nomenclature and classification system of *Pinctada* species.

Mr. Donkin, a Reader (ret.) in Historical Geography, uses the majority of the book to recount the history of pearl fishing in different geographic regions, beginning with the "Ancient East" (Egypt, Mesopotamia, eastern Arabia, present-day Iran, the Mediterranean, India, and China). The chapter "Classical World: Greeks and Romans and Their Eastern Neighbors" follows. Next we learn about the "Arabo-Persian World" (7th–15th centuries), India, and China. The "Medieval World" is discussed separately. The final chapters deal with the Age of Discoveries in both the New World (the Americas) and the Old World (all other areas).

The book is further enhanced by over 100 black-and-white illustrations and maps. The bibliography encompasses 59 pages, arguably the most extensive compilation of publications on the subject. Anyone interested in pearls will find this book not only compelling to read, but also essential as an encyclopedic reference.

Historically, pearls have been regarded as a good omen, as symbols of wisdom, truth, and beauty. With *Beyond Price*, distinguished scholar R. A. Donkin offers one of the greatest tributes to this truly unique gem.

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AMBER

By Andrew Ross, 73 pp., illus., publ. by the Harvard University Press, Cambridge, MA, 1998. US$12.95

Amber is the only gem material that traditionally has been appreciated and valued for its inclusions. This fascination has resulted in a number of interesting and well-written books on the subject. Until I received a copy of *Amber*, my favorite small introductory book on the subject was the German *Bernstein-Raritäten*, by Dieter Schlee (Staatlichen Museum für Naturkunde, Stuttgart, 1980). Although Schlee's beautifully illustrated book is still a personal favorite, it is hard to imagine how so much useful information could be contained in one small volume, as Andrew Ross has done with this new book.

The photomicrographs on the covers, which depict winged insects in amber, are interesting enough to tempt even a casual observer to open this book. Once inside, it becomes immediately apparent that virtually every page is wonderfully illustrated with photomicrographs, macrophotographs, or highly educational line drawings. The text is easy to read and understand, flowing in a logical fashion from one topic to the next.

After a few introductory pages on the nature of amber, its properties, substitutes, uses, and localities, the book focuses on descriptions and interpretations of various inclusions. Although excellent, the photographic images alone do not make this book so useful to jewelers and gemologists who need to examine amber from time to time. Rather, it is the detailed series of easy-to-follow line drawings, referred to as "Keys to Identification," that make this book special. For example, if one sees an arthropod as an inclusion, he or she can simply follow the numbered diagrams in sequence to learn, in most instances, a more precise identification beyond the initial *phylum Arthropoda.*

For anyone who has ever looked at an inclusion in amber and wondered what it was, this book will be very helpful. It may not make an entomologist out of a gemologist, but it serves as a major step in the right direction.

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GEM MINERALS OF VICTORIA

By William D. Birch and Dermot A. Henry, 120 pp., illus., Special Publication No. 4 of the Mineralogical Society of Victoria, Melbourne, 1997. Aus$34.95

Although overshadowed by the diamonds of Western Australia (Argyle), the opals of Queensland, and the sapphires of Queensland and New South Wales, the gem deposits of the Australian territory of Victoria cover a wide range, from diamonds to ornamental rocks. The first chapter of this profusely illustrated book describes early gem discoveries and the historical figures who pioneered gem collecting in Victoria. The next describes Victoria's diamonds, which were found mainly in alluvial deposits connected with gold mining. These are thought to be related to diamonds found in the Copeton (New South Wales) region; the largest of the 30 or so rough diamonds still extant weighs 8.2 ct.

Seven other chapters describe ruby and sapphire, zircon, olivine, anorthoclase, topaz, tourmaline, beryl, garnets, crystalline quartz varieties, cryptocrystalline quartz varieties, and opal. The last chapter describes other gems and ornamental rocks: calcite-ankerite concretions that resemble warm-toned agates; facetable cassiterite; massive purple corundum ("barklyite"); massive dumortierite; turquoise; and a chromian diaspore-muscovite rock called "selwynite." Chrysoberyl and moonstone have also been reported from Victoria, although no verified specimens are known.

This book appears to be intended mainly for Australian gem collectors, and it contains several geologic maps, recent photographs of gem deposits, and a table of gem properties to aid the fossicker. However, it deserves the notice of a much broader audience.

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Gemological ABSTRACTS

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ANGOLAN DIAMONDS

Blood money. M. Rapaport, *Rapaport Diamond Report*, Vol. 22, No. 42, November 5, 1999, pp. 1, 12, 13, 56.

Nowhere on Earth today is "blood money"—money obtained at the cost of another's life—more evident than in Angola, where the sale of diamonds by the Angolan rebel group UNITA (National Union for the Total Independence of Angola) is accused of fueling a vicious civil war. This article analyzes many aspects of this controversial topic with both compassion and reality.

Some observations by the author include: United Nations sanctions on Angola thus far have been unsuccessful in halting the trade in UNITA diamonds, and it is unlikely that this approach will work any better in the future; Global Witness, a nongovernment organization that has publicized the atrocities in Angola, has a rather simplistic approach of "no diamond sales, no money for guns, no war"; and, rather than trying to control the exportation of diamonds, which are small and easily transportable, politicians should advocate controlling the influx of arms.

Mr. Rapaport maintains that, from a humanitarian and moral perspective, the diamond industry must do whatever it can to ensure that diamond money is not used to fuel the conflict. The diamond industry cannot flourish, and may even be harmed, if it is tarnished by the association of "diamonds-and-war," which is the antithesis of "diamonds-and-love." *AAL*

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

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U.S. Congress: Draft legislation calls for comprehensive diamond certification. C. Even-Zohar and L. Schwartz, *Mazal U'Bracha*, Vol. 15, No. 116, December 1999, pp. 35–45 passim.

This article reprints Congressman Tony Hall's November 1, 1999, speech to the U.S. House of Representatives, as well as the full text of his proposed legislation (H.R. 3188), which would require that every diamond sold at retail in the U.S. for over $100 carry a certificate of country of origin. In response to this legislation, the authors have published their "Open Letter to U.S. Congressman Tony P. Hall." While it recognizes and applauds Congressman Hall's noble objectives, this missive clearly explains some likely effects that implementation of this bill would have. Among the important points are:

1. Less than 8% of the world's diamonds originate in war areas beyond the control of legitimate governments (i.e., in Angola, Sierra Leone, and Congo).
2. Each year, 860 million diamonds are polished in some 30 countries by perhaps one million people. Many of these diamonds are small (0.02 ct and less) and cheap; the volume is immense.
3. It would be necessary to establish an entire "certification industry" in all the diamond cutting and trading centers. The cost of certification would, in many cases, exceed the value of the diamonds themselves. For example, a tennis bracelet might require 30 different certificates of origin.
4. Certification would undoubtedly increase (perhaps double or triple) the price of some categories of polished diamonds in the U.S.
5. It is almost inconceivable that small manufacturers worldwide (e.g., Thailand, Sri Lanka, and China) could verify the source of their diamonds, which may have been bought third- or fourth-hand.
6. There is no way that country of origin can be verified for polished diamonds.
7. There are currently about $15 billion in polished diamonds in the U.S. pipeline without certificates of origin. Would a grace period be given to clear them?
8. The livelihoods of thousands of smaller- and medium-sized jewelers, diamond dealers, and even retailers in the U.S. would be affected. Unable to cope with the effects of the proposed regulations, they would become unintended victims. *AAL*

Damage to the international diamond market will not break the link between "the guns and the gold." N. Oppenheimer, *Mazal U'Bracha*, Vol. 15, No. 116, December 1999, pp. 24, 25, 27–29.

With the Angolan situation as a backdrop, De Beers's chairman reviews the relationship between natural resources and development in African countries by analyzing two opposite and contradictory beliefs. The first states that a country's wealth, and by inference the quality of life for its citizens, is determined by its mineral resources (e.g., oil, diamonds, and gold). The second proposes that an abundance of natural resources does not cause wealth but rather conflict and deprivation. Mr. Oppenheimer concludes that both beliefs are incorrect, because natural resources are "morally neutral." The key element is not the resource, but how it is exploited. For example, Botswana, with its orderly mining regime and predictable legislative and fiscal framework, has generated prosperity. Angola represents the other extreme.

It is in De Beers's best interest to break the link between mineral resources and the funding of wars for both humanitarian and business reasons. Toward this end, De Beers has supported all U.N. efforts with regard to Angola (e.g., by supplying expert advice to U.N. committees, and by strictly adhering to the diamond sanctions). In fact, De Beers has gone even further by announcing a worldwide embargo on the purchase of *all* diamonds from Angola.

Mr. Oppenheimer expressed grave concern over the possible consequences of a consumer boycott of diamonds, should an impasse develop between those seeking certification of diamond origin and those who believe it is unrealistic to maintain a failsafe marking system of diamonds through the pipeline. Not only would such a boycott jeopardize the employment of diamond miners in other African countries (such as Namibia, South Africa, and Botswana), but it would also disrupt the livelihoods of a large number of people in the cutting centers—particularly India. *AAL*

COLORED STONES AND ORGANIC MATERIALS

Chinese freshwater begins new era. B. Sheung, *Jewellery New Asia*, No. 177, May 1999, pp. 92, 94, 96, 99.

Three distinct phases in the history of the Chinese freshwater cultured pearl industry are defined. The first phase, leading up to 1985, was characterized by the production of small (4–5 mm) tissue-nucleated cultured pearls with a wrinkled surface, called "rice" or "rice crispy" pearls by the trade. The second phase, 1985–1997, was characterized by the use of the mollusk species *Hyriopsis schlegeli*. With the techniques prevalent at the time, smooth-surface tissue-nucleated cultured pearls up to 7 mm were produced. The third (present) phase of freshwater pearl culturing began in 1996; it is marked by larger (up to 10–12 mm), higher-quality cultured pearls as a result of new cultivation practices using *Hyriopsis schlegeli*.

The new culturing techniques, which have revolutionized the industry in China, involve using somewhat older, larger oysters and implanting fewer but larger mantle-tissue nuclei. It takes two years to grow a 6 mm pearl, and six years to grow one 10–12 mm. Future prospects are bright for these higher-quality freshwater cultured pearls, as they provide an affordable alternative to the Akoya product.

Several graphs illustrate price variations since 1985 for Chinese freshwater cultured pearls of various shapes.

After remaining relatively stable at about US$700/kg from 1985 to 1994, the prices of good-quality "rice" and "button" shapes have declined to about $200/kg since 1995. The prices of good-quality rounds and near-rounds, on the other hand, have increased dramatically: After remaining essentially stable at about $700/kg from 1985 to 1993, they rose to almost $3,000/kg in 1998.

JEM-S

Japanese Akoya report. B. Sheung, *Jewellery New Asia*, No. 181, September 1999, pp. 178–204 passim.

The pearl industry in Japan has suffered great losses since 1996 due to high mortality of the *Pinctada fucata* oysters. In 1996, Japan produced 16,500 kan [1 kan = 3.75 kg], whereas present annual production is about 7,000 kan. Although the specific cause of the high oyster mortality has yet to be determined, some possibilities include pollution, elevated water temperature and salinity, genetically weakened oysters, and viruses.

The underlying theme of this report, which consists of several short articles, is that the Japanese Akoya pearl industry is working hard to overcome its problems. As industry scientists search for causes of the high oyster mortality rate, farmers are looking for viable alternatives. These include the use of hybrid oysters and hatchery oysters. Once secretive about their cultivation techniques, Akoya farmers are now sharing ideas to ensure that the industry not only survives, but also flourishes once again.

JEM-S

Raman spectra of silicate garnets. B. A. Kolesov and C. A. Geiger, *Physics and Chemistry of Minerals*, Vol. 25, 1998, pp. 142–151.

Garnets are compositionally diverse and structurally complex, but their crystallographic symmetry produces relatively simple Raman spectra. This study establishes Raman vibrational frequency patterns for the most common garnet solution series. Polarized Raman spectra were obtained from four natural garnets of near end-member composition (almandine, grossular, andradite, and uvarovite), as well as synthetic spessartine and pyrope. The frequency modes established by the garnet data are the result of three types of vibrational and compositional sources. In order, these are: rotational from silica tetrahedra, translational from metal cations, and translational from silica tetrahedra. The authors suggest that this order should be the same in other orthosilicate minerals. The Raman spectra of garnets that form solution series reiterate the fact that the frequencies are a function of composition.

JL

Rubin, Saphir, Korund [Ruby, sapphire, corundum]. *extraLapis*, No. 15, 1998, 96 pp. [in German]

The efforts of 16 contributors were harnessed to produce this issue of *extraLapis*. The volume begins with a two-page synopsis of the physical properties, origins of color, problem of nomenclature for the different color varieties, and review of color treatments for corundum. Then Dietmar Schwarz summarizes the geologic conditions under which corundum forms, and the different types of rocks in which primary deposits occur (e.g., alkali basalt, marble, skarn, pegmatite, amphibolite, and gneiss), taking into account several competing theories.

Next, Susanne Greiff presents historical anecdotes from classical Hindu literature drawn from the Indian book *Mani Mala*, by Sourindro Mohun Tagore (1879). From this work, we learn that ruby and sapphire were known in India to be the same mineral long before this fact was rediscovered in Europe around 1800. Further, corundum varieties were divided into different castes, similar to Indian society.

Roland Schussel tells the story of "The Mogok Sun," a 1,734 ct ruby crystal from the Dat Taw mine at Mogok, Myanmar. Karl Schmetzer and Heinz-Jürgen Bernhardt provide a summary of research on trapiche ruby. Henry A. Hänni and Karl Schmetzer describe Douros flux-grown synthetic ruby, and Dr. Schmetzer outlines the properties of hydrothermal synthetic ruby and sapphire from Russia.

The bulk of this lavishly illustrated volume consists of comprehensive descriptions (two to four pages each) by several authors of almost every important corundum deposit in the world, including the ruby deposits of Mong Hsu, recent discoveries such as those in Madagascar, the sapphire deposits in Montana, and the promising (but remote) new ruby deposit near Nangimali, Kashmir. Each locality summary discusses the history, mining conditions, and characteristics of the material produced, with photographs of the mines and typical stones. As is frequently the case, collectors are likely to be more interested in the compilation of smaller corundum deposits noted for their fine specimens.

RT

Vergleichende Untersuchungen an Rhodolithen verschiedener Provenienz [Comparative studies of rhodolite garnets of different origin]. Th. Lind., U. Henn, and C. C. Milisenda, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 47, No. 1, 1998, pp. 53–59.

Chemically and mineralogically, rhodolite is a solid solution between pyrope and almandine, in addition to generally minor amounts of other garnet species (mainly grossular and spessartine). The authors distinguish three types of rhodolite on the basis of their visible absorption spectra. All three—designated Types 1, 2, and 3—have three absorption bands (called L_8, L_9, and L_{10}) in the yellow-green spectral range. Together, these bands create a local absorption maximum that dominates the visible spectral region between 500 and 600 nm.

The difference between rhodolite Types 1 and 2 can be found in their spectral transmission, particularly in the blue-violet portions of the visible spectrum. In Type 2, absorption in the blue-violet region is much stronger than in Type 1 because of a much stronger LMCT (ligand-metal-charge transfer). Type 3 rhodolite is characterized by relatively high Mn contents (~5–10 wt.% MnO, or ~10–20 mol.% spessartine in the samples analyzed). The Type 3 rhodolite samples also contained 0.1–0.2 wt.% of both V_2O_3 and Cr_2O_3, which is up to twice the values for these components measured in the Type 1 and Type 2 samples; these trace elements cause the much greater absorption seen in the L_8, L_9, and L_{10} bands in Type 3 rhodolite.

The authors provide the following gemological characteristics for the three rhodolite types:

Property	Type 1	Type 2	Type 3
Color	Bright blue-purple with no brown or orange "tint"	Reddish pink to red-orange	Red to orange "tint"[a]
R.I.	1.743–1.766	1.752–1.783	1.743–1.763
S.G.	3.76–3.88	3.84–4.04	3.75–3.88

[a] Type 3 stones may display a color change to greenish blue in daylight.

Although there is a direct relationship between R.I. and S.G. (i.e., as the S.G. increases so does the R.I.), there is significant overlap among these properties for the three types. *Karin Schmocker*

DIAMONDS

Ashton up but outlook mixed. *Mining Journal, London*, Vol. 332, No. 8523, March 19, 1999, p. 202.

Ashton Mining Ltd. of Australia has four principal diamond operations: the Argyle mine in Western Australia (38.2% ownership), Cuango in Angola (33.3% owned), Merlin in Australia's Northern Territory, and Cempaka in Indonesia. All are pipe mines except for Cempaka, which is alluvial. In fiscal 1998, Argyle's recorded sales rose 20% over 1997 levels, to US$398 million, roughly one-tenth the size (in value) of De Beers's sales. These higher sales were achieved during a year in which retail diamond consumption fell by 3%, possibly because the Argyle mine produces mostly inexpensive goods. The planned mine life was reduced to 2003 in 1997; a more recent expansion of the open pit extends this life to at least 2005. As a consequence of the pit expansion, higher-grade ore zones were temporarily less available, and production was expected to fall from 40.9 million carats (Mct) in 1998 to 33 Mct in 1999. Underground mining at Argyle remains a future possibility.

Cuango also yielded higher sales in 1998: Aus$216.6 million [about US$142 million], up 23% from 1997. However, the resumption of civil war in Angola has made prospects at Cuango uncertain, and four people at the project were killed in an ambush in late 1998.

Both the Merlin and the Cempaka operations are currently small. Production from Merlin is expected to reach 200,000 carats in 1999. *MLJ*

Hope springs eternal. A. Butler and R. Nicholson, *Chemistry in Britain*, Vol. 34, No. 12, December 1998, pp. 34–36.

The dramatic blue color of the Hope diamond is more easily explained than the mystery surrounding its reputation as a harbinger of misfortune.

Pure diamond is called a wide band gap semiconductor: The bonding orbitals (valence band) are full, while the anti-bonding orbitals (conduction band) are much higher in energy. This energy gap is too great for the absorption of visible light, so pure diamond is colorless. However, virtually all naturally occurring diamonds contain some impurities or crystal defects that alter their light absorption characteristics.

Most diamonds contain varying concentrations and groupings of nitrogen impurities—these are classified as Type I. Type Ia diamonds contain from 10 to 3,000 ppm nitrogen distributed throughout the crystal as small aggregates. Type Ib diamonds contain 25–50 ppm nitrogen, and are characterized by single nitrogen atoms substituting for carbon in the crystal lattice.

Nitrogen has one more electron than carbon. Extra electrons from these nitrogen atoms are forced into a separate energy level—the nitrogen donor band—between the valence and conduction bands. Visible light in the higher-energy blue and violet range is absorbed by electrons in this donor band, so the diamond appears yellow. The intensity of coloration depends on the concentration and distribution of nitrogen atoms.

Diamonds that contain less than 10 ppm of nitrogen are designated Type II. Type II diamonds that contain boron impurities—classified as Type IIb—are blue in color (like the Hope diamond). The more boron atoms present in the crystal, the deeper the blue.

Boron has one less electron than carbon. This disparity leads to a hole in the electronic structure when boron substitutes for carbon in the diamond. This hole occupies an energy level just above the valence band. Therefore, valence-band electrons can be excited into this acceptor level by absorbing light in the lower-energy wavelengths of the visible spectrum: Mostly red light is absorbed, but also some orange, yellow, and green. Blue light is not absorbed, so Type IIb diamonds appear blue. *SW*

Just your type. R. Weldon, *Professional Jeweler*, Vol. 2, No. 8, August 1999, pp. 30, 32.

A closer look at the classification of diamonds by type may provide insight into which stones are the best candidates for new enhancements such as the process used for GE POL diamonds.

Diamonds are divided into two major categories: Type I and Type II. Approximately 99% of all diamonds are Type I; they contain an abundance of nitrogen atoms and are electrical nonconductors. How this nitrogen is distributed in the crystal structure provides further discrimination of Type I diamonds.

If the nitrogen atoms are present as clusters, the diamond is classified as Type Ia—the most common variety. This category comprises colorless and some yellowish diamonds. Type Ib diamonds contain single nitrogen atoms that are dispersed throughout the crystal lattice, and are far rarer than Type Ia stones. Type Ib diamonds are typically yellowish to fancy yellow. Type Ib and mixtures of Type Ia/Ib may lose some of their color when subjected to a high pressure/high temperature environment.

Type II diamonds are rare; they contain no nitrogen (or only extremely small amounts). Type IIa diamonds are exceptionally pure. They are often very large and usually colorless, although Type IIa diamonds also may be pink, brown, or blue-green. These diamonds are inert to short-wave UV radiation. They do not conduct electricity, and they are efficient heat conductors. Type IIb diamonds are characterized by boron impurities. They do conduct electricity and are extremely sensitive to temperature changes. Most blue diamonds are Type IIb. *SW*

Multiplying mines. L. Rombouts, *Basel Magazine*, No. 5, August 1999, pp. 37–39.

Worldwide rough diamond production in 1998 totaled 120 million carats, worth US$6.7 billion. Major producers [in order of decreasing value] were Botswana, Russia, South Africa, Angola, the Democratic Republic of Congo [formerly Zaire], Namibia, Australia, and Canada. Botswana alone produced 20 million carats worth $1.6 billion. [*Editor's Note*: This represents approximately 17% by weight and 24% by value of total world production.]

Expansion of existing mines and new mine development will ensure adequate diamond production well into the next century. Geologic exploration in Africa has been concentrated in the southern and western parts of the continent, but Angola and the Democratic Republic of Congo presently are excluded due to internal turmoil. Exploration of Namibia's rich offshore deposits continues, while in Botswana and South Africa the emphasis is on exploration for kimberlite pipes. In Canada's Northwest Territories, more than 200 kimberlites have been found to date. Several of these appear to have very good ore grades and diamonds of excellent quality.

New diamond deposits are presently being developed, or are awaiting development, in Australia, Indonesia, Canada, and Russia (mainly the Sakha Republic, but also in the Arkhangelsk region). Several new mines are expected to be in production in these countries within the next five years. Exploration activity is ongoing in Brazil and Mauritania, as well as in several other countries.

Kenneth A. Patterson

Polished consumers are trading down. M. Mitchell, *Mazal U'Bracha*, Vol. 15, No. 110, April 1999, pp. 30–32.

Data from all major diamond-consuming countries indicate that the average price of polished imports has fallen, sometimes dramatically, in the 1990s. In 1990, polished imports into Japan averaged almost US$800/ct, but this declined to about $400/ct in 1998. Comparable figures for Hong Kong are $650/ct and $300/ct, respectively. Clearly, Asian consumers are buying diamonds worth only half as much as they were worth at the beginning of the decade; they are "trading down." For the U.S. there is a comparable but less-pronounced trend, yielding figures of $550/ct and $450/ct, respectively. Confirmation of this trend is seen in the carat (weight) consumption in the Japanese and U.S. markets. In Japan, 68% of all diamonds sold are less than 0.17 ct. In the U.S., these small diamonds represent 62% of the market in carat terms.

These data are used by the author, who is the marketing director of the Argyle mine, to confirm the strong current demand for low-quality Argyle diamonds in world markets. He predicts that this demand will continue. Further, it explains the surprisingly strong financial results for the Argyle mine since it began marketing its diamonds independently of De Beers in mid-1996. At present, Argyle produces about 40 million carats (Mct) of rough diamonds annually. The projected annual production at Argyle will hover around 25–30 Mct for the first five or six years of the new millennium; beyond that, the mining situation is not clear. *AAL*

Twinning in natural diamond. I. Contact twins. A. Yacoot, M. Moore, and W. G. Machado, *Journal of Applied Crystallography*, Vol. 31, 1998, pp. 767–776.

Growth histories of natural diamond contact twins have been elucidated by nondestructive techniques of X-ray topography, using both conventional and synchrotron sources. The common "triangular" contact twin (macle) results from {111} stepped-growth from a central nucleation site, sometimes marked by an inclusion. If this period of growth is followed by dissolution, then a twinned rhombic dodecahedron may result. A peritropic "twin" (having the appearance of the Star of David) consists of two macles fortuitously joined on their common {111} faces in only approximate twin orientation. In all these variations, the composition "plane" may be far from planar, because of the intergrowth of one twin component into the other. *RAH*

Twinning in natural diamond. II. Interpenetrant cubes. A. Yacoot, M. Moore, and W. G. Machado, *Journal of Applied Crystallography*, Vol. 31, 1998, pp. 777–782.

Single crystals of natural diamond that exhibit an approximately cubic morphology are known to have grown by either (a) nonstepped cuboid growth or (b) fibrous growth branching in a multiplicity of (111) columns, to give a mean surface orientation of {100}. Interpenetrant twins of diamond are uncommon; when they occur they are usually colored. They appear (with X-ray topography) to have been formed by fibrous growth on a twin origin, with the 14 growth sectors adequately filled by fibers, without the necessity of branching. *RAH*

GEM LOCALITIES

Smaragde, das "Grüne Feuer" aus Kolumbien [Emeralds, the "green fire" from Colombia]. F. Schindler, *Lapis*, Vol. 23, No. 10, 1998, pp. 13–18 [in German].

This article gives insight into the situation at the Muzo and Coscuez mines, as well as the Bogotá emerald market, all of which the author visited in 1997. Access to the mines was difficult. Mining at Muzo seemed to be under control, whereas Coscuez still resembled the Wild West. Buying emeralds—even in Bogotá—was risky because of terrorist activities, robbery, and fraud. The main attraction of this article is the many excellent photographs of the mining operations and of the exceptional emerald crystals and specimens. *RT*

Ruby and variously coloured sapphires from Ilakaka, Madagascar. K. Schmetzer, *Australian Gemmologist*, Vol. 20, No. 7, 1999, pp. 282–284.

Selected gemological properties of ruby and non-heat-treated sapphires (mostly pink and blue-violet to purple) from the recently discovered [in 1998] deposits at Ilakaka, Madagascar, are presented. Sapphires that were violet in daylight showed a change-of-color to purple in incandescent light, while those that were purple in daylight changed to reddish purple, purplish pink, or purplish red in incandescent light. The samples revealed normal absorption spectra. No evidence of growth structures or rutile silk was seen during microscopic examination, but several sets of oriented twin lamellae were observed. Dr. Schmetzer reports that the large quantities of Ilakaka pink sapphires seen in the world market are, for the most part, violet to purple sapphires that have been heat treated.

The properties (e.g., color and absorption spectra) of these samples were similar to those of sapphire and ruby from Umba, northern Tanzania, which have been known for more than 30 years, and from the Tunduru and Songea regions of southern Tanzania, which have been mined since the mid-1990s. *MT*

Sapphire find in Madagascar sparks gem rush, softens prices. J. Henricus, *Jewellery News Asia*, No. 179, July 1999, pp. 44–46, 48, 49.

The large quantities of blue and pink sapphire produced from alluvial deposits in the Ilakaka-Sakaraha area of southwestern Madagascar have instigated a gem rush unprecedented in this island country. Colors range from light to intense pink and some brownish tones, to all shades of blue, violet, purple, and color-change sapphires. Several new finds have coincided with the increase in mining activity. Most recently (in May 1999), a deposit located north of the existing mining areas and close to the town of Murarano has produced fine alexandrite in addition to sapphires.

According to wholesalers, some of the sapphires from Madagascar are comparable in quality to those from Sri Lanka and Kashmir. Blue sapphire rough reportedly ranges up to 30 ct, while pink sapphire rough ranges up to 15 ct. As a result of the new finds, the price of heated [blue] sapphires dropped about 20% between April and June 1999, while pink sapphire prices declined 20%–30%. Instances have been reported of unscrupulous dealers heating rough milky corundum and mixing it with parcels of unheated rough at the mine. This practice has caused serious problems for dealers, who believed that they were purchasing natural, unheated material. *MT*

Sapphires from Madagascar revives [*sic*] **Sri Lankan gem industry.** J. Henricus, *Jewellery News Asia*, No. 182, October 1999, pp. 54–56, 58.

For the past five years, as local sources were depleted, the gemstone industry of Sri Lanka has suffered from the lack of rough. The recent finds of large gem deposits in the Ilakaka-Sakaraha region of southwestern Madagascar have alleviated this problem. Rough with an estimated wholesale polished value of US$1 million is being imported from Madagascar every month. Most of the rough is blue or pink sapphire, although significant quantities of alexandrite and cat's eye chrysoberyl are also being imported. Sri Lankan dealers usually travel to Madagascar in groups of three to five: at least one dealer, a cutter, and an expert in selecting rough. The Sri Lankan groups are meeting stiff competition from Thai buyers.

Notwithstanding the positive aspects of a revived Sri Lankan cutting and trading industry, several concerns have surfaced. First, oversupply, particularly of heated blue and pink corundum, is having a detrimental effect on the prices of the polished goods, which have fallen 20%–40% and 50%, respectively, for heated blue and pink sapphires since early 1999 [as of the time this article was written]. Second, incidents of harassment and extortion of buyers in Madagascar's mining areas are rising.

In view of the surging interest in Madagascar gems, and the likelihood that this trend will continue, the government of Madagascar has again revised rules for trading and mining gems. Highlights include:

1. To buy rough gems (at least in the Ilakaka-Sakaraha region), dealers must form a company with a local business partner and have it registered at the Department of Mines in the capital city of Antananarivo. "Authorization documents" are then issued (cost: about US$950).
2. These documents are presented to the Gem Mining Association in Ilakaka or Sakaraha, which issues a license for the company to buy rough (cost: $35).
3. The company rents a booth in the trading area to buy from local dealers (cost: a nonrefundable deposit of $500 to the Association, and a monthly rental fee of $40).

This system is designed to prevent local miners from selling directly to overseas dealers. Local miners can legally sell only to local dealers, who in turn sell to foreign dealers. *AAL*

Why gemstones from Madagascar differ to [*sic*] **those from Sri Lanka.** J. Henricus, *Jewellery News Asia*, No. 182, October 1999, p. 59.

Large quantities of rough (particularly corundum) from the Ilakaka-Sakaraha area of Madagascar are being imported into Sri Lanka for heat treatment and cutting. Whereas original indications were that the corundum from the two countries was essentially identical, distinct differences in the reaction to heat treatment and cutting are now recognized. For example, dark corundum from Sri Lanka becomes lighter with heat treatment, whereas the reverse occurs with dark corundum from Madagascar. [*Editor's note*: Although not specified by the author, the reader can assume that all references to Madagascar in this article are to material from southwestern Madagascar (e.g., the Ilakaka-Sakaraha region).] On the other hand, better results are obtained from light-colored Madagascar corundum, which can improve dramatically with heating. Further, Madagascar corundum requires greater care in orientation when cutting, since even slight errors can result in a loss of color or a greenish appearance.

Over 50% of the rough blue sapphire produced in Madagascar is a smoky variety called the Sri Lankan name "dhun," which reacts best to heat treatment. Good results can be obtained with this variety at relatively lower temperatures and shorter heating times. Most heatable material from Sri Lanka is called "geuda," which shows the "diesel effect" (i.e., a pale brown tinge when viewed with transmitted light). Dhun, however, lacks the diesel effect.

There are three categories of geuda (in decreasing order of value): fine diesel, silky, and "ottu" (transparent and colorless with a patch of blue). Less than 10% of the corundum from Madagascar is classified as fine diesel, and about 30% is the silky or ottu type. Of the total output of Madagascar sapphire, less than 10% does not require heat treatment. *MT*

INSTRUMENTS AND TECHNIQUES

Gemological applications of X-ray diffraction topography techniques. T. Liangguang, H. Wenhui, C. Youfa, L. Huafeng, and T. Xin, *Journal of Gems & Gemmology*, Vol. 1, No. 2, 1999, pp. 41–44 [in Chinese with English abstract].

A brief review is given of X-ray diffraction topography, a powerful tool for imaging the distribution of lattice defects, which is a well-established nondestructive characterization technique used in physics and materials science. The authors apply the technique to detecting epitaxial layers grown on a gadolinium gallium garnet. The epitaxial layers have a brown-red color, are 1–3 microns in thickness, and have a chemical composition of $Be_3Fe_5O_{12}$. The layers are difficult to distinguish by microscopy, but with X-ray diffraction topography using the double crystal rocking curve method (see below), a clear difference between the substrate and the epitaxial layers was seen. Therefore, the ability of this method to detect coating layers on gem materials is confirmed.

[*Abstracter's note*: Several X-ray diffraction techniques have been developed to characterize the crystallinity and imperfections of a material. Depending on the detector and which parameter is selected from the diffracted X-ray beam, these techniques are mainly classified into two groups: imaging and intensity counting. An X-ray double crystal rocking curve is obtained by measuring an X-ray diffraction intensity curve by the double crystal method. The first crystal is used to obtain a diffracted X-ray beam that is passed through the second crystal, which is the sample being analyzed.] *Taijin Lu*

Tester model 590 for colourless moissanite/diamond: An instrument evaluation. V. M. F. Hammer and J. Stefan, *Australian Gemmologist*, Vol. 20, No. 7, 1999, pp. 298–302.

The C3 Inc. Tester Model 590, while somewhat effective, has not met the industry's needs, based on the authors' criteria. The instrument detects the contrasting absorption in the blue region of the visible and near-visible UV spectra of diamond and synthetic moissanite. During testing, a green light will illuminate and a buzzer will sound when the recorded wavelengths match those of diamond.

The instrument correctly identified round-brilliant-cut diamonds in the color range of D–M (on the GIA D–Z color grading scale) that weighed over 0.04 ct (4 points). Fancy-shaped diamonds, diamonds under 0.04 ct, and diamonds with colors lower than M often gave inconsistent or negative results, indicating synthetic moissanite. It is noteworthy that the standard color range of currently available synthetic moissanite lies in J–N, which makes the tester ineffective on low-end colors. The article concludes that the best way to distinguish diamond from synthetic moissanite is by using routine gemological identification techniques. *Rob Spencer*

JEWELRY HISTORY

Emerald man. S. Whittington, J. Vose, and C. Hess, *Archaeology*, Vol. 51, No. 4, 1998, p. 26.

The authors report on a 118.5 ct emerald figurine that they believe to be the oldest known emerald from Mesoamerica. The 2.2 inch (5.6 cm) figurine, given to the University of Maine's Hudson Museum in 1982, is carved in the shape of a man standing with arms folded over his midsection. It is not known where the emerald figurine was excavated.

Nondestructive testing proved the stone to be natural emerald. The authors indicate that the emerald contained more trace elements in common with emeralds from Muzo, Colombia (e.g., Cu, Ba, Zn, Rb, and Ti) than any other source. On the basis of similarities to small stone figures made by the Olmec (a Mesoamerican civilization that lived along the southern coast of the Gulf of Mexico), they suggest that this figurine was carved between 900 and 600 B.C. Colombian sources are known to have been mined for emeralds by 1000 A.D., so this would mean that the Muzo source was known nearly two millennia earlier. *Kenneth A. Patterson*

Hildegard von Bingen *De Lapidibus*—Welche Steine beschrieb Hildegard tatsächlich? [Which stones did Hildegard really describe?] M. Glas, *Lapis*, Vol. 23, No. 6, 1998, pp. 46-52 [in German].

Hildegard von Bingen (1098–1179) was famous in her time—and is still well-known today—for her descriptions of natural objects, particularly the "recipes" and uses of several thousand plants, animals, and minerals. Of gemological interest is her book *De Lapidibus [About Stones*], which contains information about 26 stones, almost all of them gems. An explanation for the identification of each stone is provided, using current terminology.

Although most of the stone names are familiar, almost all of them have undergone dramatic semantic changes, and we can only guess the modern-day equivalents of some. In this article one gets a brief overview of medieval mineralogy and attitudes toward gems, as well as the problems of converting medieval to contemporary nomenclature. *RT*

JEWELRY RETAILING

Diamond jewelry consumers in the United States: Who buys what, for how much, how often and why. R. Lennox, *Mazal U'Bracha*, Vol. 15, No. 115, November 1999, pp. 47–51.

The number of U.S. millionaires is increasing at roughly 20 times the rate that the country's population as a whole is growing. Twenty-one percent of U.S. households have an annual income of over $75,000. These are some of the many statistics that chronicle wealth in the U.S., the driving force behind the world diamond industry today.

Statistics for 1998, the most recent year for which complete data are available, show that in the U.S., 33 million pieces of diamond jewelry were purchased [equivalent to one per second for the entire year] at an average price of just over $655. The total—$22 billion—represents almost 50% of the world's diamond jewelry by value. Who are the individuals who purchase these diamonds? Why, and how often, do they make these purchases? Some of the answers to these questions lie in "two premises" established by J. Walter Thompson, the U.S. advertising agency for De Beers, after studying the buying habits of the American diamond consumer.

First premise: All diamonds are essentially given for the same reasons. Research has repeatedly shown that consumers in the U.S. regard a diamond as the ultimate form of love. It has no peer.

Second premise: There is no such thing as the typical diamond purchaser or receiver. The appeal of diamonds encompasses a wide range of demographic subgroups, consumer life stages, and "psychographic" profiles. If there is such a thing as an "average" diamond jewelry purchaser (excluding the engagement ring purchase), that person would be between 35 and 54 years of age, likely would have been married between five and 15 years, and already would have accumulated five or more diamond pieces. The average length of time between diamond purchases would be 2.8 years. In 1998, these "diamond addicts" purchased 59% of the market value of diamond jewelry, but they constituted only 21% of the population; clearly they are characterized by wealth.

The average consumer of the early 21st century will be different. The population is aging, and those over 65 will have much greater spending power. The most significant change probably will be related to the increasing number of financially independent women. *AAL*

SYNTHETICS AND SIMULANTS

Effects of the phosphorous-ion additive on the crystal habit of the emerald crystals grown from the V_2O_5–Li_2O–P_2O_5 fluxes. M. Kayama and J. Kuwano, *Journal of Crystal Growth*, Vol. 193, No. 4, 1998, pp. 648–655.

Because of interest in the mineralogical, gemological, and industrial applications of synthetic emerald, this study assessed the effects of phosphorous (P) concentration on the crystal growth of synthetic emeralds. Stoichiometric amounts (i.e., exact proportions) of beryl raw materials and a chromium (Cr) dopant served as the solute. A V_2O_5–Li_2O–P_2O_5 flux (with V/Li molar ratio of 1.7) was used because it yields good-quality hexagonal crystals. The crystals studied ranged from 0.95 mm to 2.31 mm long.

Crystal length increased with phosphorous addition. Crystal volume reached maximum proportions (three times that of the phosphorous-free flux crystals) at a molar ratio [P/(V+Li)] of 6.9×10^{-3}; at ratios greater than that, crystal width progressively decreased. At a molar ratio an order of magnitude higher, crystal quality began to suffer. Crystals grown from the 6.9×10^{-3} flux were cut parallel to the c-axis for electron microprobe analysis, to determine the crystallographic sites that preferentially incorporate P and Cr. The authors suggest that phosphorous ions suppressed the growth rate in the $m\{10\bar{1}0\}$ plane, which provides the appearance that c{0001} plane growth is favored. In addition, an increased P incorporation results in a decreased Li incorporation into synthetic emerald. *JL*

EPR of new nickel-nitrogen center in annealed synthetic diamond. R. I. Mashkovtsev, Yu. N. Pal'yanov, *Solid State Communications*, Vol. 111, No. 7, 1999, pp. 397–402.

A synthetic diamond was grown from a Ni solvent and heated to 2300 K. During the annealing process, the deep yellow color of the diamond diminished to become slightly yellow or greenish yellow. On the basis of the EPR spectra, the authors determined that light-absorbing defects in the annealed diamond were being caused mainly by nickel-nitrogen aggregates. The main nickel-related centers are the NE1 and NE2. In addition to a secondary center known as the NE5, the researchers discovered another absorption center that had a concentration one tenth that of the NE1. This new center has been named the RM1. On the basis of observations of hyperfine interactions between nitrogen nuclei, the authors conclude that the RM1 center consists of high levels of nitrogen aggregation, with four nitrogen atoms closely surrounding a Ni^+ ion. During exposure to UV radiation, the NE5 absorption center increased about three-fold, but the intensity of the RM1 center remained unchanged. *TB*

FTIR features of Guilin hydrothermally-grown synthetic emerald and its *[sic]* **significance.** G. Shi, *Journal of Gems & Gemmology*, Vol. 1, No. 1, 1999, pp. 40–44 [in Chinese with English abstract].

The nature of the color and the form of the water molecules in synthetic emerald from Guilin (China) were investigated by electron microprobe analysis and FTIR spectroscopy. The results show that the synthetic emerald is characterized by low contents of alkalis (0.00–2.67 wt.% Na_2O and 0.00–0.028 wt.% K_2O) and Fe. Both type I and type II water molecules are present. Nail-like inclusions are typical. *RAH*

Examining flame fusion synthetic ruby with fingerprint inclusions. T. T. Sun and Z. C. Guang, *Jewellery News Asia*, No. 181, September 1999, pp. 104, 106.

The authors determined the optical and physical properties of eight flame-fusion synthetic corundums that contained flux-induced fingerprint inclusions. All had been submitted to the Far East Gemological Laboratory in Singapore since 1998. The R.I.'s, birefringence, S.G., and fluorescence matched those of natural ruby and sapphire. The samples contained inclusions typical of material produced by the flame-fusion process (gas bubbles and curved growth bands), along with flux-induced "fingerprints." These partially healed fractures—visible with a standard gemological microscope and darkfield illumination—extended from the surface of the sample inward. They had the criss-cross pattern common to "wispy veils" seen in flux-grown stones.

Although the exact method by which the fingerprints are produced is not known, the authors suggest the following two-stage process: (1) the crystals are quench-cracked to produce fractures and fissures, and then (2) they are immersed in a molten flux that results in the filling and partial healing of these fractures and fissures. The dealers who submitted these fingerprint-induced synthetic rubies claimed that they came from Bangkok and Chanthaburi, Thailand. The senior author found such stones mixed in a parcel of natural Mong Hsu rubies during a visit to Myanmar in March 1999.

Fingerprints are induced in synthetic rubies (and other corundum varieties) to imitate the partially healed fractures seen in natural specimens and to mask the curved growth striations usually seen in flame-fusion rubies.

Wendi M. Mayerson

MISCELLANEOUS

Emerging markets: The divide widens. *Supplement to Mining Journal, London*, Vol. 333, No. 8554, October 22, 1999, 22 pp.

In this survey, countries are ranked as prospects for mining investment, so both political and economic factors are considered. Three of the top 10 emerging markets were major gem-producing countries: South Africa at no. 5, Tanzania at no. 8, and Namibia at no. 10.

The investment climate in South Africa has improved with the 1998 publication of a "white paper" that includes provisions to persuade mining companies to release mineral rights that would not be exploited otherwise. As a result, a number of "black empowerment" plans have been put into action; in diamonds, De Beers sold a portion of its Marsfontein diamond project, and management of the state-owned Alexcor diamond mine was turned over to a consortium of mainly black businessmen. South African mines produced US$900 million worth of diamonds in 1998. De Beers also announced a $250 million project to extend the life of the Premier mine; if this materializes, it would increase production from the Premier to 3 million carats per year, which is about a third of De Beers's current production from South African mines.

Tanzania's parliament passed a new Mining Act in 1998, replacing the "socialist-inspired" 1979 Mining Act. The El Niño rains of 1997 severely affected not only Tanzania's infrastructure but also specific mines: For instance, the Williamson diamond mine were flooded, as were the tanzanite mines at Merelani. Nevertheless, gemstone exports increased from $7.97 million in 1997 to $13 million in 1998.

Diamond exports from Namibia were $552 million in 1997, an estimated $560 million in 1998, and are expected to rise to $630 million in 2000. Onshore recovery by Namdeb Diamond Corp. is shrinking, but offshore mining continues to increase, with an estimated resource of 1.5 billion carats. Reportedly, 734,000 carats were recovered from offshore deposits in 1998 (51% of Namibia's total diamond output of 1.44 million carats), and this is expected to grow to one million carats by 2001. Companies engaged in offshore mining in Namibia include De Beers Marine, Ocean Diamond Mining, and Namibian Minerals Corp. *MLJ*