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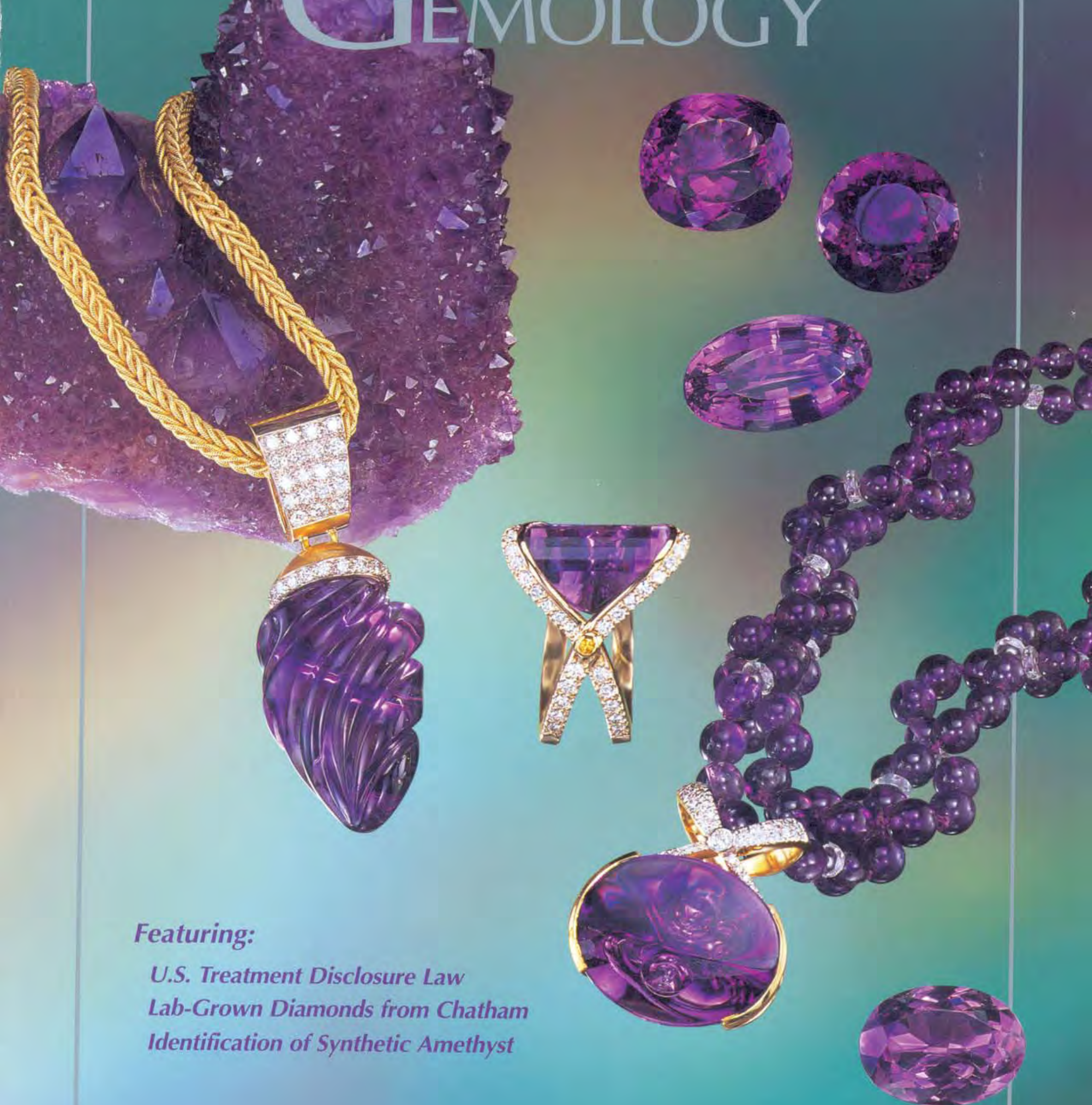
SUMMER 2004



Featuring:

- U.S. Treatment Disclosure Law
- Lab-Grown Diamonds from Chatham
- Identification of Synthetic Amethyst

THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA

GEMS & GEMOLOGY

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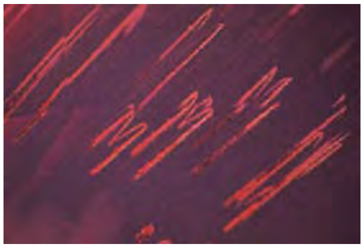
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The Results of
OUR FIRST READER SURVEY

This spring, *Gems & Gemology* conducted a reader survey, the first in the journal's 70-year history. The purpose was to better understand our readership so we could ensure that *G&G* remains relevant to the needs and interests of its audience. More than 10,600 surveys were mailed to current and former subscribers as well as GIA alumni, and we received nearly 3,500 replies, including 42% of our current subscribers from all over the world (a truly amazing response rate).

Before sharing the results, though, I'd like to thank all the respondents for taking time to provide us with valuable feedback. We needed to hear from you, and you delivered for us. I also want to congratulate to Jonathan Ng (San Gabriel, California) and Colleen Ann Murtha-Stoff (Tucson, Arizona), whose survey cards were randomly drawn to win three-year subscriptions to *G&G*, and lifetime subscriber Roland Schluessel (San Francisco), who chose the $200 Gem Instruments gift certificate.

Who Reads *G&G*?

Fifty-nine percent of the *G&G* subscribers who responded are male, while 39% are female (2% did not reply to this question). The mean age is just under 52 years old. Nearly 60% have subscribed for more than five years. Seventy percent are employed in the gem and jewelry industry, most for 10 years or more. The *G&G* reader is affluent, with a mean annual income of $90,270. (We'd like to think that reading the journal has helped them reach—and maintain—this financial success.)

Although the top occupation is retail jeweler, claimed by 38% of the respondents, our readers also include appraisers, jewelry designers, wholesalers, and lapidaries, as well as educators, research scientists, and laboratory gemologists. We were pleased to see that, in many cases, each copy delivered is read by several people.

Colored stones are the primary area of interest for 45% of the subscribers, followed by diamonds at 28%. Identification techniques, synthetics/simulants, and treatments round out the top five interest categories.

Taking Stock

Satisfaction is high, with 87% of current readers being "Very Satisfied" with *G&G*. When combined with "Mostly Satisfied," the total is 99%. Sixty-eight percent of the respondents identified *G&G*'s articles as their primary feature of interest, followed by the Lab Notes and Gem News International sections.

Of those 13% who were not "Very Satisfied," the chief concern was that the journal was too technical. However, this represented less than 4% of our subscriber respondents and was mentioned by less than 2% of the former subscribers as the reason they no longer subscribed (cost was the primary concern for this younger, less-affluent group, followed by the fact that they had left the profession).

We received a number of comments and suggestions with the survey responses, which we intend to explore in the months ahead. These include requests for better explanation of technical terms and new analytical equipment, as well as an "Ask the Expert" feature and more short notes on current or historical gemological developments. We will address specific questions about *G&G* editorial practices in future Letters sections, so we can share the information with all readers.

Among the comments were several compliments, which we hope match your experience as well:

> *Having your publication in my home and waiting room is tremendous to my business. It's educational and informative even to the general public, which is also a reflection on me.*
>
> *I cannot begin to enumerate the useful and critical information* Gems & Gemology *has brought to me, but I am grateful and I do hope that you keep up the good work.*
>
> Gems & Gemology *is the most brilliantly conceived, best organized, and most beautifully executed magazine I have ever read. How do you consistently continue to produce so superbly?* [Answer: A great staff and terrific contributors and reviewers.]

Looking Ahead

Now that we've compiled the results, we want to use the information constructively. It is evident that our readers like what is being presented in *G&G*, and we appear to be meeting their needs. Yet it is critical to the future of gemology that we attract more younger, less-affluent readers. We need to encourage them to continually upgrade their knowledge of gemology—and we need to help them by keeping the cost as affordable as possible. We also want to see even more retailers embrace the information in *G&G*. As our managing editor Tom Overton points out in his lead article this issue, there are stringent legal requirements for disclosure in the United States. The retailer must first *know* his or her product and then be able to communicate that information to the customer. We do not see the need to make any radical changes (a concern expressed by one long-time subscriber), but we will take these and the other results and recommendations into consideration as the journal continues to evolve.

Of course, any time you have a suggestion or an opinion you'd like to share with us, there's no need to wait until our next *G&G* reader survey—just e-mail us at gandg@gia.edu. *Gems & Gemology* is your journal, and we want to know what works—and what doesn't—for you.

Alice Keller

Alice S. Keller
Editor-in-Chief

LETTERS

An Old Technique to Solve a New Problem?

In the conclusion of the recent *G&G* article on beryllium-diffused ruby and sapphire (J. L. Emmett et al., Summer 2003, pp. 84–131), the authors state that "Today, there is no simple, low-cost alternative to SIMS or LA-ICP-MS, but we are working on the problem and strongly encourage others to do so as well." This writer believes that there *does* exist a low-cost plasma-based method that might reach the sensitivity required for detecting Be-diffused corundum, that is, about 5 ppma. It is a long-forgotten technique, whose instrumentation seems to have been abandoned by those companies who specialize in spectroscopy-based analytical devices.

This technique employs a carbon arc emission spectroscopic unit. Known as the Hilger Medium Quartz Spectrograph (HMQS), it was designed and manufactured by Adam Hilger Ltd., London, who abandoned its production in 1961. It was a remarkably successful analytical tool for the measurement of certain major, minor, and trace chemical elements. The plasma-excitation method used was a high-voltage AC condensed-spark emission from opposed specimen rods, unlike the DC carbon arc emission spectrographic method proposed here.

The procedure for powder analysis was quite different from SIMS or LA-ICP-MS. The small amount of powder required, less than one milligram, was tightly pressed into a 4.0 mm cylindrical cavity drilled in the centre of a 6.2-mm-diameter spectroscopically pure graphite rod. The specimen-bearing electrode and the upper counter-electrode were secured on the clamping stand, and the pre-alignment optics arrangement was used to position the plasma column's cathode layer zone image onto the slit. The lenses were positioned by careful setting of the length of the slit (at a standardized slit width) so that only that part of the specimen's plasma column near the cathode would be admitted to the HMQS. The importance of excluding other parts of the plasma, in particular the incandescent electrode tips, was that this narrow zone, called the "cathode layer" gave the greatest sensitivity of detection for trace elements.

The slit shutter was opened and a pure carbon rod was touched to both electrodes to start the arc. When the scraping from the specimen was completely vaporized and the entire spectral "burn" was recorded on a photographic plate, the shutter was closed. The actual burn period was determined by observing sodium presence in the plasma; this was done by viewing the D-line spectrum by means of a direct-vision pocket spectroscope. When its intensity fell abruptly, the burn was completed and the shutter was closed.

After development, the photographic plate was inserted in a photographic microphotometer, so that the peak height of the strongest emission spectrum line of the test element could be measured. In the case of beryllium, a suitable neighboring aluminum spectral line peak would also be recorded. As the Al concentrations of all rubies and sapphires are virtually constant, the ratios of peak heights, h_{Be}/h_{Al}, would be independent of exposure times. Thus a plot of h_{Be}/h_{Al} versus Be concentration in ppma would yield a working analytical linear graph. Variations in arc emission power during the entire specimen vaporization period would in no way affect the accuracy of the test analysis. The great virtue of photographically recording the period of the entire specimen vaporization is that all the Be-emitting photons would be integrated, along with those of the calibrating aluminum-emitting photons.

The sample for analysis had to be obtained by mechanical means, but this can be done in a manner that is not likely to affect the gemstone's optical appearance. The writer's experience with optical sampling of only the cathode layer zone of the DC carbon arc plasma indicated that no more than 0.005 ct of powder would be sufficient for successful analyses for many elements.

While this method may appear to be rather complex and labor intensive, with some practice it is an astonishingly simple and rapid procedure. The writer believes that it could offer gem testing laboratories a lower-cost alternative to SIMS. It remains to be seen if this method can attain sufficient Be ppma sensitivity to establish whether or not a corundum gemstone has been treated by Be lattice diffusion.

At the November 2003 Gem-A annual conference, the writer suggested to one of the speakers, Dr. Henry Hänni, director of the SSEF Swiss Gemmological Institute, that it might be useful to know if a commercially available instrument existed that made use of a UV spectrometer to monitor a plasma emission, instead of the expensive mass spectrometer of the LA-ICP-MS system.

Dr. Hänni had already been investigating this area and was successful in locating such a device, the Laser-Induced Breakdown Spectrometer (LIBS), which costs only in the region of US$75,000. The unit does generate circular pits on the analyzed surface of a gemstone, e.g., the girdle. However, if properly focused, it does not appear to produce further damage.

J. B. Nelson, Ph.D.
Nelson Gemmological Instruments
London

GEM TREATMENT DISCLOSURE AND U.S. LAW

Thomas W. Overton

In recent years, the obligation to fully disclose all gem treatments has changed from a mere ethical responsibility to a legal one. The U.S. Federal Trade Commission Guides for the gem and jewelry trade, which were fairly simple rules in the early 20th century, now require disclosure of any treatment to a gem material that substantially affects its value. In addition, all state deceptive trade practice regulations in the U.S. require that vendors not mislead customers as to the treatment status of gems they sell. Finally, vendors should also be aware that insufficient disclosure can subject them to substantial civil liability for fraud by nondisclosure. Several case studies demonstrate the serious risks involved in not complying with this body of rules and regulations. Suggestions for avoiding legal problems are provided.

The treatment of gem materials to increase their value (figure 1) is by no means a recent phenomenon, nor is awareness among ethical vendors that some level of treatment disclosure is necessary. However, the very concept of disclosure, its methods, and its perceived scope have evolved significantly from early efforts in the first part of the 20th century. In recent years, perhaps spurred on by public concerns over clarity enhancement of diamonds and emeralds, and ever-more-sophisticated treatments such as beryllium diffusion of corundum, the gem and jewelry industry has directed an unprecedented degree of attention toward the idea that full disclosure of gem treatments is a necessity at all levels of the trade, from the mine to the consumer.

To that end, much has been written on the morals and methods of full disclosure (see, e.g., Hoefer, 1993; Kammerling and Moses, 1995; Genis, 1998; Proust, 2001; Federman, 2002). What has often been lacking, however, is a true understanding that full disclosure is no longer just a matter of ethics; it has become a *legal* obligation in almost any transaction involving gem materials. Vendors who shirk their responsibilities in this regard risk ruinous civil lawsuits, U.S. Federal Trade Commission enforcement actions with attendant fines and bad publicity, and potential criminal prosecution and jail time.

This article will review the evolution and current status of these legal requirements, from the Federal Trade Commission (FTC) guides and comparable U.S. state regulations to more basic factors such as liability for civil fraud. Anyone who deals in gem materials needs to be familiar with this often-complicated body of rules, and must know how to navigate through them without getting into trouble. (Note that this discussion is limited to United States law; rules in other countries may differ substantially.)

Although some individuals and groups draw a distinction between *treatment* and *enhancement* (Proust, 2001), for simplicity, this article will use the term *treatment* to refer to any process that alters the natural character or appearance of a gem material.

NOTE: This article is intended for informational purposes only and should not be used as legal advice. Readers desiring more information on these subjects should consult a qualified attorney.

See end of article for About the Author and Acknowledgments.

GEMS & GEMOLOGY, Vol. 40, No. 2, pp. 106–127.

Figure 1. This collection illustrates the kinds of gem materials that historically have been subjected to treatment to improve their appearance. The center stones in these rings, counterclockwise from top right, are a 5.37 ct purple sapphire, a 2.18 ct emerald, a 2.02 ct Fancy yellow diamond, and a 1.0 ct ruby. The three-stone ring contains 3.73 carats of diamonds, and the ring in the bottom right showcases trillion-cut tanzanite and rubellite. Courtesy of Charles Koll, San Diego; photo © Harold & Erica Van Pelt.

THE EVOLUTION OF THE FTC DISCLOSURE RULES

The deceptive alteration of gem materials dates as far back as recorded history. It was enough of a problem even two thousand years ago that Pliny, the great Roman naturalist, could call it the most profitable fraud in existence (Ball, 1950). However, the distinction between the idea that one should not falsely sell a treated, less valuable stone (e.g., dyed, quench-crackled quartz) as a more valuable gem material (e.g., emerald) and the idea that a buyer is entitled to know what alterations have been performed on a gem material sold under its proper identity (e.g., oil-treated emerald) is one that did not evolve until the 20th century. Even as late as 1892, an editorial in the *Jeweler's Circular* would say no more than "[e]very jeweler . . . knows that it is to his own disadvantage to misrepresent the quality of his goods" ("How to run . . .," 1892, p. 31).

When the FTC was established in 1914, movement began toward a uniform national code for the U.S. gem and jewelry industry. The FTC's charter included a charge to prevent "unfair methods of competition" (U.S.C. title 15, section 45). Among the first industry groups it met with was the Good and Welfare Committee of the National Jewelers Board of Trade (NJBT), the forerunner of the Jewelers Vigilance Committee ("JVC's history," 2002), and within a few years it adopted the NJBT's recommended standards for gold-marking of jewelry ("For honest marketing," 1919). However, because of disagreements over what constituted an acceptable trade practice, not until 1929, at a conference of the National Wholesale Jewelers' Association in Chicago (see figure 2), did the trade agree on a comprehensive set of rules that were accepted by the FTC ("Great trade gathering . . .," 1929). These rules, which became official in October of that year, contained a number of elements that would be familiar even today, including prohibitions on misuse of the words *diamond*, *synthetic*, *genuine*, and *pearl*, among others ("Federal Trade Commission . . .," 1929). Absent, however, was any requirement for treatment disclosure. The rules were revised and expanded in 1931, though again without adding any disclosure requirements ("New trade practice rules . . .," 1931).

Following passage of the New Deal–era National Industrial Recovery Act in 1933, trade groups across the country were called on to prepare codes of fair competition ("National Industrial Recovery Act," 1933). For the jewelry industry, the end result was the Code of Fair Competition for the Retail Jewelry Trade (referred to hereafter as "the Code"), which was signed by President Roosevelt in November 1933 and thereafter administered by the National Recovery Administration (NRA; see "Hearing on code . . .," 1933; "Code of Fair Competition . . .," 1934). (Unlike FTC rules, compliance with the

June 13, 1929 THE JEWELERS' CIRCULAR 65

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GEORGE A. FERNLEY
SECRETARY

L. P. WHITE
TREASURER

ALBERT ELLBOGEN
VICE-CHAIRMAN, TRADE PRACTICE
CONFERENCE COMMITTEE

Great Trade Gathering Ends Sessions at Chicago

Jewelry Trade Conference Passes Many Resolutions on Trade Practices Which Are Submitted to the Federal Trade Commission—National Wholesale Jewelers' Association Holds One of Its Greatest Conventions and Sessions Are Enthusiastically Supported by Unusually Large Attendance

EDGEWATER BEACH HOTEL, June 7.—Chicago has done many things in the past to establish its position as a great center of the jewelry industry of America, but never has it done more to accomplish this object than in the past week.

And this hotel was the scene of the work for it housed two great conventions of the jewelry industry and a great Trade Practice Conference which brought here leaders of the various branches of the trade from all parts of the country. The work accomplished may mark an epoch in the renaissance of the jewelry business.

At the first conference or convention, (that of the Wholesale Jewelry Trade Association: the proceedings of which covering Monday and Tuesday were reported in full in the last issue of THE JEWELERS' CIRCULAR), it was announced by B. J. Doyle, sponsor for the association and the Jewelry Trade Institute that the Institute would come into being as a result of the support that he got from the wholesalers and would be functioning in the next six months. At the Jewelry Trade Conference called by the Federal Trade Commission under the auspices of the National Wholesale Jewelers Association, the industry, through its delegates and representatives from various sections of the country, adopted a series of rules or resolutions which should act as a foundation not only to develop business ethics in all branches of the trade, but which, when approved by the trade and the Federal Trade Commission, should give an opportunity to eliminate a large number of abuses which have hampered our manufacturers and distributors in the past. This may result in the dawn of a new era which may see the gradual elimination of the "gyp" wholesaler and retailer and the unscrupulous manufacturer, thereby giving an opportunity for a fair and decent profit to the legitimate merchant whose ethics are in conformity with the high standards of the jewelry business.

Last, but not least, the convention of the National Wholesale Jewelers Association which started Wednesday morning, adjourned for the trade conference and finished its proceedings at two important sessions on Thursday, established once for all the fact that the jewelers of this country are capable of holding a real business convention on constructive and instructive lines that can meet the problems that confront our manufacturers and our distributors in an intelligent and progressive way. The reports submitted, the addresses made, and the discussions that followed, proved of the highest value to those who attended and should do more to aid in helping solve the problems of the wholesaler than anything that has been done in many years. In contrast to the convention that was held Monday and Tuesday, which was one of inspirational addresses, the convention of the National Wholesale Jewelers Association was one of *work* and *achievement*—a real businessman's convention in every way. What is more, the crowded condition of the convention hall, the close attention paid to discussions and reports, and the participation therein by our leading wholesalers throughout the country indicated that this is the kind of a convention that they want; that they are deeply interested in the vital problems that confront the industry and are willing to do their part in studying them and helping to solve these problems no matter how much sacrifice it may entail.

The telegraphic report from Chicago which appeared in the last issue of THE JEWELERS' CIRCULAR, took the proceedings of the work up through the first session of the National Wholesale Jewelers convention with the opening speech of President Becken and the report of Secretary Fernley, the appointments of the committees, etc., up to the time when the members adjourned to participate in the Jewelry Trade Conference to be presided over by Federal Trade Commissioner March.

Figure 2. This 1929 article in The Jeweler's Circular *heralded the drafting of a formal set of regulations for the jewelry industry, rules that were the forerunner of the modern FTC Guides. Courtesy of* JCK.

various NRA codes was voluntary, though there was strong social pressure for businesses to adhere to their terms.)

Although the Code supplemented FTC rules rather than replacing them, it nevertheless tracked them closely, adding some details on proper nomenclature but again not requiring any treatment disclosure. Here, the U.S. was lagging behind a similar movement in Europe. As the Code was being drafted, European jewelers at the fourth International Congress of BIBOA (Bureau International des Associations de la Bijouterie, de l'Orfèvrerie et de l'Argenterie; called CIBJO since 1961) enacted a rule requiring members to disclose the use of dye to color gems ("Important jewelry standards . . . ," 1933; see also figure 3). Although this rule drew positive commentary from organizations in the U.S. such as GIA (see, e.g., Shipley, 1935), no such regulation was forthcoming from either the NRA or the FTC. Three years later, at the 1936 BIBOA congress in Berlin, the rule was expanded to state that "[s]tones which are coloured, or improved in colour, by the addition of a colouring agent, or by chemical treatment, must be so designated that the artificiality of the colour is clearly indicated" (Selwyn, 1945, p. 261).

While BIBOA's actions at the very least represented a first step forward, they also marked the first appearance of a distinction that was to complicate disclosure efforts well into the 1990s—that between treatments considered "trade accepted" and those that were not. Only the latter had to be disclosed. (And since lobbying by those who disagreed over what was or was not considered trade accepted often could be successful in changing the practices included [R. Naftule, pers. comm., 2004], this was a significant distinction.)

After the National Recovery Administration was dissolved by the U.S. Supreme Court in 1935, trade representatives spent several years trying to convince the FTC to resurrect the Code of Fair Competition in some form. In 1938, Congress expanded the FTC's mandate to prevent "unfair or deceptive acts or practices," and the FTC was empowered to promulgate rules defining specific acts as unfair trade practices (U.S. Code, title 15, section 41). Following input from the JVC and GIA, among others (see "Diamond terminology . . .," 1938; Shipley, 1938; "JVC's history," 2002), the FTC issued a revised set of rules that largely duplicated the Code ("New FTC jewelry trade rules," 1938)—including its absence of disclosure requirements. These rules would not be revised for almost two decades.

In the early 1950s, the JVC began a campaign to update the rules ("JVC submits . . .," 1954), and after several years of hearings and trade conferences, the FTC and trade groups finally agreed on a set of revisions that were issued in early 1957 ("FTC proposes . . . ," 1957). The new rules were known as the Guides for the Jewelry, Precious Metals, and Pewter Industries (referred to hereafter as "the Guides"). While the revisions were mostly aimed at combating abuses in advertising, quality marking, and pricing ("Jewelers Vigilance Committee . . .," 1957), they finally included a meaningful element of treatment disclosure (figure 4). After a preamble prohibiting any conceivable sort of misrepresentation as to gem materials, Rule 36 offered one specific interdiction:

> The sale, or offering for sale, of any diamond or other natural precious or semi-precious stone which has been artificially colored or tinted by coating, irradiating, or heating, or by use of nuclear bombardment, or by any other means, without disclosure of the fact that such natural stone is colored, and disclosure that such artificial coloring or tinting is not permanent if such is the fact [is an unfair trade practice] ("Jewelry industry . . .," 1957, p. 123).

Figure 3. In the early years of the 20th century, disclosure efforts were complicated by disagreements over which treatments were considered "trade accepted." Early European trade rules required disclosure of the use of dye to color gem materials (such as the carved chalcedony maple leaf from Idar-Oberstein shown here, which is partially dyed green), while U.S. rules did not. Courtesy of Gary and Linda Roskin; photo by Robert Weldon.

When *Jewelers' Circular-Keystone* published the new rules with commentary in its August 1957 issue, it said, "If a diamond or other natural stone has been artificially colored . . . that fact must be disclosed" (Jewelry industry . . . ," 1957, p. 123). Simple enough.

Some minor revisions to the Guides (though not the disclosure rules) were enacted in 1959, but after that, they would not be changed for over 35 years. In the interim, it appears that enforcement of Rule 36 was almost nonexistent, and few jewelers felt the need to disclose treated color that was not at risk of fading. *JCK* reported in 1979 that "the rule has been consistently ignored" (Federman, 1979, p. 125), while William Preston Jr. of the JVC lamented in a panel discussion at the 1983 Jewelers of America meeting that "little attention has been paid to [Rule 36] by the industry" (Huffer, 1983, p. 110). Even *Gems & Gemology* published the following sentiment in the mid-70s: "In most [cases of heated and/or irradiated gems], the color is indistinguishable from equivalent untreated material, and is just as stable to light, etc. Accordingly, the treatment is not cus-

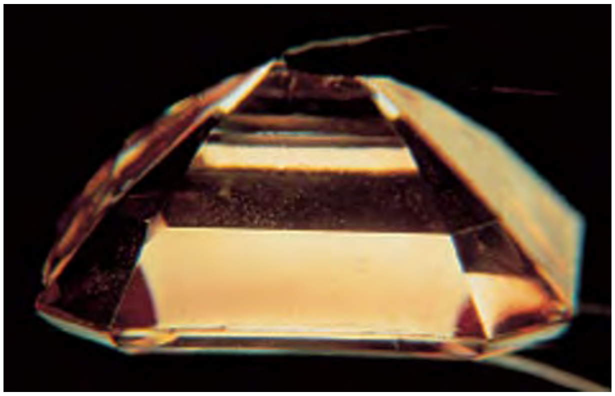


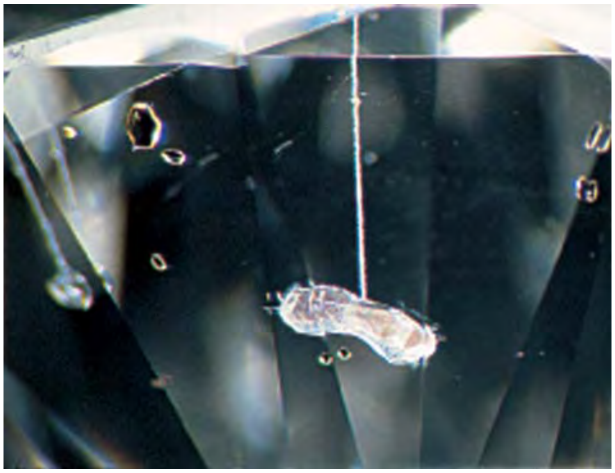
Figure 4. The coloration of diamonds by artificial coatings was one of the developments that spurred revision of the FTC guidelines in the late 1950s. This 10.88 ct yellow diamond was coated evenly with pink nail polish to imitate a natural-color pink diamond. Photo by Andrew Quinlan.

tomarily referred to and the simple designation 'natural' is used" (Nassau, 1974, p. 322).

In 1978, the FTC announced that many of its guides had become redundant and would be retired (Huffer, 1980). The JVC immediately objected, and the FTC agreed to consider retaining a revised version of the Guides if the JVC was able to produce one. This was a task that would prove far more difficult than anyone expected, and it would occupy much of the JVC's attention for the next 18 years.

The most contentious dispute proved to be over whether to disclose laser drilling of diamonds (figure 5), which many argued was a trade-accepted practice ("Lasering . . .," 1980). The JVC's initial proposal required such disclosure, but this rule encountered substantial opposition from manufacturers and diamond dealers due to the practical difficulties of detecting and disclosing the treatment with melee-sized stones (Huffer, 1980). In mid-1979, the JVC removed the requirement from its proposed rules, but this reversal itself drew criticism from industry observers ("Lasering . . .," 1980). When the JVC finally submitted its first draft of the new Guides to the FTC in 1981, it essentially split the difference by requiring disclosure of laser drilling, but only for stones of 0.20 ct and up ("JVC's history," 2002).

Figure 5. The question of whether to disclose laser drilling of diamonds was the most hotly debated disclosure issue of the 1980s. This diamond has been laser drilled to allow bleaching of the oblong inclusion in the center. Photomicrograph by John I. Koivula; magnified 20×.



Behind the storm over laser drilling, a more substantial change went little noticed. The proposed new Guides contained a significant weakening of Rule 36 (Federman, 1983; "Gem treatment . . .," 1985). Where before the rule required disclosure both of alterations to gem color *and* whether such treatments were permanent, the new rule combined these two requirements into a single rule requiring disclosure only when the alteration was not permanent. In addition, disclosure would not be required if the treatment was not detectable, even if the seller had actual knowledge of it ("Gem treatment . . . ," 1985).

Not all parties agreed on what treatments were reliably detectable, which made disclosure requirements for irradiation and heating unclear (Federman, 1983; Huffer, 1983). In addition, these and other discussions published in the trade press revealed almost no consensus on the proper scope of disclosure, nor on what was—and was not—trade accepted (see, e.g., Federman, 1979; Huffer, 1980; "Gem treatment . . . ," 1985). At the first World Congress of the International Colored Gemstone Association (ICA) in 1985, several prominent gemologists drew a distinction between treatments that duplicated natural processes and those that did not (Everhart, 1985). They maintained that treatments such as heat that "complete . . . what nature left unfinished" need not be disclosed, whereas those such as diffusion and oiling, which introduced foreign substances into the gem, should be (Everhart, 1985; pp. 1, 14). These arguments did not sway some gem dealers, who still considered oiling a trade-accepted practice that did not require disclosure (R. Naftule, pers. comm., 2004). In contrast, Robert Crowningshield of GIA and C. R. "Cap" Beesley of the American Gemological

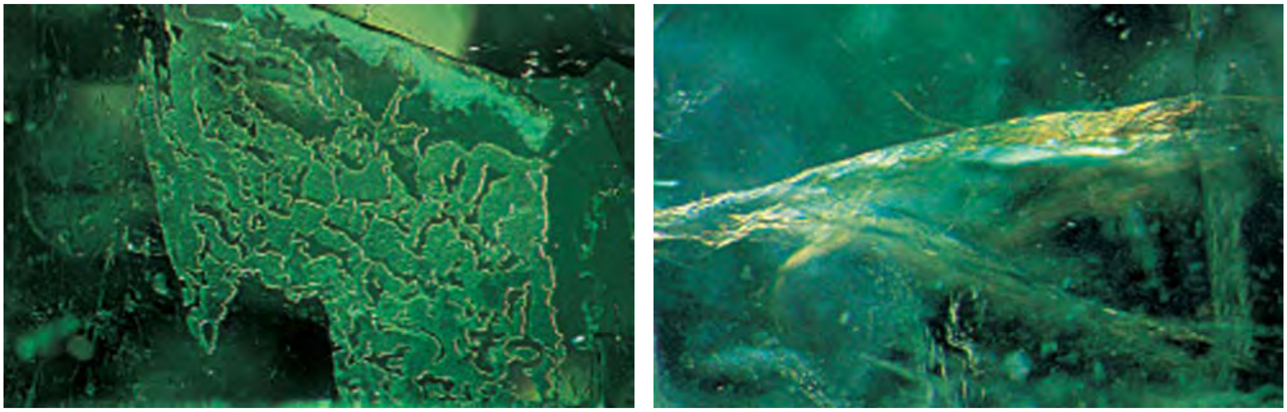


Figure 6. Industry embarrassments over undisclosed filling of diamonds and clarity enhancement of emeralds helped spur reforms in disclosure customs and FTC regulations in the 1990s. At left, the residue of a filling substance is clearly evident in this emerald. At right, the presence of filler is betrayed by the "flash effect" produced by the different refractive indices of the emerald and the filler. Photomicrographs by John I. Koivula; magnified 15× (left) and 20× (right).

Laboratory argued for full disclosure of all treatments (Federman, 1983; "Gem treatment . . . ," 1985), as did the American Gem Trade Association (AGTA), which began development of its Gemstone Information Manual during this period (R. Naftule, pers. comm., 2004).

In 1985, the JVC submitted to the FTC its "final" recommendations, which contained few changes to the disclosure rules from those offered four years previously despite these raging controversies ("JVC's history," 2002). The FTC promised to publish the new Guides in 1987, but did not. Instead, continuing disputes in the trade would delay release for another 10 years.

In the ensuing decade, Rule 36 remained in force, requiring disclosure of neither laser drilling nor a new treatment that was now spreading throughout the diamond trade: the filling of fissures with a colorless substance to enhance apparent clarity. By the time the FTC issued the new Guides in 1996, the industry had been rocked by several embarrassing incidents involving inadequate disclosure of fracture filling and laser drilling of diamonds, and clarity enhancement of emeralds (see, e.g., Everhart, 1993a,b,c; Rapaport, 1993; Federman, 1998a,b; see also figure 6). Guides or no Guides, the momentum toward full disclosure was accelerating.

In the 1996 revisions, the FTC adopted the proposed rule on permanence but not the considerations of detectability. Rule 36's preamble on misrepresentation was severed from disclosure and moved to the beginning of the Guides; the requirement to disclose artificial coloration was replaced with the following:

> It is unfair or deceptive to fail to disclose that a gemstone has been treated in any manner that is not permanent or that creates special care requirements, and to fail to disclose that the treatment is not permanent, if such is the case. The following are examples of treatments that should be disclosed because they usually are not permanent or create special care requirements: coating, impregnation, irradiating, heating, use of nuclear bombardment, application of colored or colorless oil or epoxy-like resins, wax, plastic, or glass, surface diffusion, or dyeing. (16 C.F.R. 23.22, 1996)

This new rule required disclosure of clarity enhancement, as it was not considered a permanent treatment. The FTC, however, was still not ready to require disclosure of laser drilling. It based this decision on its opinion that laser drilling was a permanent treatment with no care requirements and that left visual traces that were little different from natural inclusions. The FTC would later describe opinion on disclosure of laser drilling as being in "conflict" (FTC, 2000a, p. 78739).

Many in the industry were not happy with this decision because of the ethical implications (see, e.g., Denenberg, 1998; Parker, 1998a,b,c; Rapaport, 1998). Meanwhile, the arguments continued to mount, both over laser drilling (see, e.g., Parker 1998a) and emerald clarity enhancement (see, e.g., Federman, 1998a). In 1998, in hopes of restoring the industry's damaged reputation, the JVC and the Diamond Manufacturers and Importers Association of America asked the FTC to reconsider its rule on laser drilling. The FTC agreed to do so (FTC, 2000a).

THE 2001 AMENDMENTS, AND THE CURRENT STATE OF THE FTC GUIDES

After the scandals and embarrassments of the 1990s, public comment submitted to the FTC (43 formal comments from individuals, companies, and trade groups) was nearly unanimous in favor of the disclosure of laser drilling (42 out of 43 supported it). The FTC (2000a) thus had little problem with a rule requiring such disclosure, which it agreed to promulgate, effective April 2001 (see 16 C.F.R. 23.13; the full text of the 1957, 1996, and 2001 rules with respect to disclosure are available in the *G&G* Data Depository at www.gia.edu/gemsandgemology; see also figure 7).

Figure 7. The December 15, 2000 issue of the Federal Register published the most recent revisions to the FTC Guides, effective April 10, 2001.

78738 Federal Register / Vol. 65, No. 242 / Friday, December 15, 2000 / Rules and Regulations

FEDERAL TRADE COMMISSION

16 CFR Part 23

Guides for the Jewelry, Precious Metals and Pewter Industries

AGENCY: Federal Trade Commission.
ACTION: Final guides.

SUMMARY: The Federal Trade Commission (Commission) announces that it is revising §§ 23.13 and 23.22 of the Guides for the Jewelry, Precious Metals and Pewter Industries (Jewelry Guides or Guides), 16 CFR Part 23. The Commission has combined § 23.13, which addresses the disclosure of diamond treatments, with § 23.22, which addresses treatments of other gemstones. The Commission also has revised these sections to provide for disclosure of any treatment to gemstones that significantly affects the value of the gemstone, which would include laser-drilling of diamonds.

EFFECTIVE DATE: April 10, 2001.

ADDRESSES: Requests for copies of this document should be sent to Public Reference Branch, Room 130, Federal Trade Commission, 600 Pennsylvania Avenue, NW, Washington, DC 20580. Copies also are available on the Commission's website at <www.ftc.gov>.

FOR FURTHER INFORMATION CONTACT: Robin Rosen Spector, Attorney, Federal Trade Commission, 600 Pennsylvania Avenue, NW, Washington, DC 20580, (202) 326–3740, <jewelry@ftc.gov>.

SUPPLEMENTARY INFORMATION:

I. Introduction

The Commission announces that it is revising §§ 23.13 and 23.22 of its Guides for the Jewelry, Precious Metals, and Pewter Industries, 16 CFR Part 23 (Jewelry Guides or Guides). The Jewelry Guides address claims made about precious metals, diamonds, gemstones, and pearl products.[1] The Guides explain how to describe these products truthfully and non-deceptively and how to avoid unfair or deceptive practices. Sections 23.13 and 23.22 of the Guides address the disclosure of certain treatments to diamonds and other gemstones that are performed to improve their beauty or durability. Some treatments are not permanent because their effects fade over time. For example, gemstones sometimes are treated with a colorless oil that improves the color of the stone and helps to mask certain imperfections. Other treated gemstones require special care to retain the benefit of the treatment. For example, a stone that is fracture-filled (*i.e.*, injected with plastic or glass to hide cracks and improve its appearance) cannot be cleaned with certain types of jewelry cleaners, because the cleaner could adversely affect the treatment. In addition, re-cutting or re-setting a fracture-filled stone could damage the treatment.[2] Other gemstone treatments are permanent and do not create special care requirements, but the treated gemstone is not as valuable as a similar untreated stone.

On June 8, 1999, the Commission solicited comment on a proposal to revise § 23.13 of the Guides to require disclosure of laser-drilling of diamonds.[3] The Commission also solicited comment on a proposal to revise § 23.22 of the Guides, which addresses other gemstone treatments, to provide for the disclosure of treatments similar to laser-drilling—those that are permanent and do not create special care requirements for the stone, but significantly affect the value of the stone. The Commission received 40 comments.[4] After reviewing these comments, the Commission has decided to revise the Guides to provide for disclosure of permanent gemstone treatments that significantly affect the value of the gemstone, such as laser-drilling.

II. Background

On December 9, 1998, two jewelry trade associations, the Jewelers Vigilance Committee (JVC), a trade association promoting ethical jewelry sales practices, and the Diamond Manufacturers and Importers Association of America (DMIA), jointly petitioned the Commission to revise § 23.13 of the Jewelry Guides to add laser drilling to the list of diamond treatments that should be disclosed.[5] Laser drilling involves directing a laser beam at an inclusion and forcing acid through the resulting tunnel, thereby removing the inclusion or rendering it invisible to the naked eye. Thus, the diamond's appearance is improved.

In a 1996 review of the Guides, the Commission determined, based on the record before it, that the failure to disclose laser-drilling was not unfair or deceptive. The evidence presented in the comments to the Commission indicated that laser-drilling of diamonds was "a common practice and not an extraordinary process."[6] Moreover, the evidence demonstrated that, while laser-drilling produces a small surface opening on a diamond, "the majority of diamonds sold in the U.S. have similar surface imperfections."[7] Surface imperfections are to be expected in diamonds, except in diamonds described as flawless. The record also reflected that disclosing laser-drilling in each advertisement or promotional description could be costly and the additional advertising costs could be passed on to consumers in the form of higher prices.[8] At that time, there was a conflict in the industry regarding the need for and the appropriateness of disclosure. Therefore, the Commission decided not to amend § 23.13 of the Guides to require disclosure.

The JVC petition asks the Commission to reconsider its decision based on the following factors: (1) There is now widespread industry support for disclosure; (2) the amendment would promote industry disclosure and self-regulation; (3) disclosure would impose few costs on retailers, and therefore, no increased costs to consumers; (4) technological advances make it increasingly difficult for consumers to

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[1] The Commission issues industry guides to provide guidance for the public to conform with legal requirements. Industry guides are administrative interpretations of the laws the Commission administers. Industry guides explain how to describe products truthfully and non-deceptively and identify practices the Commission considers unfair or deceptive.

[2] The American Gem Trade Association (AGTA) publishes a manual that contains a comprehensive listing of gemstone treatments and information regarding the permanence of the treatment and special care requirements. AGTA–2 (022A).

[3] 64 FR 30448 (June 8, 1999).

[4] In the remainder of this FRN, the comments are cited to by an abbreviation of the comment name and the comment number. Attached to this FRN as Appendix A is a list of the comment name, abbreviation and comment number used to identify each commenter. The comments numbered 1 to 21 were received in response to the Commission's first request for comment dated June 8, 1999. 64 FR 30448. The comments numbered 1A to 22A were received after the Commission extended the deadline to submit comments. 64 FR 37051 (July 9, 1999). Three comments were submitted twice, by US mail and by electronic mail. Those comments are listed once and are referred to in this FRN by the number of the comment that was received first.

[5] Fifteen trade associations joined the JVC and DMIA petition: World Federation of Diamond Bourses; International Diamond Manufacturers Association; Diamond Promotion Service; Diamond Dealers Club of New York; Gemological Institute of America; International Society of Appraisers; Jewelers of America; American Gemstone Society; American Gem Society; United States Carat Club; International Confederation of Jewelry, Silverware, Diamonds, Pearls and Stones; American Gemstone Trade Association; Manufacturing Jewelers and Suppliers of America; International Standards Organization; and Diamond High Council. The petition is on the public record and copies are available by contacting the Public Reference Branch, Room 130, Federal Trade Commission, Washington, DC 20580. The petition also has been posted on the Commission's website at <www.ftc.gov>. For the remainder of this Federal Register Notice, the petition will be referred to as the JVC petition.

[6] 61 FR 27177, 27197 (May 30, 1996).

[7] Id. at 27196.

[8] Id. at 27197 n.305–06.

The JVC, however, had also asked the FTC to reconsider the degree of disclosure required for gem treatments in general, although it also wanted an exemption absolving a jeweler of legal liability if he or she did not know, and should not reasonably have known, a gem was treated (Nestlebaum, 1998). The FTC agreed with the JVC's first suggestion but rejected the second. It declined to include a knowledge requirement because it was concerned that it could provide cover for unscrupulous vendors, who might falsely profess that they were unaware of a treatment (FTC, 2000a). It asked the trade, essentially, to trust it: "The Commission's ability and willingness to exercise prosecutorial discretion in such situations should alleviate retailers' concerns that they unreasonably would be held accountable for others' illegal conduct" (FTC, 2000a, p. 78742). The final rule required disclosure if the treatment had a significant effect on the gem's value:

> It is unfair or deceptive to fail to disclose that a gemstone has been treated if:
>
> (a) The treatment is not permanent. The seller should disclose that the gemstone has been treated and that the treatment is or may not be permanent;
>
> (b) The treatment creates special care requirements for the gemstone. The seller should disclose that the gemstone has been treated and has special care requirements. It is also recommended that the seller disclose the special care requirements to the purchaser;
>
> (c) The treatment has a significant effect on the stone's value. The seller should disclose that the gemstone has been treated. (FTC, 2000a. p. 78743; 16 C.F.R. 23.22).

Several comments—that of the AGTA, for one—objected to the limitation of "significant effect" (the AGTA, which had continued to lobby for full disclosure, argued that all treatments are intended to have a significant effect on value). The FTC responded that it was necessary to establish a "practical, common sense limitation on when disclosures should be made" (FTC, 2000a, p. 78741).

The rules do not define what is meant by "significant," but the FTC's comments in the official publication of the changes do provide some guidance. "[F]ailure to disclose a gemstone treatment is deceptive only if *absent disclosure* [italics added] consumers would falsely believe that the treated gemstone is as valuable as a similar untreated gemstone" (FTC, 2000a, p. 78741). Common sense would indicate that "significant" is intended to create an exception for treatments having a negligible effect on value, but whether this exception truly exists is unclear based on further statements from the FTC: "If, in fact," a footnote to the comments states, "all treatments have [a significant] effect on the value of gemstones, then all treatments will need to be disclosed" (FTC, 2000a, p. 78741).

Subsequent FTC publications have not entirely cleared up the confusion. Its informal guide to jewelry advertising explains "significant" this way: "Consider whether the treatment makes the product less valuable than if it contained an untreated stone. Think about value from the customer's perspective and ask yourself how your customer would react if he learns about the treatment after leaving the store" (FTC, 2001, p. 3).

The comments in the December 2000 *Federal Register* also contain what amounts to a fairly important limitation on the scope of the required disclosure. They state that the FTC is "aware" of several methods of general disclosure, such as counter placards directing customers to "ask a salesperson for more information," pamphlets summarizing gem treatment information, and Internet hyperlinks to Web pages containing "more information about gemstone treatments" (FTC, 2000a, pp. 78742–78743). Such disclosure methods, the comments say, "comply with the Jewelry Guides and can be used to disclose gemstone treatments that significantly affect the value of gemstones" (FTC, 2000a, p. 78743; however, see FTC, 2000b, for more specific guidance on Internet disclosure). Based on these comments, it is not clear—except for impermanent treatments and those having special care requirements—that the Guides require direct, point-of-sale disclosures about specific stones without customer inquiries. (However, other state and local regulations may have more stringent requirements, as discussed in the section on civil fraud, below.)

HOW THE FTC ENFORCES THE GUIDES

The FTC is empowered to issue rules on its own initiative, but it has also done so in response to petitions by industry and consumer groups. The FTC is required to issue advance notice of any proposed rules, and to allow a period for public comment and sometimes a public hearing. Over the years, the FTC has promulgated several dozen formal sets of rules defining unfair trade practices in various industries and situations (see Code of Federal Regulations, Title 16, for a full list).

One of the most common questions regarding FTC rules is "Are they the law?" (see, e.g., *Retailers Legal Handbook*, 2002). The answer, despite some contrary statements in the trade press (see Beard, 2001), is indeed, "Yes."

The confusion on this point most likely stems from the fact that FTC rules are found not in the United States Code but in the Code of Federal Regulations. The distinction is essentially the same as that between a criminal prosecution and a civil lawsuit: It is the *mechanism* of enforcement that differs, not the enforceability. The FTC Act—which is part of the U.S. Code—declares that "unfair or deceptive acts or practices in or affecting commerce" are unlawful [U.S.C., title 15, section 45(a)(1)], and it is the FTC that has the authority to define what those unlawful practices are. Since the U.S. Supreme Court has held that the FTC's judgment "is to be given great weight by reviewing courts" (*FTC v. Colgate-Palmolive Co.*, 1964; see the *G&G* Data Depository for descriptions of this and other cases cited in this article), one cannot dismiss FTC rules as mere "suggestions" or uninformed opinion that can be freely ignored.

When the FTC becomes aware of an unfair trade practice, it will typically approach the offending party informally and seek a *consent agreement* to end the behavior at issue (see FTC, 2002; U.S.C. title 15, section 45–49; information in this section is drawn from these sources). Most actions begin and end with such an agreement. If a consent agreement cannot be reached, the FTC can serve an *administrative complaint*. Such complaints are handled much like civil lawsuits, although they are heard in a special court before an *administrative law judge*, and differ from a full-blown court case in that they tend to be much simpler and faster. If the administrative law judge finds a violation, he or she may issue a *cease and desist* order against the offending party. This order can be appealed to the local circuit court of appeals and from there to the U.S. Supreme Court. If not appealed, or if appealed and upheld, the order binds the offending party to cease the unfair trade practice at issue. Violating the order can result in further court action, injunctions against the practice, and monetary damages.

In cases of serious and/or ongoing unfair trade practices, the FTC may bypass the administrative action altogether and go directly to federal district court to seek an injunction or damages. If the court agrees with the FTC, *each* violation of an FTC rule can result in a penalty of up to $11,000.

In practice, at least with respect to the gem and jewelry industry, the vast majority of infractions are handled administratively, and the FTC also commonly refers complaints to the JVC for informal resolution (C. Gardner, pers. comm., 2004). Formal litigation to enforce the Guides appears to be so rare that—as of late 2003—the author was able to find only *one* published[1] federal case interpreting them (see *Manning International v. Home Shopping Network*, 2001, available in the *G&G* Data Depository), and even that case was not an FTC enforcement action. Whether this is because the industry adheres closely to the Guides, because the FTC enforces them only sporadically, or because enforcement targets readily enter consent agreements to avoid bad publicity, is not easy to determine—in large part because many infractions are handled confidentially (FTC, 2002; C. Gardner, pers. comm., 2003).

Public statements from the FTC indicate that the last possibility—the aversion to bad publicity—may be the best explanation (see Beard, 2001). Given the importance of a good reputation in the gem and jewelry trade, this is not hard to understand. It is worth pointing out as well that, even if the complaint is handled confidentially, an FTC investigation can be an enormous distraction to an ongoing business. The FTC is empowered to subpoena business records, physically search both home and store premises, and compel testimony from owners, employees, and customers (FTC, 2002). Given that the FTC uses the Guides to decide whether to bring such an action, the best practice is to treat them with the healthy respect they deserve.

STATE REGULATION OF UNFAIR TRADE PRACTICES

The FTC is not the only agency with which gem and jewelry vendors must concern themselves. All U.S. states and the District of Columbia have some form of legislation governing unfair trade practices, and these rules typically carry the full force of law. The worst the FTC can do to an unscrupulous vendor is level a heavy fine; a number of these state laws can send the same offender to jail.

The structure, scope, and enforcement methods, as might be expected, vary widely from state to state. Twelve states have adopted a model set of rules known as the Uniform Deceptive Trade Practices Act (UDTPA), and a number of others have patterned their laws after it to some extent. Some states restrict enforcement to state or local prosecutors, but most (e.g., New York, Texas, California, and those following the UDTPA) allow private suits by individuals who can prove injury from an unfair trade practice (for one recent example, see *Sanfield v. Finlay Fine Jewelry*, 1999; note also that California does not currently require proof of injury, although the state legislature is considering a change to this provision).

Some states specifically define prohibited acts, sometimes in voluminous detail (e.g., California, whose definitions are spread across thousands of code sections). Others (e.g., Florida, Massachusetts, and South Carolina) simply direct the state courts to follow FTC interpretations, which means that the 2001 disclosure rules in the Guides are enforceable as state law in those jurisdictions. In New York, by contrast, the FTC Guides are used as a ceiling—compliance with them is a complete defense to any action for deceptive trade practices (New York General Business Law section 349d).

Members of the trade who violate these laws can and have faced criminal charges (see, e.g., Everhart, 1993c). In practice, however, because of the specialized nature of the industry and the complicated gemological issues that often are involved, such prosecutions tend to be difficult, complicated, and relatively rare.

A few statutory examples are worth exploring. In states having adopted the UDTPA, "a person engages in a deceptive trade practice when, in the course of his business, vocation, or occupation, he . . . represents that goods or services are of a particular standard, quality, or grade, or that goods are of a particular style or model, if they are of another" (1966, section 2[a]). This is potentially broad enough to encompass the sale of treated gem materials without disclosure, especially with treatments such as dyeing and diffusion that involve the introduction of foreign substances or otherwise greatly alter the nature of the gem material. North Carolina, by contrast, has a much more specific prohibition:

> It is an unfair trade practice for any member of the diamond industry . . . [t]o use, or cause or promote the use of, any trade promotional liter-

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[1] A "published" case is one appearing in the official records of federal court decisions, in this case the *Federal Supplement.* Not all court decisions are published. Only those that the federal courts believe to have good precedential value appear in the reports; this includes all Supreme Court cases and most cases from the circuit courts of appeal, but only isolated cases and rulings at the trial court level (as was the ruling in *Manning International*).

> ature, advertising matter, guarantee, warranty, mark, brand, label, trade name, picture, design or device, designation, or other type of oral or written representation, however disseminated or published, which has the capacity and tendency or effect of misleading or deceiving purchasers or prospective purchasers with respect to the type, kind, grade, quality, color, cut, quantity, size, weight, nature, substance, durability, serviceability, origin, preparation, production, manufacture, distribution, or customary or regular price, of *any diamond or other product of the industry* [italics added], or which has the capacity and tendency or effect of misleading or deceiving the purchasing or consuming public in any other material respect. (North Carolina General Statutes section 66-74[1])

This is a regulation that, in the author's view, calls for full good-faith disclosure of any treatments, especially given that violation is a class 1 misdemeanor punishable by up to 45 days in jail (see North Carolina General Statutes section 15A-1340.23).

Two states also have laws that specifically govern elements of gem treatment disclosure: New York prohibits the sale of artificially colored diamonds without disclosing their treated nature (see New York General Business Law section 229-j), while Arkansas requires full disclosure of any clarity-enhanced diamonds (see Arkansas Code section 4-101-201).

A list of specific statutes governing unfair trade practices for the 50 states and the District of Colombia is available in the *Gems & Gemology* Data Depository.

DISCLOSURE AND CIVIL FRAUD

A vendor's disclosure obligations, however, do not end with state unfair trade practice regulations and the FTC Guides. One fundamental problem is not, as is often supposed, confusion over whether the Guides are enforceable or constitute the law, as discussed above. The more important question—and one that is almost never asked—is whether strict compliance with the FTC Guides is enough to fully insulate a vendor against legal action for insufficient disclosure. The answer to this question is, in fact, *no*. As discussed below, a vendor can follow the letter of the Guides and still be sued for fraud by an aggrieved buyer—and lose.

Nor do the Guides cover every conceivable sale that may take place in a jewelry store or between a gem dealer and a buyer. For example, it is not clear that the Guides cover sales of mineral specimens and rough gem material, since the definition of *gem* in section 23.25 is limited to products possessing the "beauty, symmetry, rarity, and value necessary for qualification as a gem." Though somewhat circular, the intent of this definition is made clear in the commentary: "Not all diamonds or natural stones, including those classified as precious stones, possess the necessary qualifications to be properly termed 'gems'" (e.g., figure 8). Thus, one could fail to disclose treatment of certain gem rough and not run afoul of the Guides. It is equally arguable, however, that such actions would be fraudulent.


Figure 8. Not all transactions in the gem trade are necessarily subject to the FTC Guides. The official definition of "gem" probably excludes common gem rough, such as these emerald crystals from the Santa Terezinha mine in Brazil, even though this material may be treated in its rough form. Improper disclosure may still be actionable under state fraud legislation, however. GIA Collection no. 14075; photo by Maha Tannous.

Fraud is typically a matter of state law; federal jurisdiction exists only when the act occurs in interstate commerce, when some federal entity is involved, or if a particular federal law is implicated. As with deceptive trade practices, the precise legal definition varies from state to state, but there are some generally accepted principles that can be examined here.

The traditional concept of fraud encompasses a number of different torts (*tort* is the legal term for a wrongful act creating civil liability for damages, and not all conceivably "wrongful" acts are torts; the act must be one for which the court system has recognized a remedy; Black, 1968). One of these is fraud by nondisclosure, the classic elements of which are (a) failing to disclose a fact (b) that one knows may justifiably induce another to enter or refrain from entering a business transaction (c) where there exists a duty to disclose before the transaction is consummated (American Law Institute, 1977; information in this section is drawn from that source unless otherwise noted).

Failing to Disclose. Straightforwardly enough, this means failing to communicate or otherwise make known the relevant facts, in a manner that they can be understood by the other party. This failure, of course, must be knowing—it is not fraudulent for a vendor to fail to disclose facts of which he or she is unaware. (Note that this is in contrast to the standard under the FTC Guides, which, as discussed above, does not include an exemption for a lack of knowledge. Note also that a lack of knowledge and *proof* of a lack of knowledge are two very different things, so while it may be a defense to fraud, it is a risky one.)

Justifiable Inducement. How does a vendor know whether the fact of treatment would cause a buyer to enter or refrain from entering the transaction? This is easy if it is the vendor's standard practice to discuss treatments when a buyer is considering a purchase; it is more difficult if the vendor relies on the sort of generic disclosures sanctioned by the FTC, or worse, is gambling on making as little disclosure as possible. It is, however, reasonable to assume that treatment is a matter of concern for many buyers, and it is certainly reasonable for a buyer to consider the fact of treatment in weighing a purchase. While it may be true that many retail customers do not care much about gem treatment, and that a vendor might come to believe that the fact of treatment does not enter into their purchase decisions, in practice testimony to that effect in a suit for nondisclosure would likely be viewed as highly self-serving by the court and jury. Since it is rarely the average buyer who files a lawsuit, basing disclosure decisions on what the average customer may believe is inadvisable.

A Duty to Disclose: Five Basic Rules. The ancient rule of *caveat emptor*—let the buyer beware—has not yet been consigned to the dustbin of legal history, but it has long been circumscribed by the understanding that there is a difference between placing responsibility on the buyer for what he buys and allowing the vendor to use superior knowledge to defraud, that is, to sell the buyer something substantially less than what he reasonably expects to get (Black, 1968). The precise existence of a duty to disclose material facts to a transaction is the subject of centuries of litigation, but several basic rules are recognized by legal authorities. The first four are relatively straightforward; the fifth can be quite tricky. Note that in all cases, the duty must exist *before* the transaction is consummated; once the deal is closed, any further developments are irrelevant to the question of whether fraud has been committed.

1. *A duty may exist because of a fiduciary or other similar relationship of trust and confidence between the parties.*

A fiduciary relationship is one where the law recognizes a greater level of responsibility, such as that between a trustee and a beneficiary, a bank and its depositors, and the like. It does not exist in the average vendor-buyer relationship. However, where the parties have known and dealt with each other for long periods, they may have developed a relationship of special trust and confidence if they have come to rely on each other's integrity and honesty as part of doing business. Such a state of affairs is hardly unknown in the gem and jewelry trade. This is a highly fact-specific element, and disputes are typically resolved on a case-by-case basis.

2. *A duty may be created by partial or ambiguous statements that require the full truth to make the matter clear.*

This rule recognizes the reasonable proposition that when vendors make factual representations about their products, they cannot give only half the truth; they must disclose as much information as is necessary to prevent their representations from being misleading (see, e.g., *Baskin v. Hawley*, 1986). For example, were a vendor to extol the quality of color in an orange sapphire (figure 9), he or she would be creating a duty to disclose that the color resulted from beryllium diffusion, if that was the case.

3. *A duty may arise through subsequently acquired information showing previous statements to be false, though they were believed to be true when made.*

This means that a vendor cannot take advantage of his own mistakes. Suppose a vendor were to offer a diamond in good faith as untreated, only to discover later—but before closing the sale—that it had been subjected to HPHT treatment to change the color. In that case, a duty arises to correct the earlier, erroneous statement. Such a discovery that occurs after the sale normally incurs no liability, provided there was a genuine lack of knowledge at the point of sale—something that does not include mere inventory mistakes or misreading of product tags.

4. *A duty may arise where false statements have been made without expectation that they would be acted on, if in fact they are subsequently relied on.*

This situation is not likely to arise often, but suppose a vendor, without meaning to be taken seriously, declares that all his gems are untreated when this is not the case. Should he be approached by a customer in response to this statement, the vendor must correct any misconceptions.

5. *A duty to disclose "facts basic to the transaction" may arise if one party knows the other is operating under a mistake as to them and would reasonably expect disclosure because of their relationship, the customs of the trade, or some other objective circumstances.*

It is this situation that is most likely to occur in the average retail transaction. At the outset, it must be recognized that possessing superior knowledge of one's products and superior business training does not create any sort of duty to equalize the buyer's bargaining position; such imbalances are nothing more than life in a free-market economy. At the same time, the law has increasingly frowned on attempts to take advantage of the other party's ignorance (see, e.g., American Law Institute, 1977; *Brass v. American Film Technologies*, 1993).

A "fact basic to the transaction" is not merely one that may be relevant to it; it must be a fundamental and important part of what is being bargained for. Whether that includes a gem treatment surely depends on the circumstances. Between trade professionals, any fact of treatment will almost always be basic to the transaction. At the retail level, many in the industry believe that consumers are unconcerned with treatment disclosure (Genis, 1998); if such was indeed the case, treatment of a gem would not be a basic fact. However, as a practical matter, any buyer aggrieved enough to file a lawsuit is surely going to allege that he or she considered treatment a basic element of the gem, and such an allegation could be very hard to rebut.

Figure 9. Under common-law fraud, statements regarding the quality of color in a gemstone during a sales transaction probably create a duty to disclose treatments that are responsible for creating or improving the color, such as with these sapphires, which are colored by beryllium diffusion. Photo by Maha Tannous.

Knowing whether a customer is operating under a mistake as to facts basic to the transaction can be very difficult, especially if it is not common practice to discuss treatments. While one might be tempted to avoid the entire issue in hopes of maintaining one's ignorance as to a customer's assumptions, remember that in the event of a lawsuit, every decision and action will be reviewed with perfect hindsight (see, e.g., Everhart, 1988). Courts in general, and juries in particular, tend to take a dim view of "policies of silence," especially when that silence is intended to create a business advantage or preserve a customer's ignorance.

An expectation of disclosure on the part of the buyer must be objectively reasonable. In a general sense, the reasonableness of such an expectation can be somewhat nebulous and difficult to establish. However, in light of the most recent amendments to the FTC Guides and the widespread industry attention to the issue of full disclosure—as such becomes the "custom of the trade"—it has now become more than reasonable for a customer to expect full disclosure of gem treatments.

A final question the court will look at is whether the undisclosed facts could be discovered by ordinary investigation; this is where the old principle of *caveat emptor* still comes into play. In a transaction where the customer could correct his own mistake and obviate disclosure by his own investigation, dis-

BOX A: SOME HYPOTHETICAL SCENARIOS OF FRAUD

The laws governing fraud can be better understood by reviewing a few hypothetical situations. The reader should keep in mind that the discussions are confined to the specific question of liability for fraud, *not general moral obligations, state laws, or the FTC Guides* (although most, if not all, of the situations described here would indeed violate the Guides). They are also mainly the author's opinions and should not be taken as the final word on the subject.

1. A gem dealer offers a parcel of heat-treated sapphires to a retail jeweler. The two have never done business before, and the gem dealer is under the mistaken impression that the jeweler is an experienced gemologist who is capable of recognizing heat treatment when she sees it. The dealer does not disclose the treatment. The jeweler, believing the sapphires to be unheated but saying nothing, purchases them after an inspection. The gem dealer is not liable to the jeweler because he is unaware of the jeweler's assumption. (See Rule 1 in "A Duty to Disclose" in the main text.)

2. Same scenario as 1, except the jeweler and gem dealer have done business for over 10 years, the jeweler has come to rely on the gem dealer's honesty and integrity, and she has previously told him she intends to sell only unheated sapphires in her store. The gem dealer is liable to the jeweler, as he knows she cares about heat treatment and she is relying on a relationship of trust and confidence. (See Rules 1 and 5.)

3. A retail jeweler sells a variety of jade jewelry in her store, all of which is dyed (see, e.g., figure A-1). A customer asks if all her jade is "natural." She replies that she sells no synthetic stones in her store. The customer replies "That's good, because I've heard about all the things they're doing to jade these days, and I only want the natural stuff." The jeweler says nothing, and the customer buys a jade ring. The jeweler is liable to the customer because she failed to correct the misconception created by her earlier statement (even though what she said was the truth). (See Rules 2 and 3.)

Figure A-1. The pieces in this collection of jadeite carvings owe their color to dye. Failure to disclose the dye could be fraudulent. Courtesy of John Ng; photo by Robert Weldon.

closure may not be necessary. However, since the buyer is not required to have professional expertise or undertake extraordinary steps to discover undisclosed facts, this element favors the vendor mostly in transactions between experienced merchants, and less so in those between a retailer and the average customer, especially given the sophisticated nature of modern gem treatments and the increasing difficulty of detection.

Should the reader find all this theory flying too far overhead, Box A provides some examples that apply these rules to hypothetical situations.


FTC FASHION JEWELRY

3/4 Ct. Diamond Earrings

Retail Price - $1365.00
Our Low Price - $ 975.00

Item#: GRTDEAL
Shipping Weight: 0.1 Lbs.

Classic diamond solitaire earrings. Our sparkling round-cut diamonds are colorless and have only slight inclusions. Straight from the FTC's Washington DC diamond mines. Set in a stylish six-prong setting of 14 karat gold. The perfect fashion accessory for that special occasion.

Figure A-2. Internet vendors of gems and jewelry must take care to ensure that their product disclosures are not impaired by poor Web design. This example from the FTC's guidebook "Dot Com Disclosures" illustrates potential problems. Here, the hyperlink for "more details" is insufficient to disclose that the "$^3/_4$ ct" weight is actually a range, because of the importance of this information to the potential buyer.

4. Same scenario as 3, except the customer instead volunteers that he is "looking for a bargain" and doesn't care about any treatments. The jeweler is not liable to the customer because treatment is not a fact that would induce him either to enter or not enter the transaction.

5. Same scenario as 3, except the customer says nothing about treatment and simply buys the ring after a brief inspection. However, he has been referred to the jeweler by a mutual friend who praises her honesty and integrity. The jeweler, through this friend, is aware of the nature of the referral and that the customer is looking for untreated jade. The jeweler is liable to the customer because treatment is a fact basic to the transaction, the jeweler is aware of the customer's mistaken assumption, and the customer can reasonably expect disclosure. (See Rule 5.)

6. A retail jeweler who has heard about the new FTC Guides prepares a brief brochure explaining common gem treatments and places a stack of these brochures next to a potted plant in the back corner of his rather large store. Believing he has complied with the Guides, the jeweler does nothing more. A customer enters and begins inspecting the jeweler's selection of rubies, all of which have been heat treated. During her inspection, the customer remarks to the jeweler that she is looking for a "100% natural stone." The jeweler says nothing, and the customer buys a ring. He is liable to the customer despite his brochures unless she has some reason to be aware of their existence. (Again, see Rule 5.)

7. An Internet retailer sells a variety of jewelry and loose stones on his Web site. Each item has a separate page with multiple photographs and numerous pertinent facts such as carat weight, color, dimensions, clarity, and gem locality, along with a brief discussion of the item and its qualities. Treatments, if any, are not listed. Disclosure is limited to a vague, general discussion (in which treatment information is mixed together with a great deal of other gem information) that can be reached only from a single hyperlink on the home page. A customer, visiting the site, assumes from the wealth of information on each item page that any treatments would be listed. She purchases an emerald ring under the erroneous belief that the emerald is untreated; in fact, it has been clarity enhanced with a resin filler. The Web site owner is liable to the customer because: (1) the individual descriptions are "partial statements" (see Rule 2) that need more information to be fully truthful (especially with an impermanent treatment that requires special care); (2) his arguable concealment of the treatment information in his ambiguous, difficult-to-find disclosure page indicates his awareness that the fact of treatment is something that might induce customers not to buy his products (see Rule 5); and (3) he has indeed "failed to disclose," as his efforts fall well short of what is required by customs of the trade (see, e.g., FTC, 2000b; see also figure A-2).

CASE STUDIES ON DISCLOSURE

The brief capsules that follow here are meant as illustrations of the potential pitfalls of inattention to proper disclosure, not as judgments on the actions of the participants. In all cases, the descriptions are based on reports in the public record.

Kawin Chotin Jewelers, St. Louis, 1993. In the summer of 1993, Jody Davis, an investigative reporter at St. Louis, Missouri, television station KSDK, received two telephone calls a few weeks apart. Both were from consumers complaining that they had been sold fracture-filled diamonds (see,

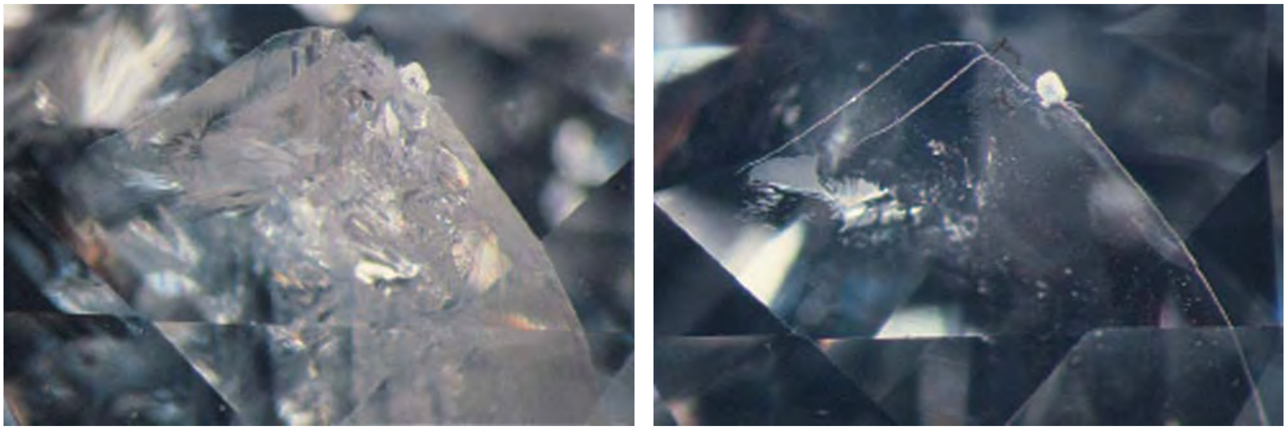


Figure 10. Undisclosed sale of fracture-filled diamonds led to several industry scandals during the 1990s. As shown here (before filling, left; after filling, right), injection of a glass filler into a diamond's cleavage cracks can produce dramatic differences in apparent clarity. Photomicrographs by John I. Koivula; magnified 15×.

e.g., figure 10) without having been told about the treatment, only to discover the truth when they had the diamonds appraised elsewhere. Both complaints concerned the same store: Kawin Chotin Jewelers (Bates 1993a; Everhart, 1993a). Mr. Davis filmed an exposé on the subject, which aired August 27. Other customers came forward, and Mr. Davis eventually broadcast four follow-up reports. It would come out that Kawin Chotin had apparently sold hundreds of filled diamonds without disclosure, and former employees even stated on camera that they were instructed not to tell customers about the treatment (Everhart, 1993a). The incident caused an explosion of press coverage, both on television and in trade and consumer publications. The local jewelry industry was thrown into chaos for months afterward as panicked consumers rushed to have their diamonds checked for filler (Bates 1993b, 1994c; Everhart, 1993b). The Missouri state attorney general fined Kawin Chotin $50,000 for violating the state deceptive trade practice laws, and co-owner Rick Chotin, trying to make good on his mistake, spent almost $1 million in an effort to refund his customers' money or replace their diamonds (Everhart, 1993c; Bates, 1994a). The financial stress became so great that Kawin Chotin was forced to file for bankruptcy protection and, in early 1994, Rick Chotin committed suicide (Bates, 1994b,c).

One interesting element of this unfortunate saga was that Kawin Chotin was arguably complying with the FTC Guides in force in 1993, which did not specifically require disclosure of "fracture filling," only that customers not be misled about the quality of the product. The only specific disclosure required by the 1957 Guides—then still in effect—was of artificial coloring. In addition, from the reports in the trade press, it appears that customers were being charged fair prices for the filled diamonds; they simply weren't being told about the treatment.

Whether or not it violated the Guides, this nondisclosure of fracture filling was a clear case of fraud. The angry reactions from Kawin Chotin customers leave little room for argument that the treatment was both an element on which they might have based their purchase decisions and a fact "basic to the transaction." To the extent that Kawin Chotin made any representations about the clarity of their diamonds—say, in an appraisal concurrent with the sale—that would have created a duty to disclose the treatment. Even absent that, Kawin Chotin clearly knew their customers had no knowledge of the filler, and the customs of the trade required disclosure, especially since they had a written agreement with their supplier, Diascience (now Yehuda Diamonds Co.), to do just that (Bates, 1993a).

Diamonds International/Almod Diamonds, 1997. In November 1997, a woman from Long Island, New York, while on vacation with her family in Barbados, purchased an attractive round brilliant diamond from a store run by Diamonds International, a chain owned by Almod Diamonds of New York City (Parker, 1998a). The stone was reportedly a well-cut, good-looking 1.02 ct E–SI_2, and the woman was initially very happy with it. What she had not been told—since the FTC Guides did not require it at the time—was that the diamond had been laser drilled. On her return home, she had the diamond appraised for insurance purposes, and the appraiser immediately pointed out the laser drilling. Shocked and disillusioned, she began a three-month crusade to get her money back (Parker, 1998a).

Almod's initial response was that, while they were sorry for her disappointment, the Guides did not require disclosure of laser drilling, so they would not refund her money. Rather than accept that explanation, she responded with a telephone and letter campaign to convince Almod to change its mind. She contacted the JVC, the FTC, the New York Department of Consumer Affairs, the New York State Attorney General's office, the local Better Business Bureau, the New York Consumer Protection Board, and trade publications such as *Rapaport Diamond Report* (Parker, 1998a). When the Department of Consumer Affairs contacted Almod in response to her complaints, the company finally gave in and refunded the money.

This case is an excellent example of the risks in using the FTC Guides as a ceiling for one's level of disclosure. According to published reports, Almod had actually been disclosing laser drilling prior to the 1996 revisions, but when the new rules were issued, they stopped requiring their salespeople to do so. The FTC in fact responded to the woman's complaint with an opinion that Almod's policy was not unfair or deceptive (Parker, 1998a). Thus, although Almod might have been safe from an FTC enforcement action, its unfortunate change in policy resulted in months of public embarrassment and unwelcome attention from state regulators.

Fred Ward and Blue Planet Gems, 1994–1999. This case between well-known gemologist and author Fred Ward and one of his customers is probably the most prominent lawsuit dealing with treatment disclosure in the past few decades. Although the case also turned on complicated insurance coverage issues (discussed in more detail in Federman, 1998b), for many in the industry it has come to symbolize the stakes involved in treatment disclosure. Many of the facts of this case are in dispute, but some elements are not. Mr. Ward sold a wedding ring set with a 3.65 ct Colombian emerald to a long-time friend in 1994 for $38,500 (Ward, 1997a,b; figure 11). The emerald had been examined by an independent appraiser, but was not sold with a report from a gemological laboratory. (Mr. Ward suggested getting one after the sale, but the customer declined.) However, Mr. Ward did provide her with a copy of his book on emeralds (Ward, 1993), which discusses emerald treatment extensively.

Figure 11. This ring, set with a 3.65 ct Colombian emerald, was at the center of a nearly five-year-long lawsuit over alleged nondisclosure of clarity enhancement. Photo © 1996 Fred Ward.

Shortly afterwards, the customer struck the emerald on her kitchen counter, and a large fracture became apparent. The customer's insurance company refused to replace the emerald, alleging that the fracture was pre-existing (but concealed by filler) and not the result of the impact—a question that became the central dispute in the case (Federman, 1998b). The customer sued her insurance company and Mr. Ward. After several years of litigation, a jury found against Mr. Ward and awarded treble damages for fraud, with an additional $160,000 for the plaintiff's attorney's fees (Ward, 1997b).

This verdict is troubling on a number of levels, not in the least because the customer testified repeatedly that Mr. Ward had in fact discussed (though not in writing) the clarity enhancement of emeralds during their negotiations, as well as his belief that this emerald had been subjected to light oiling (Federman, 1998b). The Guides in effect in 1994 did not even require this much, so such a discussion was certainly enough to satisfy the 1957 rule on treatments. Compliance with the Guides, however, was not enough to keep Mr. Ward out of court.

The definition of fraud by nondisclosure in the District of Colombia (where the trial took place) tracks the classic definition closely enough: There must be knowing nondisclosure of a material fact that should have been disclosed, as well as reliance on that nondisclosure (see *Feltman v. Sarbov*, 1976). The allegedly undisclosed material fact here was that the emerald contained a large fracture that was filled with an artificial resin such as Opticon. Given that the customer admitted being told about some level of clarity enhancement, the jury must have believed that Mr. Ward knew the emerald was filled with resin but chose only to disclose the use of oil. This is problematic given that, even as late as 1999 when the case finally ended, most experts felt that identifying emerald fillers was difficult and required sophisticated laboratory equipment (see, e.g., Johnson et al., 1999; McClure et al., 1999). Such logical inconsistencies in the verdict are likely why the judge threw out the treble damages during post-trial litigation (Ward, 1997b), and why Mr. Ward's law firm ultimately paid the remaining damages for him as part of a malpractice settlement. Testing conducted for his appeal (which was never filed) indicated that the emerald had been broken by the impact (F. Ward, pers. comm., 2004), although this development could not undo nearly five years of difficult litigation and all its negative consequences.

Methods that jewelers can use to protect themselves from such personal and professional misfortunes will be discussed in the next section, and in Box B, which provides some practical guidance on disclosure for the retail jeweler.

THE FUTURE OF DISCLOSURE, AND SOME SUGGESTIONS

As should be clear by now, good intentions and minimal compliance with the Guides are not enough to protect a vendor from legal action. The author cannot stress too much that the legal framework for disclosure should be viewed as a *minimum*, one that is not necessarily adequate protection in the event of a lawsuit. It takes only one unhappy buyer to file a complaint, and, no matter the outcome, it likely will result in an expensive defense and substantial bad publicity.

It is important to remember that the rules discussed in this article—FTC Guides, state laws, and civil fraud—do not exist in isolation. In a disclosure dispute that reaches the point of litigation, it is likely that all three will come into play. A buyer can file suit for both fraud and violation of a state unfair trade practice law. The Guides can be used as evidence of the customs of the trade, even if the FTC has no involvement in the case (this occurred in both the *Sanfield* and *Manning International* cases cited above; see also Beard, 2001). Both unfair trade practice laws and the Guides can be used to establish that a buyer has a reasonable expectation of disclosure in a suit for fraud. Taken together, this overlapping set of regulations leaves very little room for vendors who are looking for ways to avoid making full disclosure.

And what of those vendors who practice full disclosure in their sales presentations? While it should be standard procedure to discuss all treatments in a positive way with every buyer, this alone is not enough. Without physical evidence of disclosure, a court—and jury—are reduced to weighing competing testimony. Furthermore, in any suit where there are significant technical issues to resolve, as would be the case in a disclosure dispute, the litigation frequently becomes a "battle of the experts"—a battle in which expert witnesses often deliver diametrically opposed opinions to the jury. This is one of the things that occurred in the Ward emerald trial described above, and the outcome of such a case can be highly unpredictable.

It has been the author's experience, as a practicing attorney, that lawsuits thrive on paperwork. The more pre-litigation documents a vendor has to support his or her good-faith efforts at full disclosure, the better. The vendor who has no such evidence of disclosure runs the risk that the jurors will be more inclined to identify with the aggrieved consumer, regardless of what actually happened.

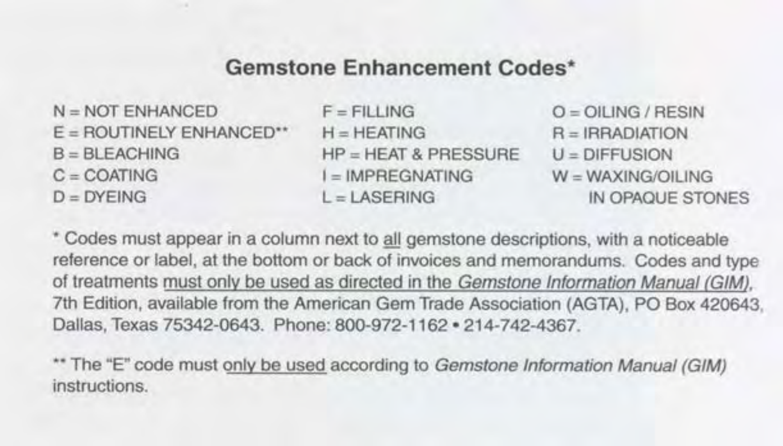
At a bare minimum, all necessary disclosure information should be printed on the invoice and/or receipt for the gem or item of jewelry and explained at the point of sale.

The use of independent appraisals, independent laboratory reports, and photomicrographs can also be helpful, to the extent warranted by the value of the stone. Any additional paperwork or other evidence documenting the state of the gem should be physically attached (e.g., by stapling) to the invoice and/or receipt such that post-sale removal will leave detectable traces. Obviously, the vendor should retain copies of all these documents in a secure location, preferably off-site.

For Internet sales, disclosure information should be included in any receipt provided with the transaction, whether e-mailed or generated onscreen for printing. All such transactions should be logged, Internet protocol (IP) addresses recorded, and the records preserved for at least several years, both digitally and as off-site hard copies. Separate "gem treatment information" Web pages should be simple, straightforward, and uncluttered with extraneous information. They should not require any great effort to find, nor should they be the only means of disclosure. *The best practice is to describe treatments clearly and list them as prominently as carat weight, clarity, and similar information*, preferably hyperlinking any treatment text to more detailed discussions for interested buyers both during shopping and at the point of sale. The construction of the Web site should not be susceptible to accusations that treatment information is being deliberately obscured or concealed, or that the vendor is trying to "disclose without disclosing" through ambiguous or factually deficient discussions (e.g., bare statements that most gem materials are treated or simple lists of commonly treated materials, without any other information). The FTC (2000b) offers excellent guidance on how to properly construct a commercial Web page, including a number of examples of sufficient and insufficient methods of disclosure (again, see figure A-2).

Both Internet and traditional storefront vendors should have *written* disclosure policies that comply with all applicable federal and state laws. All employees should be trained in the company policy and required to sign a statement that testifies to their receipt and understanding of it. Such documents must be turned over to the opposing party in the event of a lawsuit, so they should be carefully reviewed for legal compliance and possible errors well before any problems arise. Although this point might seem self-evident, vendors must ensure that written policies are actually *followed*. Having a disclosure policy that employees routinely disregard is probably worse than having none at all.

Most major trade groups have some sort of guidelines for disclosure (see, e.g., AGTA, 1999; "Promoting disclosure," 2002; see also figure 12). These guides are also admissible as evidence of the customs of the trade, so vendors who belong to one or more trade groups should be careful to maintain scrupulous compliance with their disclosure guidelines and ethics policies, as any deviations are sure to be highlighted in the event of a lawsuit. In most cases, these trade guidelines exceed legal requirements, though this will depend on where the vendor is operating. As with the FTC Guides, while they may be an excellent starting point, formulaic adherence rather than a conscientious good faith effort is a road to trouble. Where trade guidelines use a system of coding to represent treatments, such codes also should be fully explained during the transaction (codes should be used only within the trade; their use with consumers is inadvisable and may violate association guidelines).



Gemstone Enhancement Codes*

N = NOT ENHANCED
E = ROUTINELY ENHANCED**
B = BLEACHING
C = COATING
D = DYEING
F = FILLING
H = HEATING
HP = HEAT & PRESSURE
I = IMPREGNATING
L = LASERING
O = OILING / RESIN
R = IRRADIATION
U = DIFFUSION
W = WAXING/OILING IN OPAQUE STONES

* Codes must appear in a column next to all gemstone descriptions, with a noticeable reference or label, at the bottom or back of invoices and memorandums. Codes and type of treatments must only be used as directed in the *Gemstone Information Manual (GIM)*, 7th Edition, available from the American Gem Trade Association (AGTA), PO Box 420643, Dallas, Texas 75342-0643. Phone: 800-972-1162 • 214-742-4367.

** The "E" code must only be used according to *Gemstone Information Manual (GIM)* instructions.

Figure 12. Shown here is the verbiage required on all invoices and receipts issued by members of the American Gem Trade Association (AGTA, 1999). Various treatment disclosure methods are required of members of AGS, CIBJO, and ICA, among others. Members who fail to comply with these guidelines may encounter legal problems distinct from any disciplinary action taken by the association. Codes such as these should only be used within the trade. Reprinted with permission of AGTA.

If one believes that there is nothing to disclose, the best practice is to ensure that one has solid evidence of a lack of treatment, especially with sales of expensive goods, which are more likely to result in litigation should problems arise later. If there is no way to prove an absence of treatment, that fact should be discussed with the buyer and documented in writing.

As a final point, to disclose a treatment properly, one must be aware of it. In an era when full understanding of some treatments may require a degree in solid-state physics, sound gemological expertise and ongoing education are more important than ever. Where any doubt may exist, suspect stones should be submitted to an independent gemological laboratory for an identification report.

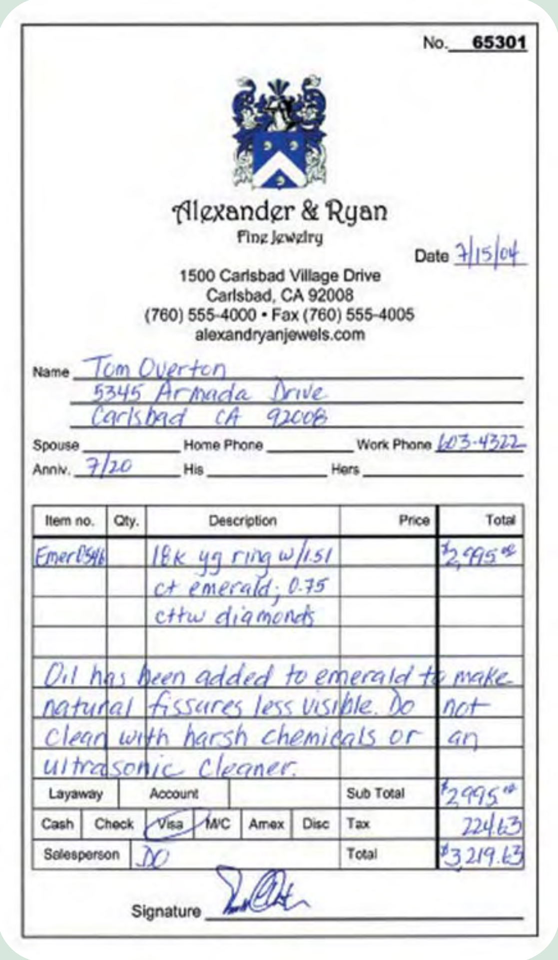
BOX B: PRACTICAL COMPLIANCE WITH LEGAL DISCLOSURE REQUIREMENTS

How can jewelers comply with so many legal requirements when their sales associates are neither attorneys nor, in many cases, gemologists? While it is impossible to anticipate every disclosure situation, a few simple rules can go a long way toward avoiding trouble.

Terminology is less important than understanding. While the FTC Guides do provide specific language for describing synthetics and simulants and the terminology that is appropriate for certain gem materials, unfortunately they do not provide similar guidance for gem treatments. There is no clear way to know, for example, whether "fracture filled" is preferable to "clarity enhanced" or whether either term, standing alone, is sufficient. *No specific treatment disclosure language is sanctioned or prohibited by the FTC Guides or other regulations.* The primary goal with each sale should be to ensure that the buyer has a clear understanding of the treatment(s) at issue and any special care requirements that may exist. If buyers understand what they are buying, the legal requirements should be satisfied.

Understanding must flow in all directions. Anyone selling gem materials *must* know what he or she is selling. Vendors must demand full and clear disclosure of all treatments from their suppliers, and must understand what is being disclosed to them. A jeweler who does not understand a treatment cannot make a customer understand it. In larger stores and chains, where it may be impractical to train all sales associates in the details of gem treatments, a manager should intervene at some point before the sale is closed to properly explain the treatment (and, at a minimum, sales associates should be trained not to close such a sale without manager assistance). Given the number of treatments that may be encountered in the current market, reference materials should be kept close at hand. Some potentially useful sources are AGTA (1999), McClure and Smith (2000), Smith and McClure (2002), and *Diamonds: . . .* (2003). Some commonly encountered gem treatments (adapted from Smith and McClure, 2002), with some suggested retail sales approaches, are presented in table B-1.

Put it in writing! No matter what may be said during the sales transaction, a clear written description of the treatment (and special care requirements, if any) must accompany every invoice and/or receipt (see, e.g., figure B-1). *This point cannot be overemphasized.* Where justified by the value of a stone, reports from recognized gemological laboratories are also very useful. Without written evidence of disclosure, proving compliance later may be impossible. Copies of these written records should be stored in a safe, organized manner for later retrieval.



No. 65301

Alexander & Ryan
Fine Jewelry
1500 Carlsbad Village Drive
Carlsbad, CA 92008
(760) 555-4000 • Fax (760) 555-4005
alexandryanjewels.com

Date 7/15/04

Name Tom Overton
5345 Armada Drive
Carlsbad CA 92008

Spouse ______ Home Phone ______ Work Phone 603-4322
Anniv. 7/20 His ______ Hers ______

Item no.	Qty.	Description	Price	Total
Emer0546		18k yg ring w/1.51		$\$2{,}995^{00}$
		ct emerald; 0.75		
		cttw diamonds		

Oil has been added to emerald to make natural fissures less visible. Do not clean with harsh chemicals or an ultrasonic cleaner.

Layaway	Account					Sub Total	$\$2995^{00}$
Cash	Check	[✓ Visa]	M/C	Amex	Disc	Tax	224.63
Salesperson	DO					Total	$\$3{,}219.63$

Signature ______

Figure B-1. This sample invoice shows how written disclosure can be incorporated into a retail sales receipt. It is very important that plain, unambiguous language be used, rather than codes or technical terms that, though common in the trade, may confuse average consumers.

TABLE B-1. Commonly encountered gem treatments and suggested disclosure language.

Gem material	Frequently encountered treatments	Examples of suggested retail sales approaches[a]	Examples of suggested language for retail receipts
Beryl	Clarity enhancement, Dyeing, Surface coating, Thermal enhancement, Irradiation	“Emeralds typically have naturally occurring eye-visible fissures. As a result, they have traditionally been oiled or treated with a resin filler to make these fissures less visible. Your emerald has been oiled or resin-filled to improve its appearance. This may not be a permanent treatment, so do not subject the stone to ultrasonic cleaners or harsh chemicals. In most cases, however, if the fissures become visible again, the original appearance can be restored through re-treatment.”	“An oil or resin has been added to the emerald to make natural fissures less visible. Do not clean with harsh chemicals or ultrasonic cleaners.”
Corundum	Dyeing, Surface coating, Thermal enhancement, Diffusion treatment, Irradiation	“Because the finest colors of ruby and sapphire are so rare, heat treatment has traditionally been used to improve the color of less remarkable stones. This treatment is similar to natural processes, and many gem dealers refer to it as ‘completing what nature left unfinished.’ Your blue sapphire has been heat treated, but this is a permanent enhancement and the color should not fade in conditions of normal use.”	“The sapphire has been heat-treated to enhance the blue color.”
Diamond	Clarity enhancement, Dyeing, Surface coating, Laser drilling + chemical bleaching, HPHT annealing, Irradiation, Irradiation + heating, Ion implantation of boron	“Some colors are extremely rare in natural diamonds but can be duplicated through irradiation, irradiation and heating, or high-pressure/high-temperature processing. Your diamond owes its color to such a treatment, but the color change is permanent and should not fade in conditions of normal use.”	“The diamond has been subjected to irradiation to create the green color.”
Jadeite	Dyeing, Surface coating, Chemical bleaching, Impregnation	“To achieve the appearance of the much sought-after fine Imperial jadite, some jadeite needs treatment, which often involves bleaching to remove stains and subsequent filling with a polymer to strengthen the jade [or dye to improve the color]. Your jade bangle has been [bleached and polymer impregnated/dyed] to give it this fine appearance. Although this treatment is typically stable under conditions of normal use, it may not be permanent. You should use care in cleaning and avoid methods such as ultrasonic cleaners and harsh chemicals.”	“The jadeite has been bleached to remove natural stains and polymer impregnated. Do not clean with harsh chemicals or ultrasonic cleaners.”
Pearl	Dyeing, Chemical bleaching, Irradiation, Oiling, Filling	“Black cultured pearls are some of the most highly prized gems in the world, but it is possible to create affordable black cultured pearls through the use of dye, as is the case with this strand. This is not necessarily a permanent treatment, so you should avoid prolonged exposure to sunlight and, as with all pearls, use care in cleaning and handling.”	“The cultured pearls have been dyed to create a black appearance. Protect from sunlight. Do not clean with harsh chemicals or ultrasonic cleaners.”
Topaz	Surface coating, Chemical treatment, Thermal enhancement, Irradiation, Irradiation + heating	“While natural blue topaz does exist, it is rare and expensive. Virtually all blue topaz on the market today owes its color to irradiation in combination with heat treatment. While it is generally not possible to detect this enhancement, it is best to assume this stone has been irradiated to produce the fine blue color. This is a permanent treatment and should not fade in conditions of normal use and care.”	“The topaz may have been irradiated and heated to create the blue color.”
Tourmaline	Clarity enhancement, Surface coating, Thermal enhancement, Irradiation	“Many tourmalines are heated to improve their color. While there is currently no reliable method to detect whether a tourmaline has been heat-treated, it is possible that this stone has been heated. This is a permanent treatment, and the color should not fade in conditions of normal use and care.”	“The tourmaline may have been heat-treated to enhance the color.”
Turquoise	Dyeing, Impregnation, Zachery treatment	“Because turquoise is very porous, the color may change over time from exposure to skin oils or other substances. The Zachery treatment not only enhances the blue color, but also makes the turquoise less porous so the color is less likely to change under conditions of normal wear and care.”	“The turquoise has been treated by the Zachery process to enhance the blue color and reduce porosity.”
Zoisite	Thermal enhancement	“The vast majority of tanzanite is actually brown when it comes out of the mine. Bringing out the fine violet-blue color you see here requires careful heat treatment, and without it, stones of this color would be exceedingly rare. This is a permanent treatment and should not fade in conditions of normal use and care.”	“The tanzanite has been heat-treated to create the violet-blue color.”

[a] *Note that these are merely suggested means of verbally explaining the treatment to a potential customer. They should not be the only means of disclosure, which, as discussed in the text, must also be delivered in writing.*

CONCLUSION

In the second issue of *Gems & Gemology*, GIA founder Robert M. Shipley set out what he believed to be the essentials of a "diamond man's" equipment (1934). He listed only a 10× triplet loupe, a diamond scale, a Moe gauge, and a good diffused light source. Those who believe that trade in diamonds and colored stones should focus on their beauty and uniqueness can be forgiven some disillusionment at the prospect that such a list now seems to require an attorney as well. They can take solace in the fact that the gem and jewelry trade is not alone in facing this dilemma.

The amazing advances in gem treatment methods over the past few decades have dramatically expanded the availability of beautiful gem materials, and made it possible for average consumers to possess attractive ornaments that were once reserved for the wealthy. The dark side of such progress is the added responsibility to ensure that these consumers are not misled about what they are buying. Similar technological advances in other industries have led to increased government oversight and regulation of those fields, and it is naïve to think the gem and jewelry trade should somehow be immune. While the legal requirements discussed in this article are fairly broad, meeting them is not beyond the means of any vendor. A continuing commitment to ethics, careful attention to detail, and a healthy dose of foresight should be enough to keep most members of the gem trade out of trouble.

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LAB-GROWN COLORED DIAMONDS FROM CHATHAM CREATED GEMS

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Synthetic colored diamonds (yellow, blue, green, and pink) from a new source in Asia are now being sold by Chatham Created Gems of San Francisco, California. Some of this new material displays hues and weaker saturations that more closely resemble natural diamonds than most of the synthetic diamonds we have encountered previously, which typically had very intense colors. These as-grown and treated type I and type II synthetic diamonds, produced by a high pressure/high temperature process, have many distinctive visual and spectroscopic features that serve to separate them from natural diamonds. These include geometric patterns of color zoning and luminescence, metallic inclusions, and bands seen in the visible and photoluminescence spectra.

One of the most important gemological developments in recent years has been the commercial availability of jewelry-quality synthetic diamonds. What for almost three decades was primarily an industrial or research product is now becoming a commodity in the gem and jewelry marketplace. In addition to the products being offered by such companies as the Gemesis Corp. and Lucent Diamonds, Chatham Created Gems of San Francisco, California, has introduced a line of synthetic diamonds from a new source (figure 1). This article presents results of our examination of a large group of these high pressure/high temperature (HPHT) laboratory-grown diamonds in yellow, blue, green, and pink colors showing a full range of saturation, from weak to strong. Our examination indicates that most of the yellows and blues represent "as-grown" colors (i.e., those produced by nitrogen and boron impurities during diamond crystallization), while the greens and pinks are the result of either growth or growth plus post-growth treatment processes (i.e., irradiation, with or without subsequent heating).

A single manufacturer is supplying Chatham Created Gems with approximately 500 carats of synthetic diamond crystals per month, with future increases in production planned (T. Chatham, pers. comm., 2004). The material is faceted in China into cut goods that range from a few points (melee) to as large as 2 ct. Chatham Created Gems is the sole distributor of this material for jewelry purposes. Previous gemological reports on synthetic diamonds produced in Russia and sold by Mr. Chatham (see, e.g., Scarratt et al., 1996) may not be applicable to the new HPHT-grown material described here, which is grown in Asia with a non-BARS press.

This article provides information on material from all four color categories of this new product, including descriptions of green and pink synthetic diamonds, which have not been reported on extensively in the gemological literature. Most of the green samples display this color because they contain both blue and yellow growth sectors. Some of this new material displays hues and weaker saturations that more closely resemble natural diamonds

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See end of article for About the Authors and Acknowledgments.

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Figure 1. A new, undisclosed source is producing a broad range of synthetic diamonds for Chatham Created Gems of San Francisco. The loose faceted yellow, blue, and pink lab-grown diamonds shown here range from 0.28 to 0.51 ct. The jewelry set with pink and blue lab-grown diamonds is by Judith Conway. The ring set with a 1.19 ct yellow lab-grown diamond is by Doris Panos. Courtesy of Chatham Created Gems; photo by Harold & Erica Van Pelt.

than most of the synthetic diamonds we have encountered in the past, which have had very intense colors. Furthermore, a number of the examined samples are very low-nitrogen-containing synthetic diamonds that are nearly type IIa material; past reports on synthetic diamonds that are type IIa described material that was colorless or near colorless (for an explanation of diamond types, see Collins, 1982, 2001). The broad commercial availability of these new synthetic diamonds with lighter, more "natural-looking" colors reinforces the need for gemologists to understand how to identify them.

MATERIALS AND METHODS

We examined a total of 129 samples during this study, selected from a broad range provided by Chatham Created Gems. There were 20 crystals (0.44–1.74 ct) and 109 faceted samples (0.13–1.34 ct). In terms of their basic hues, there were 39 yellow (including one green-yellow and one yellow-brown), 29 blue, 16 green (including one greenish gray), and 45 pink samples (including one pinkish purple), some of which are illustrated in figure 2. (Note that all color terminology is according to the nomenclature used by the GIA Gem Laboratory to describe fancy-color diamonds.) Most of these are

Figure 2. These blue, green, pink, and yellow laboratory-grown faceted diamonds (0.13–1.34 ct) are representative of the faceted material examined for this study. Photo by Maha Tannous.

representative of the product now being sold, although the yellowish green and greenish blue samples currently are not available commercially. The faceted samples exhibited a range of styles, including round brilliant, cut-corner rectangle modified brilliant, and octagon shapes.

Standard gemological properties were obtained on most of these samples. For research purposes only, GIA Gem Laboratory graders assigned equivalent clarity and fancy color grades to these synthetic diamonds (GIA does not issue grading reports on synthetic diamonds). Internal features were observed with a binocular gemological microscope using various illumination techniques. Reactions to UV radiation were viewed in a darkened room with four-watt long- (366 nm) and short-wave (254 nm) Ultraviolet Products lamps. Absorption spectra were observed with a desk-model Beck prism spectroscope. Electrical conductivity was tested for 27 faceted blue samples and eight of the green samples with a gemological conductometer.

Samples from each of the four color groups were selected for more advanced testing. We used a Thermo-Spectronic Unicam UV500 spectrophotometer to record the absorption spectra of 65 samples (13 yellow, 14 blue, 14 green, and 24 pink). Each was held in a cryogenic cell cooled by liquid nitrogen, with the spectrum taken over a range of 250–850 nm at a scan rate of 30 nm/min and a bandwidth of 0.5 nm. Absorption spectra in the mid-infrared range (6000–400 cm^{-1}, with 1 cm^{-1} resolution) were recorded for 98 samples (30 yellow, 23 blue, 15 green, and 30 pink) at room temperature with a Thermo-Nicolet Nexus 670 Fourier-transform infrared (FTIR) spectrometer. Photoluminescence (PL) spectra were recorded with a Renishaw 1000 Raman microspectrometer over a range of 520–1050 nm using a 20 mW 514.5 nm Argon-ion laser; the 61 samples analyzed (14 yellow, 13 blue, 11 green, and 23 pink) were held in a cryogenic cell cooled by liquid nitrogen. Five summed scans were accumulated for each sample to achieve a better signal-to-noise ratio.

Qualitative chemical analyses of 12 samples (2 yellow, 3 blue, 3 green, and 4 pink) were obtained by energy-dispersive X-ray fluorescence (EDXRF) spectroscopy using either of the following two instruments: a Thermo-Noran Omicron system operating at an accelerating voltage of 25 kV with beam currents between 0.6 and 3.2 mA, and a Kevex Spectrace QuanX system operating at an accelerating voltage of 35 kV with a beam current of 0.35 mA.

Room-temperature cathodoluminescence reactions of four samples (one from each color group) were observed with a Luminoscope ELM-3R cathodoluminescence (CL) unit operating at 15 keV and 1.0 mA. The luminescence patterns seen with this CL unit are similar to those that would be observed with the De Beers DiamondView diamond verification instrument (see Welbourn et al., 1996).

RESULTS

The faceted samples varied in clarity from VVS to I (most were VS or SI); their clarity grades were influenced mainly by the number, size, and visibility of metallic inclusions. In some instances, removal of prominent inclusion(s) located near the culet would improve the clarity considerably.

The samples represent various diamond types (as determined by infrared spectroscopy) with different gemological properties. Table 1 summarizes the visible-range absorption bands recorded in the spectra of all four colors of synthetic diamonds, and gives their causes. Table 2 lists the photoluminescence (PL) bands (and their causes) recorded for all four colors of these synthetic diamonds.

Some samples represent as-grown colors produced during crystallization, while others are due to a combination of the growth process and post-growth treatment. Therefore, the four color groups will be described individually to clarify the explanation of their diagnostic features.

Yellow. *Visual Appearance.* All 39 samples in this group were type Ib, and included hues of yellow (2), brownish orangy yellow (16), orangy yellow (7), orange-yellow (12), and green-yellow (1), as well as one sample that was yellow-brown (figure 3). The eight crystals (0.63–1.74 ct) displayed typical cuboctahedral morphology. In general, they were well developed in shape, with flat faces and sharp corners and junctions between faces; however, some displayed slight distortions due to missing crystal faces or unequal development of faces.

If graded for color, the 31 faceted samples would be described as Fancy (1 sample), Fancy Vivid (8), and Fancy Deep (20).

Features Seen with Magnification. All the crystals and faceted samples exhibited some form of growth sector–related color zoning, which varied from prominent (where colorless zones could be seen) to subtle (lighter and darker yellow zones), as illustrated in figure 4. Such zoning is best observed by immersing the sample in water to minimize surface reflections (figure 5). Since the table facet is usually cut parallel to a cubic crystal face for maximum weight retention, placing a faceted sample table down in water often revealed the cross- or square-shaped color zoning pattern that is characteristic of synthetic diamonds (see, e.g., Shigley et al., 1995). Another way to check for zoning in a faceted sample is to hold the stone between the table and the culet and then rotate it, noting changes in color zones at intervals of 90°.

A number of samples also displayed intersecting patterns of internal graining, often seen as hourglass or funnel-shaped patterns (figure 6). This graining represents the boundaries between growth sectors.

The 31 faceted samples (0.21–1.34 ct) represented a broad range of clarity grades (VVS—3 samples, VS—4, SI—9, and I—15). The low grades were primarily due to the presence of metallic inclusions

TABLE 1. UV-Visible absorption features recorded for the Chatham synthetic diamonds studied.

Wave-length (nm)	Band label	Cause[a]	Yellow		Blue		Green		Pink
			As-grown (11)	Treated (2)	As-grown (13)	Treated (1)	As-grown (8)	Treated (6)	Treated (24)
271		Nitrogen	St[b], Common[c]	St	Wk to Mod, Common	St	St, Common	St	St, Common
393		Irradiation	——[d]	——	——	Wk	——	Mod to St	——
412	GR8	Irradiation	——	——	——	Wk	——	Wk	——
416	GR6	Irradiation	——	——	——	Wk	——	——	Wk, Rare
419	GR5	Irradiation	——	——	——	Wk	——	Wk	——
424	H6	Irradiation + heating	——	——	——	Wk	——	Wk	Wk, Common
429	GR3	Irradiation	——	——	——	Wk	——	Wk	Wk, Rare
442	2.087 eV	Irradiation + heating	——	——	——	——	——	——	Wk, Common
489		Irradiation + heating	——	——	——	Wk	——	Mod	——
494	2.51 eV	Nickel	Wk, Common	Wk	——	——	——	——	——
503	3H	Irradiation	——	——	——	Wk	——	Wk	——
523	NE3	Nickel	——	——	——	——	——	Wk	——
527	2.351 eV	Nickel	——	——	——	——	——	Wk	——
575	NV^0	Irradiation + heating	——	——	——	——	——	——	Wk to St, Common
595	595 nm	Irradiation + heating	——	Wk	——	Mod	——	Wk to Mod	Wk to Mod, Common
637	NV^-	Irradiation + heating	Wk, Common	Wk to St	——	——	——	Wk	Wk to St, Common
647		(Unknown)	——	——	——	——	——	Wk	——
658		Nickel	Wk, Common	Wk	——	——	——	——	——
667		Irradiation	——	——	——	Mod	——	Wk	——
741	GR1	Irradiation	——	Wk to Mod	——	St	——	Mod to St	Wk, Common

[a] *Reference: Zaitsev (2001).*
[b] *Intensity: Wk = weak, Mod = moderate, and St = strong, based on a subjective judgment of peak height.*
[c] *Abundance: Rare = present in less than one-third of samples investigated, Common = present in more than one-third of samples investigated.*
[d] *—— = not present.*

TABLE 2. List of photoluminescence features recorded for the Chatham synthetic diamonds studied.

Wave-length (nm)	Band label	Cause[a]	Yellow		Blue		Green		Pink
			As-grown (12)	Treated (2)	As-grown (12)	Treated (1)	As-grown (6)	Treated (5)	Treated (23)
527	2.351 eV	Nickel	——[b]	Mod	——	Wk	——	Wk	——
530		(Unknown)	——	St	Wk, Rare	Mod	Wk, Rare	Wk to St	——
535		Irradiation + heating	——	Wk	——	Wk	——	Wk	——
546	2.267 eV	Nickel	Wk[c], Common[d]	——	——	Wk	Wk, Rare	——	Wk, Rare
552		(Raman Band—Intrinsic to diamond)	(Common)	(Common)	(Common)	(Common)	(Common)	(Common)	(Common)
559		(Unknown)	Wk, Rare	——	Wk, Rare	Wk	Wk, Common	——	——
562		(Unknown)	——	——	——	Wk	——	——	——
575	NV^0	Irradiation + heating	Wk to Mod, Common	Mod to St	Wk, Common	Mod	Wk to St, Common	Wk to St	St, Common
580		Nickel	Wk, Rare	St	Wk, Common	Wk	Wk, Rare	Wk	——
589		(Raman Band—Intrinsic to diamond)	(Common)	(Common)	(Common)	(Common)	(Common)	(Common)	(Not observed)
596		(Raman Band—Intrinsic to diamond)	(Common)	(Common)	(Common)	(Common)	(Common)	(Common)	(Not observed)
611		(Unknown)	Wk, Common	——	——	——	Wk, rare	——	——
623		Nickel	Wk, Rare	——	——	——	——	——	——
637	NV$^-$	Nitrogen	Wk to St, Common	St	Wk, Rare	Mod	Wk to St, Common	St	St, Common
647		(Unknown)	——	——	——	St	——	Mod to St	——
657		Nickel	Wk, Common	——	——	——	——	Wk to Mod	——
693		Nickel	Mod to St, Rare	——	——	——	——	——	Mod, Rare
704		Nickel	Wk, Rare	——	——	——	——	——	——
711		Nickel	——	——	——	——	Wk, Rare	——	——
721		Nickel	——	——	——	——	——	Wk to St	——
727		Nickel	Wk to Mod, Rare	——	——	——	——	——	——
732		Nickel	——	Wk	——	——	——	——	——
741	GR1	Irradiation	——	St	——	St	——	Mod to St	——
744	GR1	Irradiation	——	Wk	——	St	——	Wk to Mod	——
800		(Unknown)	Wk, Rare	——	——	——	——	——	——
808		(Unknown)	Wk, Rare	——	——	——	Wk, Rare	Wk	——
883 +884	1.40 eV	Nickel	——	——	Wk, Rare	——	Wk to Mod, Rare	——	Wk, Rare

[a] *Reference: Zaitsev (2001).*
[b] *—— = not present.*
[c] *Intensity: Wk = weak, Mod = moderate, and St = strong, based on a subjective judgment of peak height.*
[d] *Abundance: Rare = present in less than one-third of samples investigated, Common = present in more than one-third of samples investigated, and Not observed = not observed due to laser-induced fluorescence of the sample.*

Figure 3. Among the "yellow" synthetic diamonds examined during this study are those that would be described as orange-yellow, orangy yellow, and yellow (on the left, from left to right: 0.35–0.62 ct); brownish orangy yellow and orangy yellow (center: 0.28 and 0.21 ct); and yellow-brown (right: 0.22 ct). Photos by Maha Tannous.

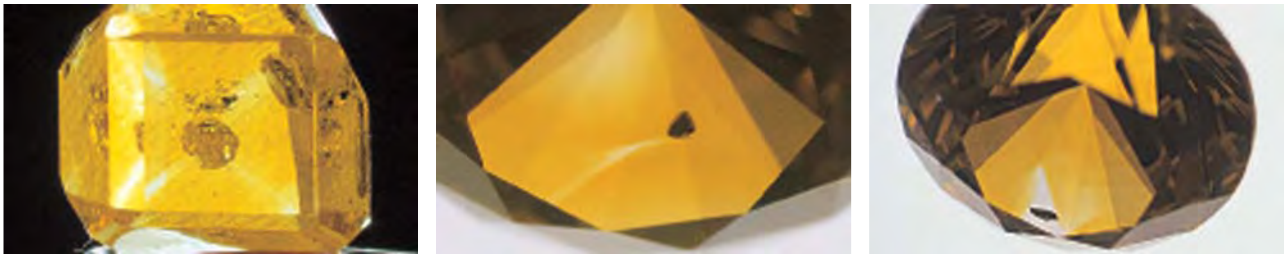


Figure 4. All the synthetic diamonds showed color zoning related to growth sectors. The yellow crystal (0.63 ct) on the far left exhibits a cross-shaped pattern of four narrow colorless zones that point toward the cube faces at the corners of the crystal; the gray area near the middle represents the seed location on which the original crystal grew. The 0.47 ct orangy yellow sample in the center has a prominent metallic inclusion, as well as color zoning due to the uneven distribution of nitrogen between growth sectors. Yellow sectors contain nitrogen, while colorless sectors contain little if any of this impurity element. The 0.57 ct sample on the far right displays similar yellow and colorless growth sectors, which are diagnostic of many laboratory-grown diamonds. Photomicrographs by J. E. Shigley; magnified 15×, 20×, and 20×.

(see, e.g., figure 7). In samples with better clarity, the relative absence of metallic inclusions could make these synthetic diamonds more difficult for gemologists to identify.

Luminescence. All the yellow samples were inert to long-wave UV radiation. When exposed to short-wave UV, one was inert, and the others fluoresced yellow-green, green, or green-yellow (one strong, 9 moderate, and 27 weak). The majority (34 samples) displayed an uneven fluorescence pattern, normally with a distinctive area that did not fluoresce. The generally weak intensity of the short-wave UV fluorescence means that observation must be carried out in a darkened room after letting one's eyes adjust to the low light level.

The one yellow-brown sample also was a type Ib diamond, but it had different UV fluorescence reactions: weak red to long-wave UV, and moderate orangy red to short-wave UV (and displaying a cuboctahedral pattern). These reactions corresponded more closely to the UV fluorescence of the pink synthetic diamonds examined in this study (see below).

Figure 8 shows the green, cross-shaped cathodoluminescence pattern of one of the yellow samples, which is diagnostic of synthetic diamonds (see, e.g., Shigley et al., 1995).

Figure 5. Immersion in water reveals the different color zoning patterns in these two yellow synthetic diamonds (0.60 and 0.49 ct; viewed table-down). These patterns depend on several factors: the shape and relative sizes of the faces on the original crystal, the area of the original crystal contained within the faceted sample, the orientation of the crystal relative to the facet arrangement, and the relative distribution of nitrogen between growth sectors. Photomicrograph by J. E. Shigley.

Figure 6. Intersecting internal graining, often in hourglass- or funnel-shaped patterns, represents another diagnostic visual feature of synthetic diamonds. These patterns are best observed through the pavilion facets (as shown here), or by looking near the edges of the table facet. Photomicrograph by J. E. Shigley; magnified 20×.

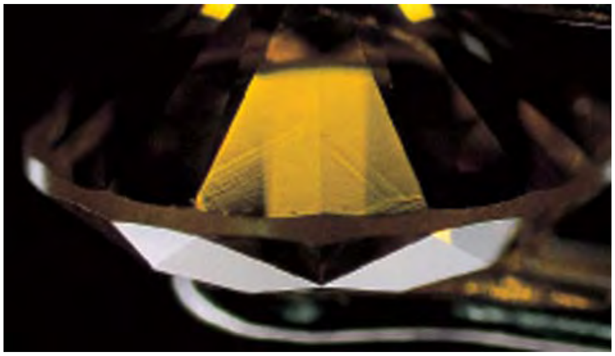


Figure 7. Metallic inclusions are another key identifying feature of laboratory-grown diamonds. They appear black and opaque in transmitted light, and gray and metallic in reflected light. They can display a wide variety of shapes, as shown in this 0.62 ct sample. Photomicrograph by J. E. Shigley; magnified 40×.

Visible Spectra. Using a prism spectroscope and transmitted light, we observed sharp absorption bands in only two of the 39 samples. The green-yellow sample (figure 9) exhibited a weak 595 nm band. The yellow-brown sample (again, see figure 3) exhibited a band at 637 nm that is caused by the NV^- (nitrogen vacancy) center (Zaitsev, 2001). The remaining 37 yellow samples displayed a gradually increasing absorption toward the ultraviolet end of the spectrum (beginning below 500 nm) that is typical for type Ib diamonds, natural and synthetic, and is the cause of their yellow color.

Advanced Instrumentation. Figure 10 presents visible-range absorption spectra for some representative samples of the synthetic diamonds examined in this study (again, see table 1). Figure 10A, for a brownish orangy yellow sample, shows sharp but very weak bands at 494, 637, and 658 nm (the weakness of these features meant that they could not be seen with the desk-model spectroscope), as well as the broad region of absorption below 500 nm that is responsible for the yellow color.

Figure 10B shows the visible-range spectrum of the one yellow-brown sample. Besides the absorption below 500 nm, there is a region of absorption from 500 to about 620 nm, as well as weak bands at 595, 658, and 741 nm and a strong band at 637 nm. These sharp bands are evidence that this type Ib synthetic diamond had been irradiated and then heated (Zaitsev, 2001). (Similar features were present in the spectrum of the green-yellow sample, but it appears that this sample was annealed at lower temperatures and/or for shorter periods of time.)

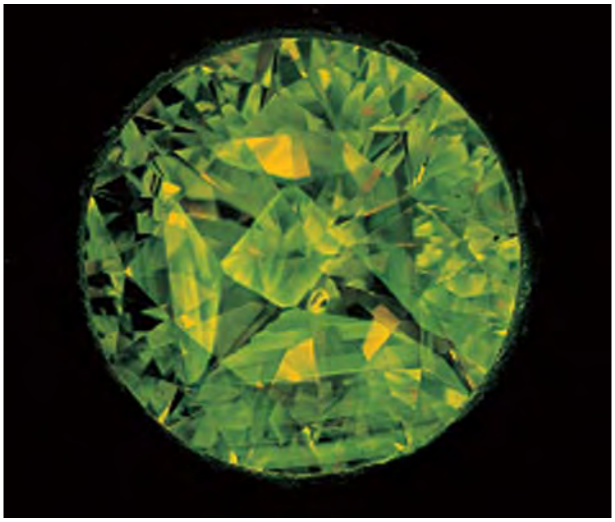


Figure 8. When exposed to a beam of electrons in a vacuum chamber, most synthetic diamonds exhibit cathodoluminescence in various colors. This luminescence often reveals the internal growth sector arrangement, such as the cross-shaped pattern seen in this 0.47 ct orangy yellow laboratory-grown diamond. These CL images are similar to those produced by the De Beers DiamondView and can be used to separate natural from synthetic diamonds (Welbourn et al., 1996). Photo by S. Muhlmeister and C. M. Breeding.

Figure 11 provides mid-infrared spectra for a range of the samples that were examined in this study. Figure 11A, which is for the same sample as in figure 10A, reveals the features below 1400 cm^{-1}

Figure 9. When examined with a prism spectroscope, the spectrum of this 0.34 ct green-yellow synthetic diamond (with a large metallic inclusion near the culet) exhibited a weak 595 nm absorption band, which indicated that it had been irradiated and heated to change its color. Photo by Maha Tannous.

that are characteristic of type Ib diamonds with a moderate amount of nitrogen.

Representative photoluminescence spectra for the samples in this study are given in figure 12. Figure 12A shows a PL spectrum for this same brownish orangy yellow sample, which is typical for the other yellow synthetic diamonds tested (again, see table 2). Figure 12B shows the PL spectrum of the same yellow-brown sample as in figure 10B.

Chemical analysis of a yellow crystal revealed the presence of Fe and Ni, which are undoubtedly from the flux metals used for diamond crystallization. The other yellow sample (which is equivalent to VS_2 clarity) did not show any trace-element impurities with EDXRF spectroscopy.

Blue. *Visual Appearance.* The 29 samples in this group were blue (18), grayish blue (6), grayish greenish blue (3), greenish blue (1), and green-blue (1). The one crystal had a greenish blue color that was different from the other samples in this group. The 28 faceted samples had colors that would be described as Fancy (6 samples), Fancy Intense (6), Fancy Deep (14), or Fancy Dark (2); two of these are shown in figure 13. In general, these faceted samples (0.13–0.50 ct) weighed less than the yellow synthetic diamonds.

The 29 laboratory-grown diamonds in this color category fell into two main groups—those that were type IIb+IIa (12 of the 24 samples for which infrared spectra were recorded), and those that also contained some isolated nitrogen in addition to boron and thus were a mixture of type IIb and Ib (11 of the 24 samples). The former contained growth sectors that were

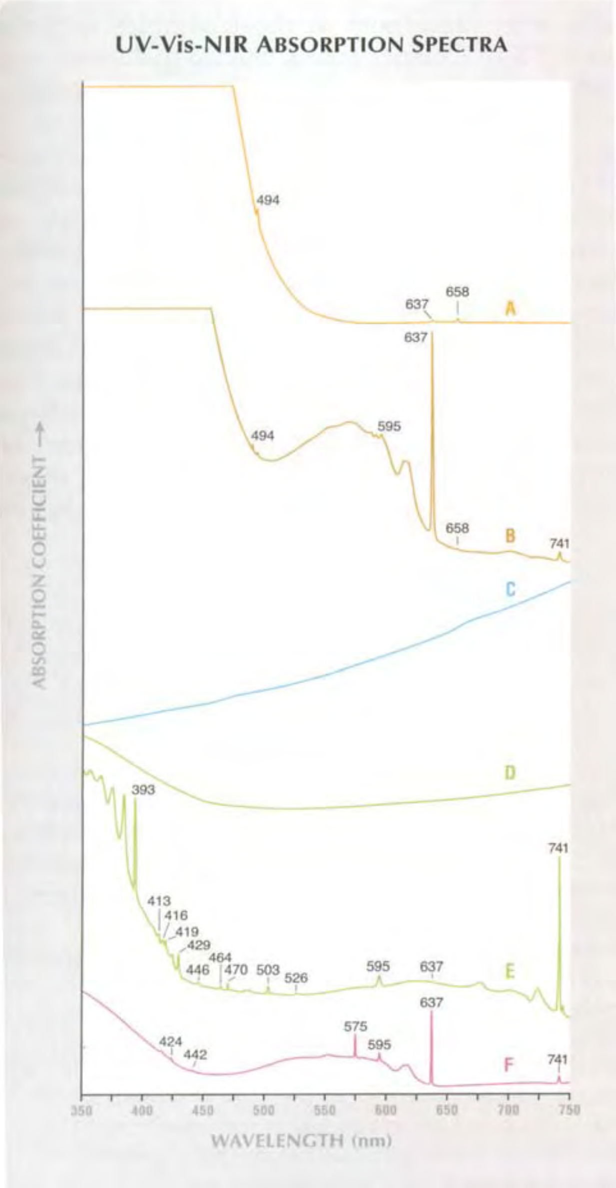


Figure 10. The visible absorption spectra of representative samples of the colored synthetic diamonds examined during this study provide information on their causes of color and, in some instances, evidence of post-growth treatments (again, see table 1). Each spectrum has been equally scaled along the horizontal and vertical axes. (A) The brownish orangy yellow color of this 0.28 ct faceted sample results from the broad region of absorption beginning below about 500 nm. Superimposed on this are weak sharp bands at 494, 637, and 658 nm. The 494 and 658 nm bands are due to the presence of Ni impurities, and the 637 nm band is due to the NV^- (nitrogen-vacancy) optical center. (B) The spectrum of the 0.22 ct faceted yellow-brown sample provides evidence that it was treated by irradiation and heating (i.e., a strong 637 nm peak, absorption between 500 and 620 nm, and weaker features at 595 and 741 nm). The 494 and 658 nm bands are again due to the presence of Ni impurities. (C) Gradually increasing absorption toward the IR region is responsible for the color of the blue synthetic diamonds, as shown for a 0.29 ct faceted sample. (D) Increasing absorption toward both the UV and IR regions, and weaker absorption between 500 and 600 nm, produces the yellowish green color of this 0.16 ct faceted sample. (E) In contrast to spectrum D, this spectrum for a 0.34 ct faceted yellowish green synthetic diamond exhibits numerous strong (393 and 741 nm) and weak absorption bands that are attributed to irradiation. (F) This 1.08 ct purplish pink crystal also reveals a number of absorption features (mainly at 575, 595, 637, and 741 nm) that provide evidence of irradiation and heat treatment.

blue and colorless, while the latter had sectors that were blue and yellow. Such blue-yellow mixed-type synthetic diamonds have been described before (Shigley et al., 1992; Rooney et al., 1993; Hainschwang and Katrusha, 2003). Figure 14 illustrates how these mixed type IIb+Ib synthetic diamonds can exhibit both blue and yellow colors when viewed face up (they also may display either a grayish or greenish overall appearance depending on the amount of nitrogen impurity present). The one treated greenish blue sample was type Ib with so little nitrogen that it could almost be considered a type IIa diamond (or a nominal type IIa; see figure 15).

Features Seen with Magnification. All 28 faceted samples displayed some form of blue-colorless or blue-yellow color zoning (figures 16 and 17), with varying degrees of visibility, due to differences in boron (or boron and nitrogen) content between growth sectors. Only the greenish blue crystal did not show color zoning.

The clarity of these faceted samples corresponded to grades ranging from VVS to I (VVS—4 samples, VS—3, SI—9, and I—12). One or more metallic inclusions were prominent in those samples with the lower (VS to I) clarity grades, but no inclusions were readily visible in those with the better (VVS) grades.

Luminescence. When exposed to long-wave UV radiation, 17 of the faceted samples were inert, and the remainder fluoresced a very weak or weak orange or orangy red. With short-wave UV radiation, they fluoresced in various colors—11 were green, 13 were yellow-green to green-yellow, three were orangy yellow or yellowish orange, and one was orangy red. Most samples fluoresced stronger to short-wave than long-wave UV radiation. The greenish blue crystal was inert to both wavelengths. Those that fluoresced did so with weak to moderate intensities, and the majority showed cross, square, or line patterns. Except for

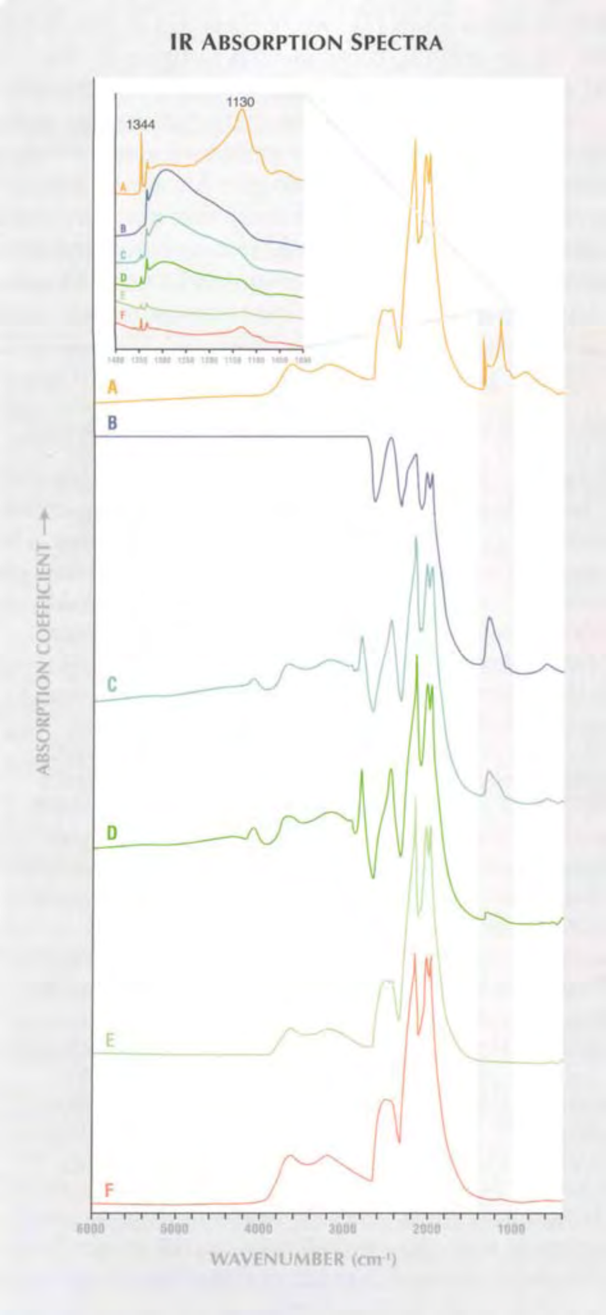


Figure 11. These mid-infrared spectra are representative of the synthetic diamond samples examined. Each spectrum has been equally scaled along the horizontal and vertical axes. For comparison, the so-called "nitrogen region" (1400–1000 cm^{-1}) of each spectrum has been expanded vertically to show weak absorption features. (A) This type Ib, 0.28 ct, faceted brownish orangy yellow sample contains a moderate amount of nitrogen impurities. (B) The type IIb blue synthetic diamonds have a small amount of type Ib nitrogen, as evidenced by the absorption at 1344 cm^{-1} in the inset for this 0.27 ct faceted example. Below 3000 cm^{-1}, the absorption exceeds the scale of the graph. (C) This 0.17 ct faceted greenish blue sample is a mixture of type IIb plus type Ib. (D) This 0.16 ct faceted green sample is also a mixture of type IIb plus a small contribution of Ib. (E) The type Ib features (see inset spectrum) in this 0.34 ct faceted green synthetic diamond are so weak that it is nearly type IIa. (F) This type Ib, 0.37 ct, faceted orangy pink sample would also be considered as nominally type IIa.

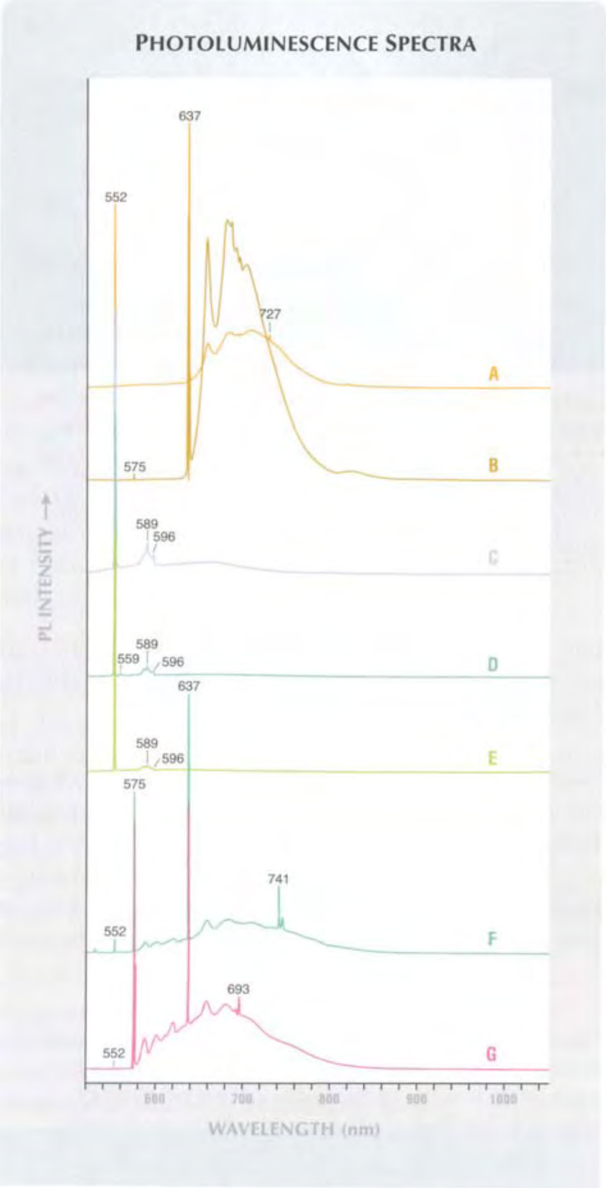


Figure 12. Important information was also derived from the photoluminescence spectra of the synthetic diamonds examined during this study (again, see table 2), as illustrated for these representative samples. (A) This brownish orangy yellow sample has features due to the NV⁻ center (637 nm) and nickel impurities (727 nm). (B) This irradiated and heated yellow-brown sample shows features due to the NV⁰ (575 nm) and NV⁻ centers (637 nm). (C) The features at 552, 589, and 596 nm in this grayish blue sample are intrinsic to diamond. (D) This grayish greenish blue sample exhibits the same features as in C, along with a weak feature at 559 nm of uncertain origin. (E). The spectrum of this yellowish green sample is similar to C. (F) The 575, 637, and 741 nm bands are evidence of irradiation and heating of this bluish green sample. (G) This pink sample displays the "treatment" bands at 575 and 637 nm, as well as the 693 band due to nickel impurities.

the one sample that fluoresced orangy red, the remainder emitted greenish or yellowish phosphorescence that persisted for 60 seconds or more.

Figure 18 shows the blue cathodoluminescence with the cuboctahedral pattern typical of synthetic diamonds that was seen in the sample tested.

Visible Spectra. None of the 29 samples displayed any sharp absorption bands when viewed with the prism spectroscope.

Electrical Conductivity. All 27 of the faceted samples tested with a gemological conductometer displayed weak electrical conductivity. Each of these 27 samples also displayed visible electroluminescence (in the form of momentary flashes of white or bluish white light; i.e., "sparks") when touched by the conductometer probe. Visible electroluminescence may be seen in both natural and synthetic blue diamonds, but is more common in the synthetics because they usually contain significantly more boron.

Advanced Instrumentation. The visible absorption spectrum for a type IIb (plus weak Ib) sample, as illustrated in figure 10C, shows increasing absorption toward the red end of the spectrum. The mid-infrared spectra for two samples—the first with a higher boron content than the second—can be seen in spectra B and C of figure 11.

Photoluminescence spectra C (a grayish blue

Figure 13. Different boron contents are responsible for the variation in color saturation in the blue lab-grown diamonds (here, 0.22 and 0.27 ct). Photo by Maha Tannous.

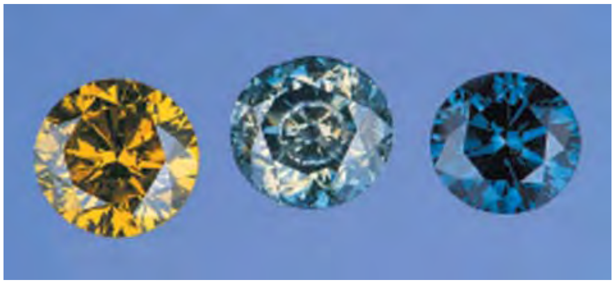


Figure 14. The 0.35 ct yellow synthetic diamond (left) is type Ib, and the 0.27 ct blue sample (right) is type IIb. The 0.36 ct sample in the center represents a mixed type Ib + IIb. Yellow and blue can clearly be seen in the face-up orientation—this combination of growth sectors can give rise to a faceted sample that would be described as green or grayish green. Photo by Maha Tannous.

sample) and D (grayish greenish blue) of figure 12 both display bands that are intrinsic to diamond (again, see table 2).

EDXRF analysis of three samples revealed the presence of Fe and Co, or just Fe, from the metallic flux used for growth. Nickel was not detected by this method despite the presence of PL spectral bands attributed to this impurity.

Green. *Visual Appearance.* This category of 16 synthetic diamonds can also be divided into two groups. The first is a mixed type IIb+Ib (8 out of the 14 samples for which IR spectra were recorded) that, in many ways, is similar to the blue-yellow samples described above. Here, however, the green overall color due to the blue and yellow growth sectors is more apparent, so that the samples would be described as being predominantly green in the GIA color grading system.

The second group is represented by very weak type Ib (or nominal type IIa) lab-grown diamonds (6 out of the 14 samples) that owe their green color to treatment by irradiation. The two groups have different gemological properties.

Although there were only 16 samples that were basically green, they represented a broad range of hues: blue-green (1), bluish green (1), grayish bluish green (1), green (3), grayish green (3), greenish gray (1), yellowish green (2), grayish yellow-green (1), and yellow-green (3). As indicated by their visible spectra (see below), the color in all three of the yellow-green type Ib crystals (see, e.g., figure 19) had been produced by irradiation. Thus, these samples were different from the more blue-green samples that represent as-grown mixed type IIb+Ib synthetic diamonds.

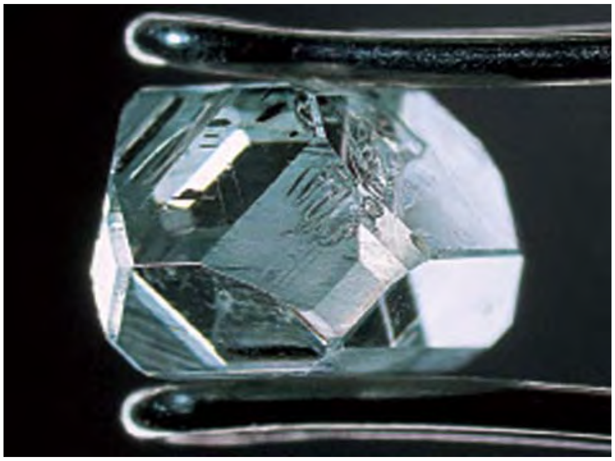


Figure 15. This 0.99 ct type Ib (nominal IIa) boron-free crystal exhibited a greenish blue color (due to radiation exposure) that was different from the blues of the other lab-grown diamonds examined during this study, which owe their coloration to the presence of boron. Photomicrograph by J. E. Shigley.

The colors of the 13 faceted samples (0.16–0.41 ct; see, e.g., figure 20) would be described as Light (1), Fancy Light (2), Fancy (9), and Fancy Dark (1).

Features Seen with Magnification. The three yellow-green crystals displayed typical cuboctahedral morphology but unusual striations (again, see figure 19). Most of the 16 samples displayed some form of color zoning (with lighter and darker, or blue and yellow, growth sectors) that could be seen

Figure 16. Like nitrogen, boron becomes concentrated in some internal sectors and not in others during crystal growth, leading to these distinctive patterns of blue and colorless zones separated by sharp boundaries. Photomicrograph by J.E. Shigley; magnified 20×.

Figure 17. When viewed table-down immersed in water, the blue and colorless (samples on the left), or blue and yellow (right), zoning in cross- or square-shaped patterns is more readily apparent in these four laboratory-grown diamonds. Photomicrographs by J. E. Shigley; magnified 20×.

even in the lighter samples. The clarity of the 13 faceted samples varied from equivalent VS to I grades (VS—4 samples, SI—4, and I—5). Most of the samples corresponding to SI and I contained metallic inclusions. As shown in figure 21, some samples also displayed remnants of the original crystal surface that were located near the girdle area; such remnants could be useful for identification purposes because they can show striations or dendritic markings not seen on natural diamond crystals.

Luminescence. The samples in this category displayed a range of UV fluorescence reactions. Most of the irradiated type Ib samples exhibited very weak to weak orange to reddish orange fluorescence of similar intensities to both long- and short-wave UV radiation. However, the three yellow-green type Ib crystals fluoresced weak green to long-wave UV but were inert to short-wave UV. None of these irradiated type Ib samples exhibited fluorescence zoning patterns, nor any phosphorescence when the UV lamp was turned off.

In contrast, for the most part the mixed type IIb+Ib samples were inert to long-wave UV radiation (one fluoresced weak orange), but showed weak to moderate yellow-green or green-yellow fluorescence to short-wave UV (one fluoresced a moderate orangy yellow). All of these samples revealed some form of fluorescence zoning pattern (in the shape of a cross, square, or lines), and all displayed persistent yellow, yellow-green, or orange-yellow phosphorescence (60 seconds or more).

Figure 22 shows the blue cathodoluminescence—and the characteristic cuboctahedral pattern—of the green sample tested.

Electrical Conductivity. Six of the eight mixed-type IIb+Ib samples displayed weak electrical conductivity and visible electroluminescence. The other two were not conductive.

Figure 18. The cathodoluminescence of this 0.27 ct blue synthetic diamond reveals the distinctive arrangement of internal growth sectors. Photo by S. Muhlmeister and C. M. Breeding.

Figure 19. As determined by spectroscopy, the color of this 1.06 ct yellow-green crystal is due to irradiation and heat treatment. Also notable are the unusual curved striations that cover much of the surface. Photomicrograph by J. E. Shigley.

Figure 20. In comparison to the blue and yellow synthetic diamonds examined during this study, most of the green samples exhibited less saturated colors. Photo by Maha Tannous.

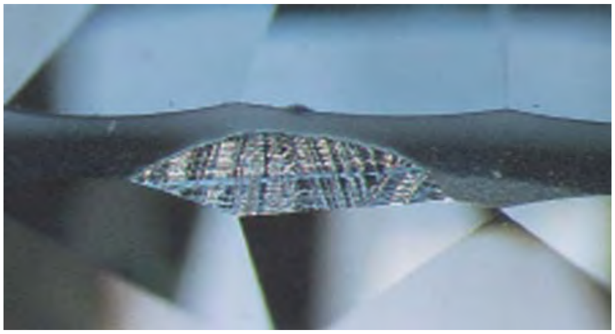


Figure 21. On occasion, small areas of the original crystal surface are retained on a faceted synthetic diamond. This 0.19 ct sample shows the striated crystal surface, which is distinctive of many laboratory-grown diamonds. Photomicrograph by J. E. Shigley; magnified 30×.

Visible Spectra. Of the 16 samples, only 4 (all yellowish green and yellow-green type Ib samples that had been irradiated) displayed sharp absorption bands in their spectra when viewed with the prism spectroscope. One displayed a sharp 595 nm band, and the three crystals each displayed a 494 nm band (again, see table 1).

Advanced Instrumentation. The visible absorption spectrum of a representative as-grown type IIb+Ib yellowish green sample (figure 10D) shows absorption toward both ends. In contrast, the spectrum of the irradiated type Ib yellowish green sample (figure 10E) is typical of that seen for an irradiated green diamond, with numerous sharp radiation-produced absorption bands (again, see table 1).

The mid-infrared spectrum of a mixed type IIb+Ib sample shows features due to both nitrogen and boron impurities (figure 11D). Figure 11E presents a similar spectrum for one of the irradiated, very weak type Ib samples, where there is an almost complete absence of nitrogen-related absorption features in the region below 1400 cm^{-1}. Thus, although the latter are type Ib synthetic diamonds, they are described as being "nominally type IIa" since their nitrogen content is so low.

The PL spectrum of the mixed type IIb + Ib diamond is dominated by intrinsic features (figure 12E), whereas that of the irradiated specimen displays several emission lines (figure 12F).

EDXRF analysis indicated the presence of Fe and Co in two of the samples tested (plus Mn, Ni, and

Figure 22. The cathodoluminescence of this 0.31 ct grayish green sample displays the distinctive arrangement of internal growth sectors identifying it as a lab-grown diamond. Photo by S. Muhlmeister and C. M. Breeding.

Figure 23. Among the "pink" samples examined during this study were those with orangy pink (0.18 ct), pink (0.21 ct), and pinkish purple (0.23 ct) hues. This is very similar to the range of hues encountered in natural pink diamonds. Photo by Maha Tannous.

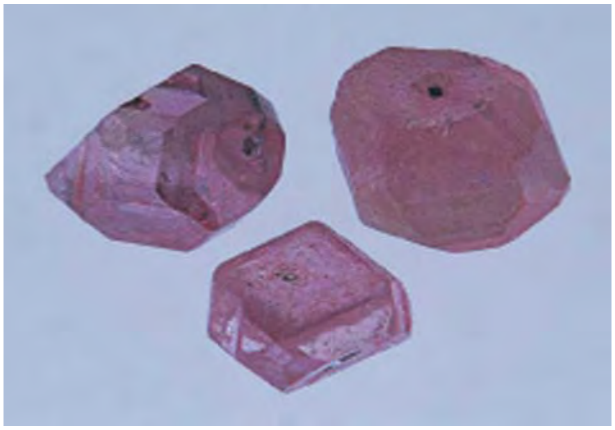


Figure 24. Note the cuboctahedral morphology of these representative samples of pink synthetic diamond crystals (0.44–0.87 ct). Photo by Maha Tannous.

Figure 25. This comparison of color zoning patterns in a 0.32 ct sample (left) and a 0.39 sample (right) illustrates how the pattern is less visible in samples with lower saturation (as on the left). Photomicrograph by J. E. Shigley; magnified 20×, water immersion.

Cu in one of these), but no metallic impurities were detected in the third sample.

Pink. *Visual Appearance.* As with the green synthetic diamonds mentioned above, the 45 pink samples represent very low-nitrogen type Ib material (nominally type IIa due to the very weak nitrogen-related absorption bands in the infrared spectra). When grown, type Ib synthetic diamonds are yellow; the pink color of these samples is due to post-growth irradiation and heat treatment (the same process used to produce treated pink natural diamonds—Collins, 1982; Kammerling et al., 1995). These pink samples are similar in many respects to the treated red synthetic diamonds described by Moses et al. (1993).

A range of hues were represented in this group (see, e.g., figure 23): orangy pink (16), brownish orangy pink (1), pink (15), purplish pink (12), and pinkish purple (1). The color grades of the 37 faceted samples would be described as Fancy (11 samples), Fancy Intense (18), Fancy Vivid (7), and Fancy Deep (1).

Features Seen with Magnification. The eight pink crystals we examined had a typical cuboctahedral morphology (figure 24). They were on average smaller than the yellow synthetic diamond crystals we examined (0.44–1.08, versus 0.63–1.74 ct), and their shape and surface features appeared more irregular.

The clarity of the 37 faceted samples (0.16–0.51 ct) varied from VVS to I on the GIA clarity-grading system (VVS—1 sample, VS—12, SI—7, and I—17). Again, these grades were based mainly on the position and visibility of metallic inclusions. All exhibited some pattern of color zoning related to their crystal shape, although this pattern was difficult to see in those samples that were less saturated (figure 25). This zoning consisted of purplish pink and orangy pink areas separated by sharp planar graining (figure 26). Metallic inclusions were present in almost all samples (figure 27).

Luminescence. All samples in this group exhibited moderate to strong orange or orangy red long-wave

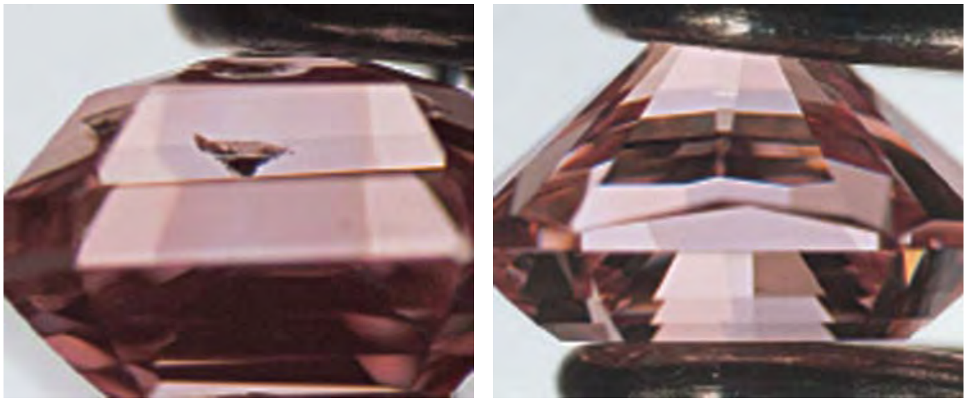


Figure 26. Shown here are two examples of color zoning seen in the pink synthetic diamonds (0.41 and 0.33 ct). The zoning appears as orangy pink and purplish pink areas separated by sharp boundaries (known as planar graining) that are often perpendicular to the table (left), but may occur at an angle to this facet (right). This color zoning is best seen by observing close to the girdle plane of the sample. Photomicrographs by J. E. Shigley.

Figure 27. The metallic inclusion in this 0.41 ct sample displays a brownish halo as the result of a tension fracture being created when the inclusion solidified. Photomicrograph by J. E. Shigley; magnified 40×.

UV fluorescence. When exposed to short-wave UV radiation, the samples fluoresced weak, moderate, or strong orange. Twenty-eight of the 45 samples had stronger long-wave than short-wave UV fluorescence, while the remainder appeared to fluoresce in similar intensities to both wavelengths. In most cases, these fluorescence reactions appeared to be evenly distributed, although cross-like or line patterns could be seen in a few. When the UV lamp was turned off, 7 of the 45 samples displayed a weak orange phosphorescence of limited duration (5–10 seconds); the remaining samples did not phosphoresce.

Figure 28. The cathodoluminescence of this 0.39 ct pink synthetic diamond reveals the growth-sector arrangement typically seen in synthetic diamonds. Photo by S. Muhlmeister and C. M. Breeding.

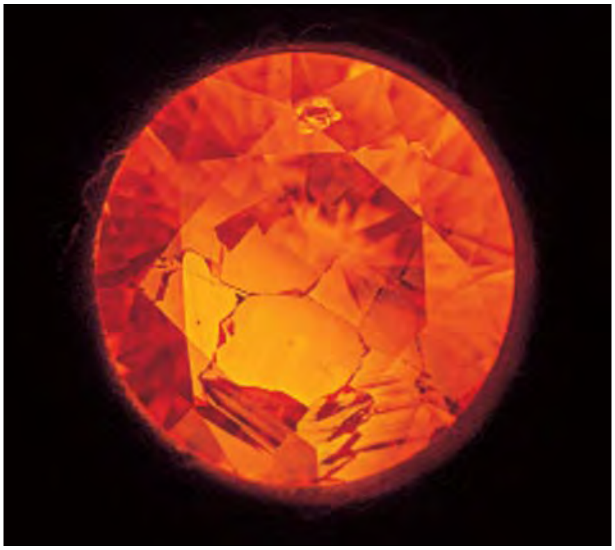


Figure 28 shows the orange cathodoluminescence pattern of the one pink sample tested.

Visible Spectra. When observed with the prism spectroscope, all but 2 of the 45 samples showed a sharp absorption line at 637 nm, and 19 displayed sharp bands at 595 nm.

Advanced Instrumentation. These pink synthetic diamonds displayed a number of sharp absorption bands in their visible spectra (see table 1 and figure 10F). These spectral features are very characteristic of yellow type Ib diamonds that have been irradiated and heated to create a pink-to-red color (Collins, 1982). The infrared spectra of this group (figure 11F) indicate that these samples contain little nitrogen, as evidenced by the very weak nitrogen-related absorption features below 1400 cm^{-1}. The PL spectrum in figure 12G shows several of the same features as the visible spectra, along with a peak at 693 nm due to nickel impurities.

When analyzed by EDXRF, Fe, Ni, and Co (and possibly Cu) were detected in three of four samples (no metals were detected in the fourth sample analyzed).

DISCUSSION AND IDENTIFICATION

As we have seen from the data presented above (and summarized in the *G&G* Data Depository at www.gia.edu/gemsandgemology), many of the characteristics of the new synthetic diamonds supplied by Chatham's Asian manufacturer do not differ appreciably from others that have been grown by this method (HPHT). Nevertheless, as is often the case with synthetic materials that are produced by different manufacturers, there are features present in some of these synthetic diamonds that are unlike those we typically see in other HPHT-grown products.

One of the most interesting observations is that the majority of the irradiated pink and green synthetic diamonds contained so little nitrogen that one would expect them to be very pale in their "as grown" state, although we are aware (based on our experience with natural diamonds) that low concentrations of isolated nitrogen can result in strong colors. As stated above, many were close to being classified as type IIa. This is important because to date low-nitrogen-content synthetic diamonds have been difficult to manufacture, and the only ones we had seen previously were those created in the manufacturer's attempt to grow near-colorless material. Unfortunately, we do not know what the original appearance of the Chatham pink and green samples was before they were irradiated. It may well be that the low nitrogen concentration is necessary to produce the lighter pink colors. More information is needed before we can assess the significance of this development.

Another interesting fact about this new product is the availability of as-grown greens, which had seldom been seen before in synthetic diamonds. The curious combination of blue type IIb and yellow type Ib in the same crystal, which produces a green face-up color in a finished stone, may be a consideration for some who prefer not to have irradiated material.

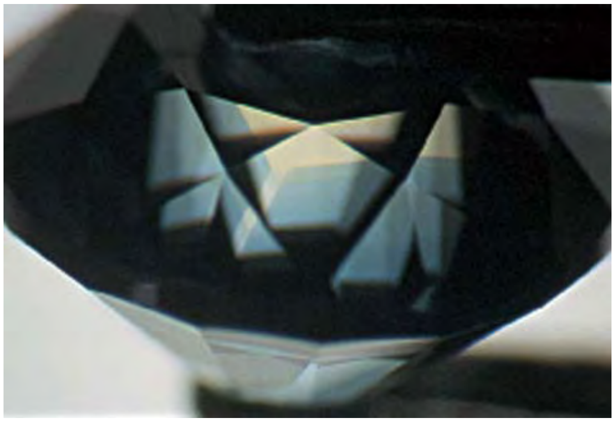
Also important, as noted above, is the fact that the colors of a great many of these synthetic diamonds more closely resemble those commonly seen in natural colored diamonds, particularly in the blues, pinks, and greens. For the most part, the colors of other synthetic diamonds have been "better than nature," as is typical of synthetic gem materials, whether they are diamonds, rubies, or emeralds. The danger here is the possibility that a gemologist might let his or her guard down when it comes to identifying one of these lab-grown diamonds by virtue of the fact that they do not "look" lab grown. While this may seem like a basic issue, it is nonetheless a very real trap that can be easy to fall into.

As for the identification of these laboratory-created diamonds, the indications and features of those we examined are fairly consistent with those produced by other HPHT manufacturers in the past. Many still contain metallic flux inclusions (which, if present in sufficient quantity, would make the host gem magnetic), still show patterned color zoning and ultraviolet fluorescence related to their cuboctahedral morphology, and still display characteristic features using advanced instrumentation, such as nickel-related absorption and photoluminescence lines and the presence of Ni, Co, or Fe in their chemistry. (The occurrence of nickel is extremely rare in natural diamonds [see Chalain, 2003].) These samples, however, showed some additional features worth noting.

The type IIb or mixed type IIb+Ib blue-to-green samples all showed the color zoning that is distinctive of synthetic diamonds (figure 29). In addition, the presence of blue and yellow color zoning in the same item does not occur in natural diamonds. These features are diagnostic and make identification of these synthetics fairly straightforward. It should be noted that, unlike other colors, the fact that the short-wave UV fluorescence is commonly stronger than the long-wave UV is not particularly useful with blues. While natural type IIb blues often do not fluoresce at all, it is common for them to show this property when they do (King et al., 1998).

There is little information published about synthetic pink diamonds, primarily because so few have been seen until now. Most irradiated type Ib synthetic diamonds we examined previously were red. Identification of the pinks should first revolve around establishing the fact that they are irradiated to this color, which is a rare occurrence even in natural diamonds. It is well documented that most natural pink diamonds owe their color to plastic deformation of their crystal lattice (see, e.g.,. Chapman and Humble, 1991; Collins, 1982, 2001), which gives rise to distinctive properties such as strong strain visible in polarized light (figure 30) and related strong graining and color zoning (figure 31). These features are not present in the pink Chatham synthetic diamonds, which should immediately alert the gemologist that a more critical examination is warranted (figure 32). Of course, as mentioned earlier, orange fluorescence to long- and short-wave ultraviolet radi-

Figure 29. All of the type IIb and mixed type IIb + Ib samples we examined for this study displayed color zoning following the cubo-octahedral habit of the crystals, which is very characteristic of synthetic diamonds. This sample shows blue and yellow color zoning following a distinctly unnatural pattern. While most of the samples in this study showed some kind of unnatural zoning, the patterns in these types were by far the most pronounced. Photomicrograph by Shane F. McClure; magnified 28×.



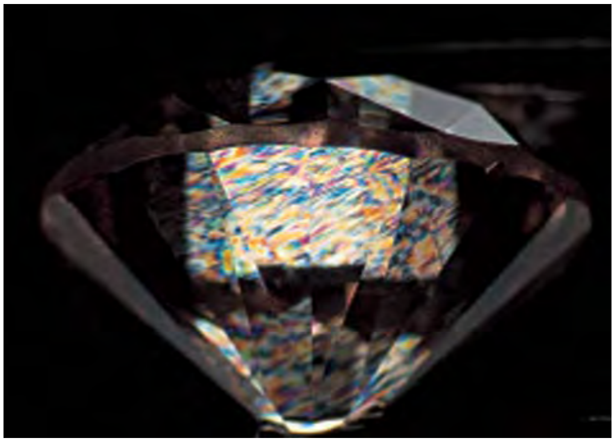


Figure 30. The strong strain usually present in natural pink diamonds (seen here in polarized light) was not observed in any of the Chatham synthetic pink diamonds examined. Photomicrograph by Shane F. McClure, magnified 16×.

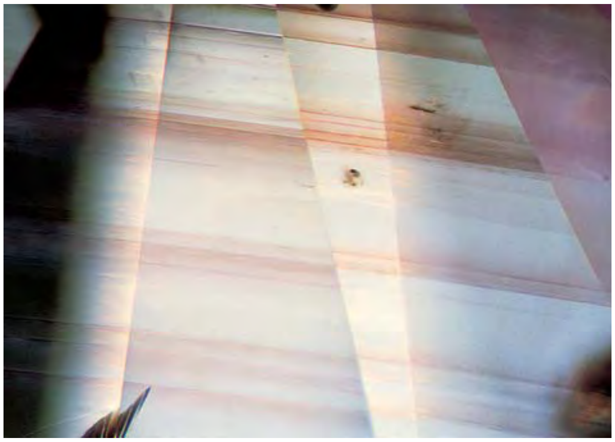


Figure 31. Color zoning in natural pink diamonds typically follows the strain patterns in the form of uneven parallel bands, as shown here, which is not seen in pink laboratory-grown diamonds. Photomicrograph by John I. Koivula; magnified 15×.

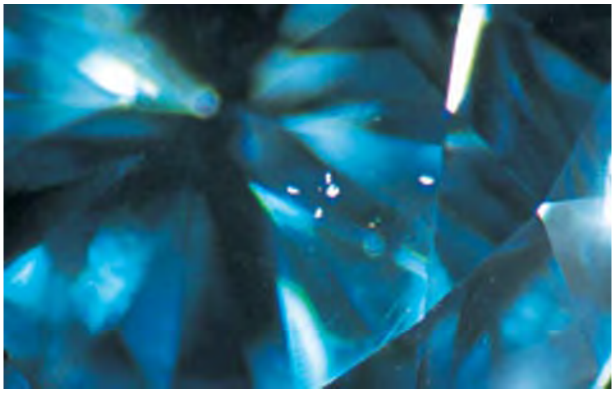
ation and the presence of 595, 637, as well as (possibly) 575 nm lines in a prism spectroscope are indications that a pink diamond is an irradiated type Ib. However, both natural and synthetic type Ib diamonds can be irradiated and heated to produce a pink color. Whether it is natural or lab grown must be determined by inclusions, color zoning, or analysis with advanced techniques. It should be noted that some rare natural type IIa pink diamonds may also fluoresce orange (Moses et al., 1993).

The most significant aspect of these new synthetics from the point of view of identification reflects a continuing trend with synthetic diamonds in general (Shigley et al., 2002). As might be expected, improvements in the growth technique have led to steady improvements in the product, so that they tend to be cleaner overall (figure 33). The fluorescence patterns are also diminishing in strength and size, such that some of the samples in this study did not fluoresce at all. This means that the gemologist must be extremely careful when examining suspect stones.

None of the samples in this study were completely free of inclusions. Even those that were of VVS quality contained flux in the form of sparse clouds (figure 34). With practice and experience, these clouds can be recognized by their appearance, but it is not an easy separation. Suffice it to say that a diamond that contains only a sparse cloud as a clarity feature should be examined carefully.

Figure 32. The color zoning seen in these pink synthetic diamonds consisted of distinct areas of purplish pink and orangy pink with sharp, well-defined borders. Photomicrograph by James Shigley; magnified 15×.

Figure 33. The size and frequency of metallic inclusions in modern synthetic diamonds has been diminishing for some time. Often they are small and difficult to recognize as metallic flux. Photomicrograph by Shane F. McClure; magnified 40×.



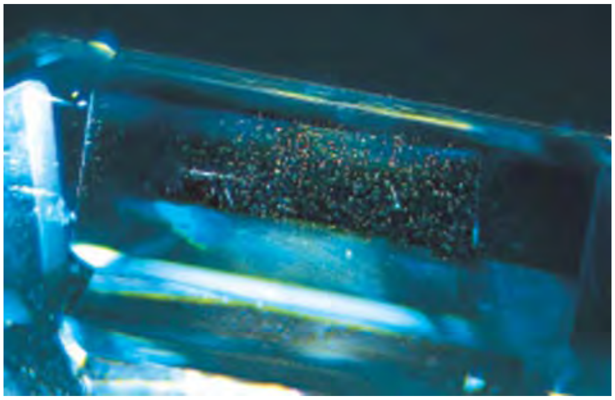


Figure 34. Sometimes the only inclusions present in these samples were sparse clouds of pinpoints. With some experience, it is possible, though difficult, to recognize the difference in appearance between these clouds and those found in natural diamonds. Photomicrograph by Shane F. McClure; magnified 37×.

It is important to point out, however, that all of the samples we tested for this report could be identified by gemological means. In some cases, careful examination is required, but the combination of inclusions, graining, fluorescence, and color zoning would conclusively identify all these samples as synthetic.

The De Beers Diamond Trading Company's DiamondView instrument is also very useful to detect characteristic surface patterns in higher-energy UV fluorescence. This instrument is now available to the trade, but it is considerably more expensive than standard gemological instruments, and training is required to interpret the results correctly.

CONCLUSIONS

A new group of laboratory-grown diamonds being marketed by Chatham Created Gems—under the name "Chatham Created Diamonds"—represents a wide range of hues and, in some cases, very natural-looking color saturations. The samples examined in this study exhibited many visual features that would aid in their identification, and testing with advanced instrumentation would provide additional spectral and chemical evidence of their laboratory origin. The increasing availability of synthetic diamonds such as the ones examined here reinforces the need for gemologists to know the means of their identification.

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THE 3543 CM^{-1} INFRARED ABSORPTION BAND IN NATURAL AND SYNTHETIC AMETHYST AND ITS VALUE IN IDENTIFICATION

Vladimir S. Balitsky, Denis V. Balitsky, Galina V. Bondarenko, and Olga V. Balitskaya

The proper use and limitations of IR spectroscopy for identifying natural versus synthetic amethyst of various types have been investigated, focusing on the region 3800–3000 cm^{-1}. The presence of absorption bands at approximately 3680, 3664, and 3630 cm^{-1} unambiguously proves artificial origin, but only for samples grown in near-neutral NH_4F solutions. Conversely, there are no unambiguous diagnostic features in the IR spectra of the more commercially significant synthetic amethyst grown in alkaline K_2CO_3 solutions. Nevertheless, previous investigators have found potential diagnostic value in absorption bands at approximately 3595 and 3543 cm^{-1}. Although the 3595 cm^{-1} band is not found in the spectra of synthetic amethyst, it also is frequently absent from those of natural amethyst. The 3543 cm^{-1} band is found in the vast majority of synthetic amethysts grown in alkaline solutions, but this band also is sometimes present in natural amethyst—so it provides only tentative evidence of synthetic origin. Moreover, the 3543 cm^{-1} band is absent from some varieties of synthetic amethyst. The unambiguous identification of natural versus synthetic amethyst therefore must be based on a combined examination of the IR spectra, internal growth structures (including twinning), and inclusions.

Recently, we have studied in detail the relationship between conditions of formation and the absorption spectra of natural and synthetic amethyst in the 3800–3000 cm^{-1} region to determine whether infrared spectroscopy can be used to identify synthetic origin (see Balitsky et al., 2003, 2004). Previously it was shown that both natural amethyst and synthetic amethyst grown in alkaline solutions share similar spectral features in this region (Balakirev et al., 1979; Zecchini, 1979; Balitsky, 1980; Lind and Schmetzer, 1980; Zecchini and Smaali, 1999). Two absorption bands are almost always present in both types—an intense feature at 3585 cm^{-1} and a relatively weak one at 3612 cm^{-1}—due to the presence of OH^- defects in the quartz structure (Rossman, 1988). Also characteristic is a broad band with a maximum near 3400 cm^{-1}, which often overlaps the absorption bands mentioned above, that is related to the presence of molecular water (Kats, 1962; Rossman, 1988). In addition, the IR spectra of some natural amethyst exhibits an absorption band at 3595 cm^{-1} that is never found in the spectra of synthetic amethyst (Zecchini, 1999). There are also indications that an absorption band near 3543 cm^{-1} occurs rarely in the IR spectra of natural amethyst, but is present in the overwhelming majority of synthetic amethysts (Fritsch and Koivula, 1987; Fritsch and Rossman, 1990; Zecchini and Smaali, 1999).

Thus, the 3543 cm^{-1} band has become established as one of the basic features indicative of synthetic origin in amethyst. However, it has been shown recently that this band commonly occurs in

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See end of article for About the Authors and Acknowledgments.

GEMS & GEMOLOGY, Vol. 40, No. 2, pp. 146–161.

Figure 1. Large quantities of synthetic amethyst are present in the gem trade, but challenges remain in separating this material from its natural counterpart. In some cases, infrared spectroscopy may provide evidence of natural or synthetic origin. The synthetic amethyst in this suite of jewelry is set with diamonds (and opal in the ring); the oval checkerboard cut in the pendant weighs 4.91 ct, and the loose samples are 1.94, 1.18, and 0.73 ct (GIA Collection nos. 20662, 20664, and 20665, respectively). Jewelry courtesy of Gems of La Costa, Carlsbad, California; photo by Maha Tannous.

the IR spectra of natural amethyst from the Caxarai mine in Brazil (Kitawaki, 2002). According to our own data, this band also is present in some amethyst from other localities.

These factors have created uncertainty with respect to the usefulness of IR spectroscopy in general, and the 3543 cm^{-1} band in particular, for identifying the natural or synthetic origin of amethyst. Given the quantity of synthetic amethyst in the jewelry market (figure 1), we performed the present study to investigate the characteristics of the 3543 cm^{-1} band in various growth sectors of synthetic amethyst manufactured under different conditions, as well as the effects of growth rate, crystallographic orientation, gamma irradiation, and annealing on this band.

THE MORPHOLOGY AND INTERNAL GROWTH STRUCTURE OF SYNTHETIC AMETHYST

To provide a better understanding of the results of this investigation, we will first consider some features of the morphology and internal structure of synthetic amethyst crystals grown on seed plates of various orientations, and compare them to those of natural quartz (figure 2). Crystals of natural quartz commonly show faces of the hexagonal prism *m* $\{10\bar{1}0\}$, positive rhombohedron *r* $\{10\bar{1}1\}$, and negative rhombohedron *z* $\{01\bar{1}1\}$ (figure 2A). In addition, faces of the trigonal trapezohedron *x* $\{51\bar{6}1\}$ and trigonal dipyramid +*s* $\{11\bar{2}1\}$ may be present. In general, the particular faces present on synthetic amethyst crystals depend on the orientation and size of the seed plate, as well as on the growth rate and duration. As a rule, the *m*, *r*, and sometimes *z* faces are common for synthetic amethyst grown in alkaline solutions on the seeds cut parallel to *z*, *r*, and the basal pinacoid *c* {0001} (figure 2B). However, the *m*, *r*, *z*, +*s*, positive trigonal prism +*a* $\{11\bar{2}0\}$, and negative trigonal prism –*a* $\{2\bar{1}\bar{1}0\}$ faces are typical for synthetic amethyst grown in NH_4F solutions on seeds cut parallel to *c* and *s* faces (figure 2C). The trigonal prism faces are found between those of the hexagonal prism, perpendicular to the X-axis. These faces are rarely present on natural quartz crystals (Dana et al., 1962), but they are commonly found on synthetic quartz (including crystals grown in NH_4F solutions on seeds cut parallel to *c* and *s* with ZY orientation).

The growth of synthetic amethyst in alkaline solutions takes place mainly on seed plates cut parallel to *z* and, very rarely, on seeds cut parallel to *r* (Balakirev et al., 1979; Balitsky, 1980; Balitsky and Lisitsina, 1981). Such crystals usually have an elongate tabular form (figure 3A). When the *z*-seed is used, the crystals are dominated by *z* and *m* faces, and also show smaller *r* faces. The *z* growth sectors are of primary importance in such crystals; only rarely do they contain significant *r* sectors, and *m* growth sectors are absent (figure 3B). These crystals sometimes contain spindle-shaped Dauphiné *r*-twins within the *z* sectors (see, e.g., the plate at the bottom of figure 3B). The same morphology and growth structure have been seen in Japanese and Chinese synthetic amethyst grown under equivalent conditions (figure 4).

When the *r*-seed is used, the crystals show *r* and *m* faces (figure 5), and the *z* faces (and sectors) are typically absent. The *r* sectors almost always contain polysynthetic Brazil twins (see figure 5, inset).

Very rarely, synthetic amethyst crystals are grown on seeds cut parallel to *c* or on seeds with an unconventional orientation. These crystals are characterized by morphological and color-distribution characteristics that differ from those described above. For example, crystals grown on seeds cut parallel to *c* may have a tabular shape with well-developed *m*, *r*, and *z* faces (figure 6). Such crystals typically consist of bicolored synthetic amethyst-citrine, with the amethyst portion formed by both *z* and *r* sectors. When the seed plates used are nearly cubic in shape, the grown crystals acquire a prismatic habit with an even distribution of *r*, or *r* and *z* sectors (figure 7). These crystals may yield faceted synthetic amethyst of high quality (figure 8).

The growth of synthetic amethyst in near-neutral NH_4F solutions is done on seed plates cut parallel to *c* or *s* (Balitsky, 1980; Balitsky et al., 2000). The crystals are elongated on the Y- or X-axis, and their particular habit and internal structure are defined by the orientation of the seed plates and the growth rates of the main faces (i.e., *c*, +*s*, and +*a*; figures 9 and 10). In contrast to crystals grown in alkaline solutions, the *z* and *r* sectors are insignificant, and there are practically no *m* faces.

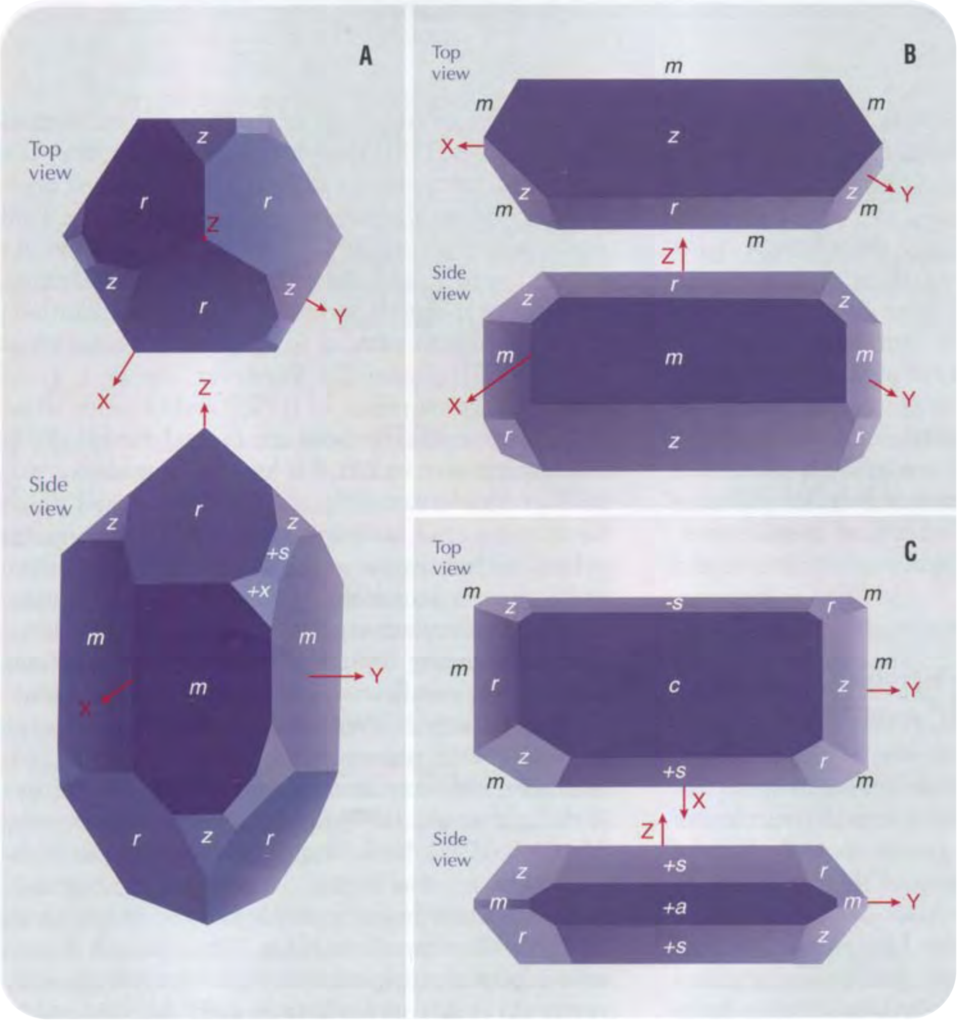


Figure 2. These drawings show the principal faces and crystallographic axes for natural quartz (A) and synthetic amethyst grown in alkaline K_2CO_3 *solution on a seed cut parallel to* z *(B) and in near-neutral* NH_4F *solution on a seed cut parallel to* c or s *(C). The notation of X, Y, and Z axes follows the convention used by crystal growth technologists for an orthogonal coordinate system (in contrast, most mineralogists refer to* a_1, a_2, a_3, *and c axes for the hexagonal crystal system). The labels* r *and* z *refer to faces of positive and negative rhombohedra, respectively, and the hexagonal prism is* m*. Some faces have positive or negative designations, depending on their location relative to the X and Y axes; this is the case for the trigonal trapezohedron* x*, the trigonal bipyramid* s*, and the trigonal prism* a*. Natural quartz crystals rarely show the trigonal prism* a*, and typically do not have* c *faces, which are oriented perpendicular to the Z (optic) axis.*

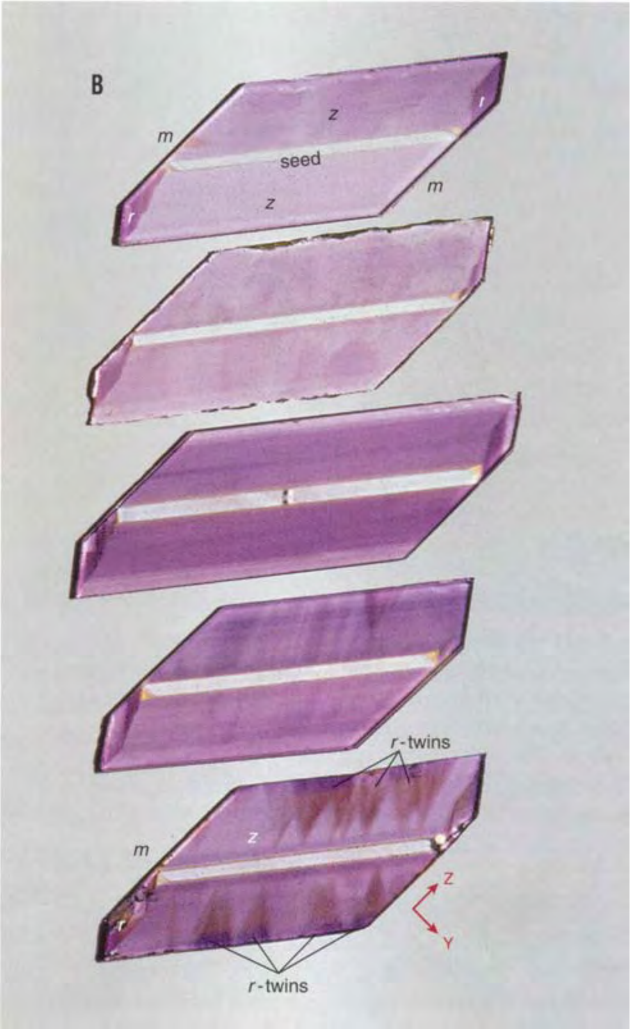


Figure 3. The synthetic amethyst crystals in image A show the typical morphology resulting from growth in alkaline K_2CO_3 solutions on seeds cut parallel to z*; the largest crystal is 23 cm long. Image B shows polished slices that were cut from such crystals (2 mm thick, sliced parallel to* a*). Note the colorless seed plate along the center of each slice. The crystals are formed mainly by* z *growth sectors, while* r *sectors occupy small portions. Faceted synthetic amethysts prepared from such crystals consist almost entirely of the* z *sector. However, Dauphiné twinning may augment the* r *sectors in such crystals (see bottom slice), so that faceted material may contain both* z *and* r *sectors. Photos by V. S. Balitsky (image A) and Maha Tannous (image B).*

MATERIALS AND METHODS

To ensure reliable results, we studied a total of 238 commercially available samples of hydrothermal synthetic amethyst that were grown by us under known and controlled conditions, at facilities in Aleksandrov (VNIISIMS) and Chernogolovka (IEM RAS). This included a core group of 120 crystals (0.3–12 kg each) and slices cut from them, most of which were grown in alkaline K_2CO_3 solutions at temperatures of 300–350°C and pressures of 1000–1500 atm in the presence of Fe^{3+} and an oxidizer (Balitsky and Lisitsina, 1981). The seed plates in these samples mainly were cut parallel to *z*, as is the case for most of the synthetic amethyst in the gem trade. However, eight additional crystals (0.2–0.4 kg each) were grown in these solutions on seeds cut parallel to *r*, and more than 50 crystals were grown on seeds cut parallel to *c* in conjunction with a

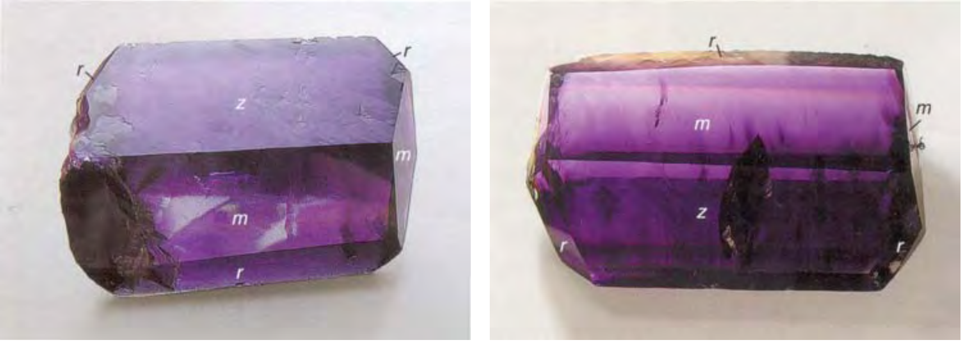


Figure 4. These crystals of synthetic amethyst were grown in the 1980s in China (left, 8.5 cm long) and Japan (right, 12 cm long). They show identical morphologic features to those of the Russian samples in figure 3, and were apparently produced under equivalent conditions. Photos by V. S. Balitsky.

Figure 5. Synthetic amethyst crystals grown in alkaline K_2CO_3 solutions on seed plates cut parallel to r *are dominated by* r *sectors. The 2-mm-thick plate on the bottom was sliced parallel to* a *from a similar crystal. The inset shows numerous polysynthetic Brazil twins in the* r *sector, which were brought out by etching the slab in a strong $NH_4F \cdot HF$ solution. Photos by V. S. Balitsky.*

Figure 6. These synthetic quartz crystals were grown in alkaline solutions on seeds cut parallel to c, *and show well-developed* m, r, *and* z *faces. The two crystals on top are shown before gamma irradiation and those on the bottom, after irradiation to create the amethyst coloration (the largest crystal measures 21 × 7 cm). The inset shows a slice through the upper portion of a synthetic ametrine crystal (2 mm thick, cut parallel to* a*), which consists of the* z *and* r *sectors. Synthetic amethyst faceted from such material will include both of these sectors, and therefore will show varying behavior of the 3543 cm^{-1} absorption band. Photos by Maha Tannous and D. V. Balitsky (inset).*

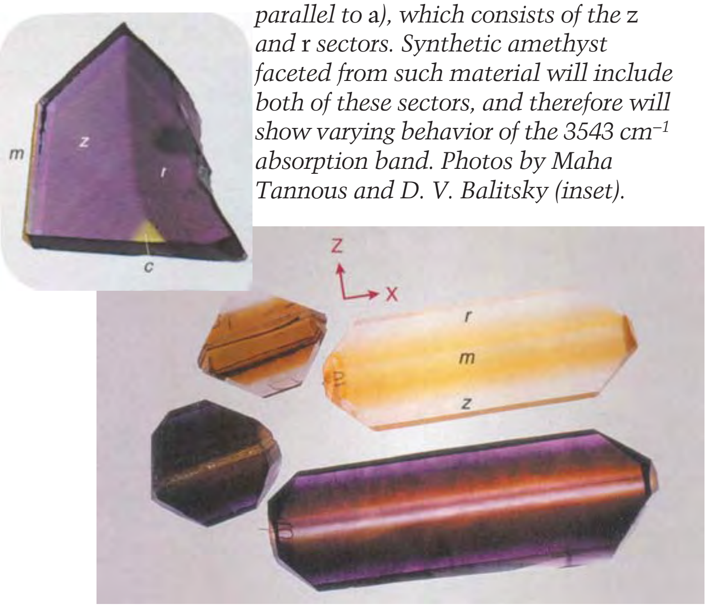


Figure 7. Prismatic crystals of synthetic amethyst are grown in alkaline solutions on seeds that are nearly cubic in shape. Such crystals have well-developed m, r, *and* z *faces, and their morphology closely resembles that of natural quartz crystals. The yellow color in the center of the prism correlates to* c *sectors, whereas the amethyst areas consist of rhombohedral sectors. Photos by V. S. Balitsky.*

metal mask containing holes of 10–50 mm in diameter. In the latter case, it was possible to grow prismatic crystals that were very similar to natural amethyst in terms of morphology and internal growth structure (Balitsky and Balitskaya, 1985; Balitsky et al., 1999).

Also used in this study were 30 synthetic amethyst crystals (0.2–1.2 kg each) that we grew in NH_4F solutions (Balitsky, 1980; Balitsky et al., 2000) at temperatures of 240–350°C and pressures of 80–300 atm, on seeds cut parallel to *c* and *s*. In addition, we studied more than 80 crystals of bicolored synthetic amethyst-citrine (0.3–0.7 kg each), grown in K_2CO_3 solutions under the same conditions that are used to produce commercial amethyst, but on seed plates cut parallel to *c*.

Figure 8. The ends of the prismatic crystals can be faceted to yield high-quality synthetic amethyst, which will consist of both z *and* r *sectors. The crystal termination measures 2.4 cm high. Photo by Maha Tannous.*

A few synthetic amethyst crystals from China (four samples) and Japan (three) also were studied.

To achieve the purple amethyst color, all of the crystals—which were colorless or pale yellow to yellow as grown—were subjected to ionizing radiation (5 megarads of gamma rays from a ^{60}Co source). Color stability was tested by heating 53 of the samples in the 310–700°C range for 1–4 hours.

IR spectra (in the 3800–3000 cm^{-1} region) were recorded on all of the samples, before and after irradiation; we used a Nicolet Avatar 320 FTIR spectrometer at room temperature, with an unpolarized beam. A total of 580 spectra of synthetic amethyst grown in alkaline solutions, and more than 50 spectra of samples grown in near-neutral solutions, were recorded. The samples were prepared as polished plates (2–10 mm thick) cut parallel to *x*, *c*, and, more rarely, to unoriented surfaces. Typically one slice was prepared from each crystal. However, several plates were cut from some crystals so that the IR spectra could be recorded in different orientations. In addition, one cube-shaped sample (10 mm on each side) of synthetic amethyst grown in an alkaline solution was prepared for spectroscopy with the edges oriented parallel to the X, Y, or Z axes.

The IR spectra of 52 samples of natural amethyst from the following localities also were recorded: Caxarai mine in Rondonia State (4 samples) and unspecified deposits (10) in Rio Grande do Sul State, Brazil; Anahí mine, Bolivia (9); Vatikha deposit, Middle Ural Mountains, Russia (14); Khasavarka deposit, Polar Urals, Russia (6); Angarskoye deposit, central drainage basin of Angara River, eastern Siberia, Russia (2); and the Rhodope Mountains, Bulgaria (7). The samples consisted of polished plates (2–4 mm thick) cut parallel to *c*, *m*, and *a*.

RESULTS AND DISCUSSION

Our study confirmed the findings of numerous investigators who have compared the IR spectra (including the 3543 cm^{-1} band) of natural amethyst to its synthetic counterpart grown in alkaline solutions (see, e.g.,

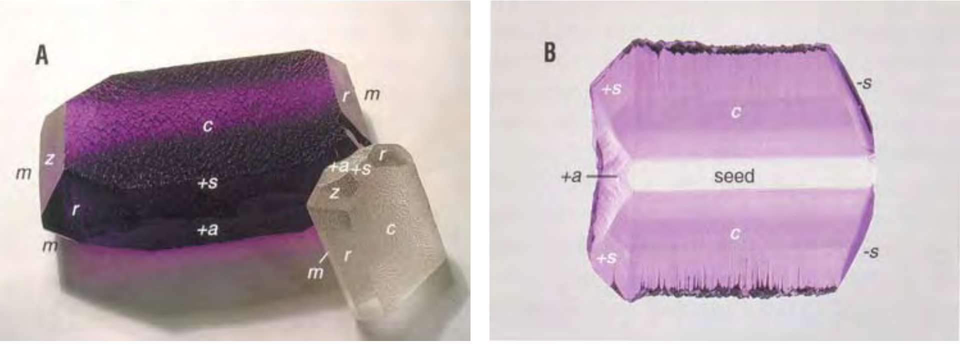


Figure 9. Image A shows synthetic quartz crystals (before and after irradiation) grown in NH$_4$F solutions on seeds cut parallel to c. *Image B shows the growth sectors in a 2.5-mm-thick plate that was sliced parallel to* m. *The crystals are dominated by* c *sectors, with subordinate* +a, +s, *and* –s *sectors. Photos by V. S. Balitsky.*

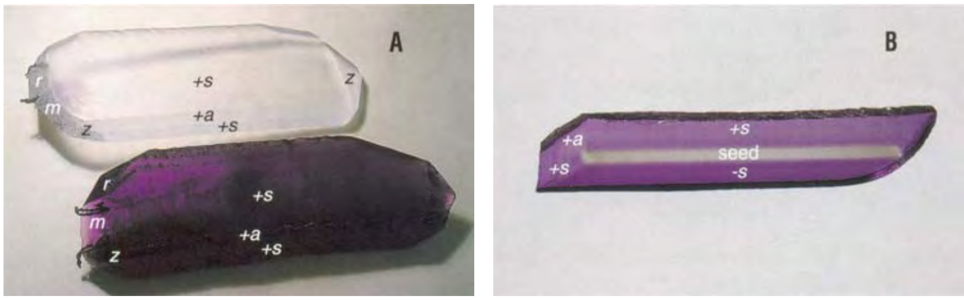


Figure 10. Image A shows synthetic quartz crystals (before and after irradiation) grown in NH$_4$F solutions on seeds cut parallel to s. *As depicted in image B of a 4-mm-thick plate that was sliced parallel to* m, *the dominant growth sectors are* +s *and* –s, *and* +a *is subordinate. Photos by V. S. Balitsky.*

Zecchini, 1979; Zecchini and Smaali, 1999; Balakirev et al., 1979; Balitsky and Lisitsina, 1981; Fritsch and Koivula, 1987; Fritsch and Rossman, 1990; Kitawaki, 2002). The 3543 cm^{-1} band is typically absent from the spectra of natural amethyst, except in samples from Brazil's Caxarai deposit (Kitawaki, 2002), as well as in some samples from other localities (e.g., Brazil's Rio Grande do Sul State; Bulgaria's Rhodope Mountains; and Russia's Khasavarka and Angarskoye deposits; see figure 11). Furthermore, the occurrence of this band varies according to different growth sectors and zones within a given crystal. Note, however, that we did not observe this peak in the spectra that we recorded of samples from the Vatikha deposit.

For comparison, the presence or absence of the 3543 cm^{-1} band in the IR spectra of synthetic quartz grown in alkaline solutions will be covered below. The unusual IR spectra shown by synthetic amethyst grown in near-neutral NH_4F solutions will be discussed at the end of this section.

Our observations suggest that the presence or absence of the 3543 cm^{-1} band reflects certain conditions of crystal growth common to both natural and synthetic amethyst. It appears that the most important factors are those related to the formation of amethyst and citrine color centers—that is, structural (amethyst) and nonstructural (citrine) impurities of Fe^{3+} (Balitsky and Balitskaya, 1985).

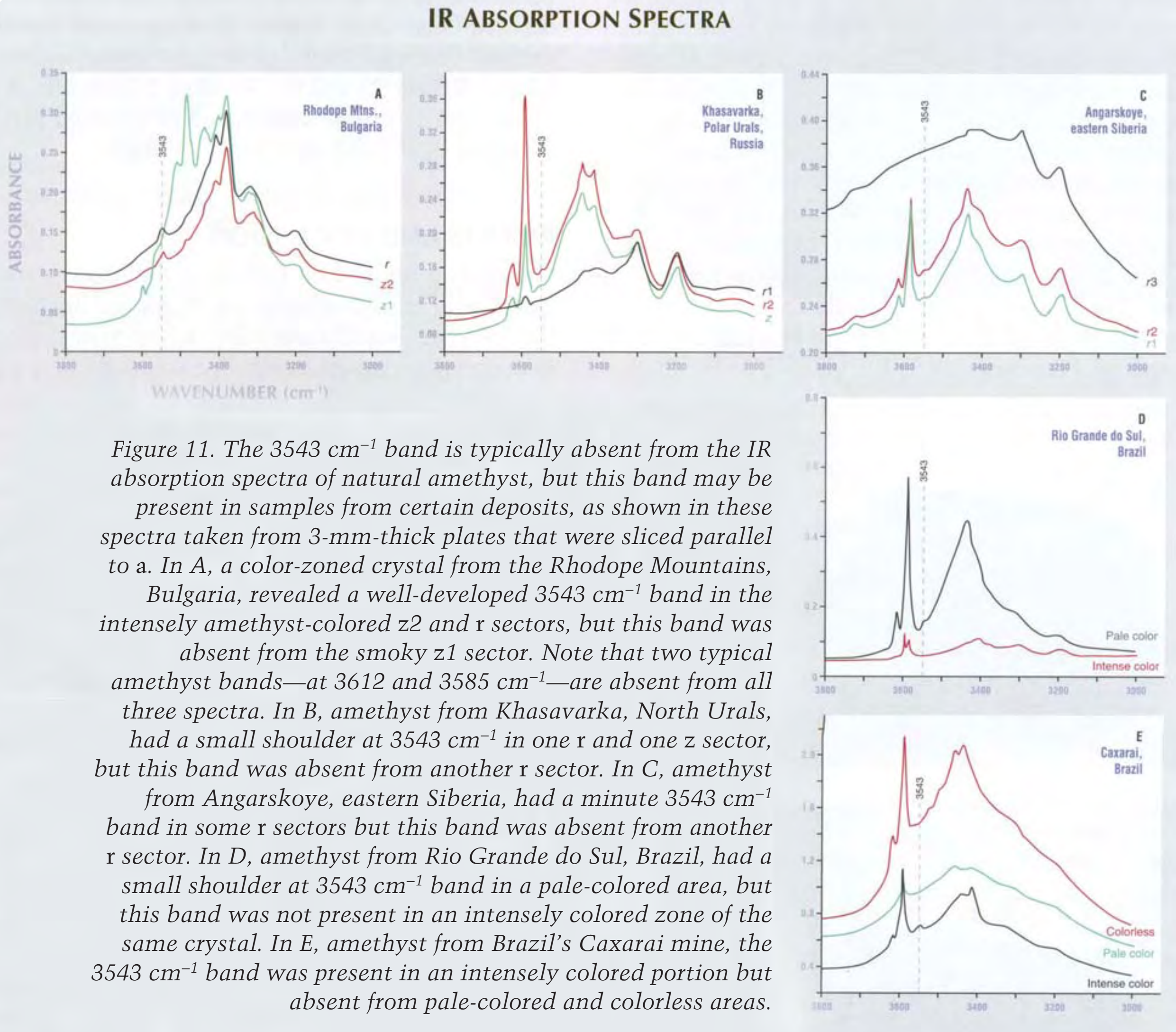


Figure 11. The 3543 cm^{-1} band is typically absent from the IR absorption spectra of natural amethyst, but this band may be present in samples from certain deposits, as shown in these spectra taken from 3-mm-thick plates that were sliced parallel to a. *In A, a color-zoned crystal from the Rhodope Mountains, Bulgaria, revealed a well-developed 3543 cm^{-1} band in the intensely amethyst-colored* z2 *and* r *sectors, but this band was absent from the smoky* z1 *sector. Note that two typical amethyst bands—at 3612 and 3585 cm^{-1}—are absent from all three spectra. In B, amethyst from Khasavarka, North Urals, had a small shoulder at 3543 cm^{-1} in one* r *and one* z *sector, but this band was absent from another* r *sector. In C, amethyst from Angarskoye, eastern Siberia, had a minute 3543 cm^{-1} band in some* r *sectors but this band was absent from another* r *sector. In D, amethyst from Rio Grande do Sul, Brazil, had a small shoulder at 3543 cm^{-1} band in a pale-colored area, but this band was not present in an intensely colored zone of the same crystal. In E, amethyst from Brazil's Caxarai mine, the 3543 cm^{-1} band was present in an intensely colored portion but absent from pale-colored and colorless areas.*

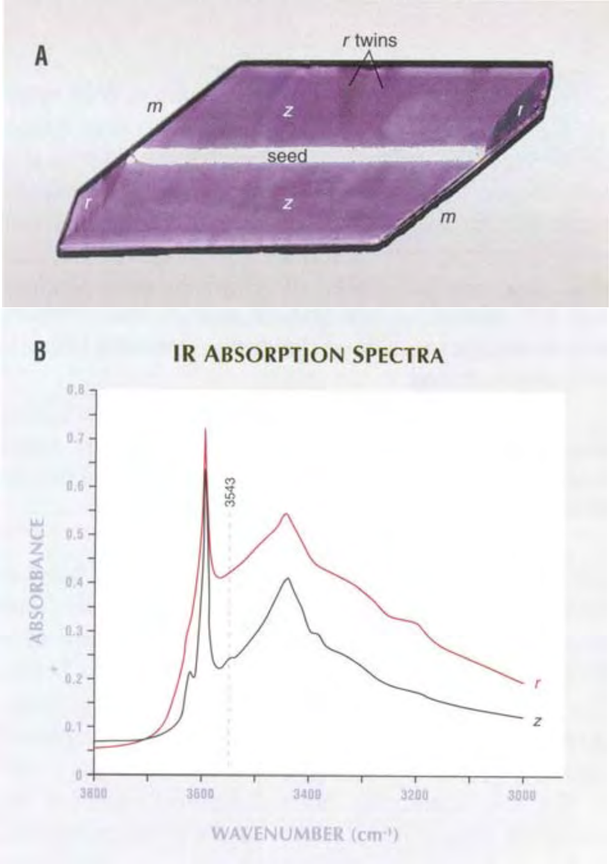


Figure 12. This synthetic amethyst plate in image A (3 mm thick and 7.3 cm long, sliced parallel to a*), grown in an alkaline solution on a seed plate cut parallel to* z*, provides an example of Condition 1. Before irradiation, the* z *sectors were colorless and the* r *sectors were pale yellow. Then, as shown in image A after irradiation, the* z *sectors became purplish violet and the* r *sectors turned very dark purple. The IR spectra in part B demonstrate that the 3543 cm*$^{-1}$ *band was present in the* z *sectors, but absent from the* r *sectors. Photo by D. V. Balitsky.*

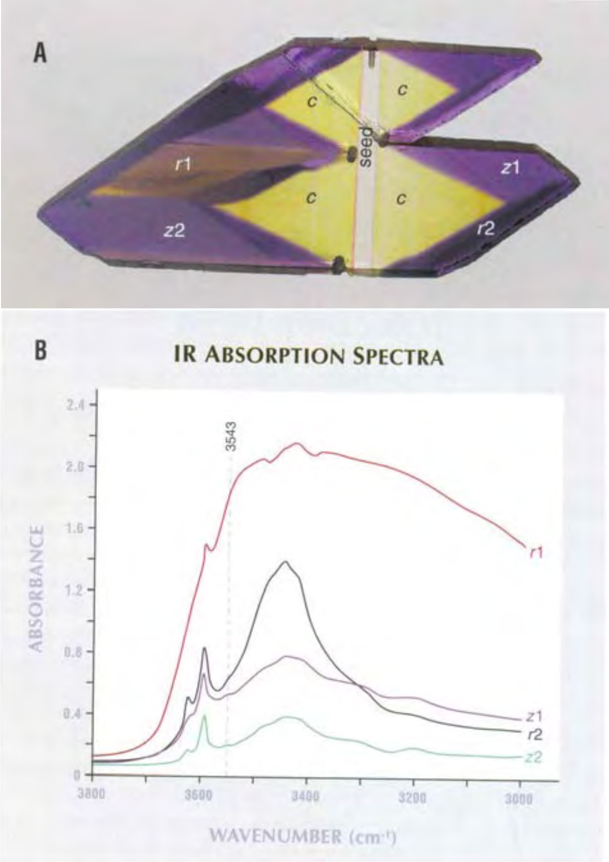


Figure 13. As another example of Condition 1, the plate of synthetic ametrine in image A (3 mm thick and 8 cm long, cut parallel to a*) was grown in an alkaline solution on a seed cut parallel to* c*. Before irradiation, the* z *sectors were very pale yellow, and the* r1 *sectors were yellow, with slightly more intense color in the* r *sector (i.e., it contained more citrine-forming impurities). As seen here after irradiation, the* z *sectors turned purple-violet, whereas the* r *sectors turned brownish yellow (sector* r1*) and very dark purple (sector* r2*). The IR spectra in part B show that the 3543 cm*$^{-1}$ *band was absent from the* r *sectors, and barely present (to various degrees) in the* z *sectors. Photo by D. V. Balitsky.*

Relation to Growth Sectors in Synthetic Amethyst. In the colorless as-grown crystals that were produced in alkaline K_2CO_3 solutions, the 3543 cm^{-1} band was either completely absent or occurred only rarely as a very weak peak or a shoulder. However, our investigations revealed four conditions (according to the *z* and *r* growth sectors) that govern the presence and absence of the 3543 cm^{-1} band in synthetic amethyst grown in alkaline solutions after irradiation to produce the amethyst color. Although the four conditions described below indicate extreme situations, gradational characteristics also are possible according to variations in the growth conditions (a full list is available in the *G&G* Data Depository at www.gia.edu/gemsandgemology).

Condition 1. The 3543 cm^{-1} absorption band is present in the *z* sectors and absent from the *r* sectors (figures 12 and 13). This was the case for about 70–80% of the studied samples.

For this condition, the *z* sectors are colorless or very pale yellow before irradiation. This confirms that these sectors did not contain significant citrine-forming impurities (Balitsky and Balitskaya, 1986). In contrast, *r* sectors (as well as Dauphiné *r*-twins) within the same crystals initially are pale yellow to pale yellowish brown. With irradiation they become amethystine, sometimes with a barely visible

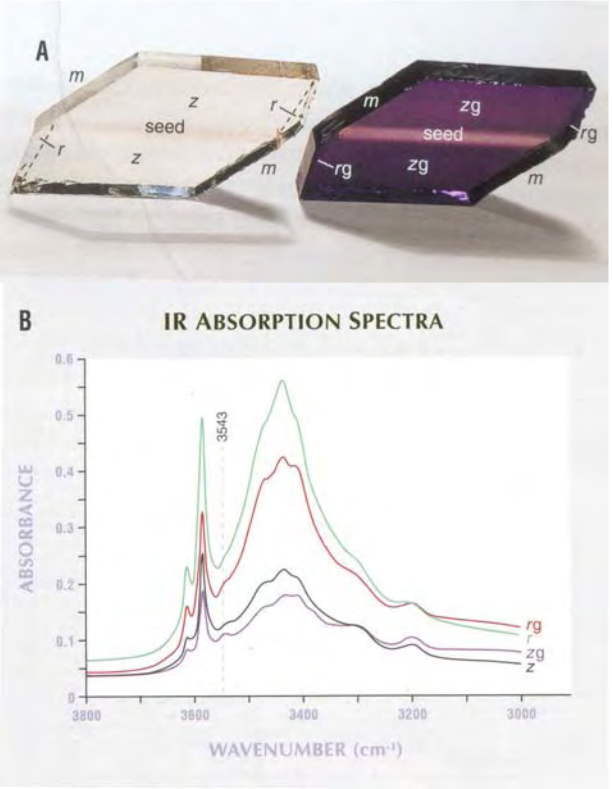


Figure 14. To illustrate Condition 2, image A shows plates of synthetic amethyst (3 mm thick and 7 cm long, sliced parallel to a*) that were grown in alkaline solutions on seeds cut parallel to* z*. Before irradiation, both the* z *and* r *sectors were colorless, indicating that they contained no citrine-forming impurity. After irradiation, both rhombohedral growth sectors became purple-violet (somewhat darker in the* r *sectors). The IR spectra in part B show that before irradiation, the 3543 cm^{-1} band was hardly noticeable (as a shoulder) in the* z *sectors, and was absent from the* r *sectors (labeled* z *and* r*, respectively). After gamma-irradiation, this band became distinct in the* z *sectors and appeared as a shoulder in the* r *sectors (zg and* rg*, respectively). Photo by V. S. Balitsky.*

brownish tint. This proves that the *r* sectors, as well as the Dauphiné *r*-twins, contain both citrine- and amethyst-forming impurities (Balitsky and Balitskaya, 1986).

In the example shown in figure 13, the citrine-forming impurity is only absent from the *z* sectors, and their IR spectra include the 3543 cm^{-1} band. However the *r* sectors captured more of the citrine-forming impurity and acquired a primary yellow to yellow-orange color. After gamma irradiation, they changed to brownish yellow (sector *r*1) and very dark reddish violet (sector *r*2).

According to our data, this situation was most common for synthetic amethyst grown during the 1970s and '80s in Russia. We have observed over the last decade that the amount of synthetic amethyst with a colorless *z* growth sector before irradiation was reduced by as much as 20–30%. We believe that this may be related to efforts to raise production by increasing the growth rate of the crystals, which results in more of the citrine-forming impurity being captured.

The samples of synthetic amethyst from China (grown in the 1980s) and Japan showed the same features; for all practical purposes, they could not be distinguished from the Russian material.

Condition 2. Less commonly, the 3543 cm^{-1} band is present in both the *z* and *r* sectors (figure 14). This was shown by about 20–30% of the Russian synthetic amethyst we studied that was grown before the 1990s and by nearly 40–50% of later production. We saw analogous IR spectra in our samples of Japanese synthetic amethyst.

For this condition, both the *z* and *r* sectors are colorless before irradiation—and therefore contain only structural amethyst-forming impurities. We have also noted intermediate cases in which the *z* sectors are perfectly colorless but the *r* sectors are very pale yellow before irradiation. This indicates the presence of traces of the nonstructural citrine-forming impurity. After irradiation, both rhombohedral growth sectors become purple-violet, but the *r* sectors have a somewhat darker color (and also a smaller 3543 cm^{-1} band).

Condition 3. Very rarely, the 3543 cm^{-1} band is absent from both the *z* and *r* sectors (figure 15). In this case, before irradiation both sectors are pale yellow to yellow or brownish yellow, which shows the presence of a citrine-forming impurity (in addition to an amethyst-forming impurity). After irradiation, both growth sectors become purple-violet, sometimes with a brownish tint. The intensity of this tint increases according to the amount of the citrine-forming impurity.

According to information from Dr. Liu Guobin (pers. comm., 1998) almost all Chinese synthetic amethyst grown on *z* seeds was pale yellow to yellow before irradiation. Our examination confirmed that the as-grown yellow color of Chinese synthetic amethyst also is caused by nonstructural iron impurities. In such material, the 3543 cm^{-1} band is absent from both the *z* and *r* sectors.

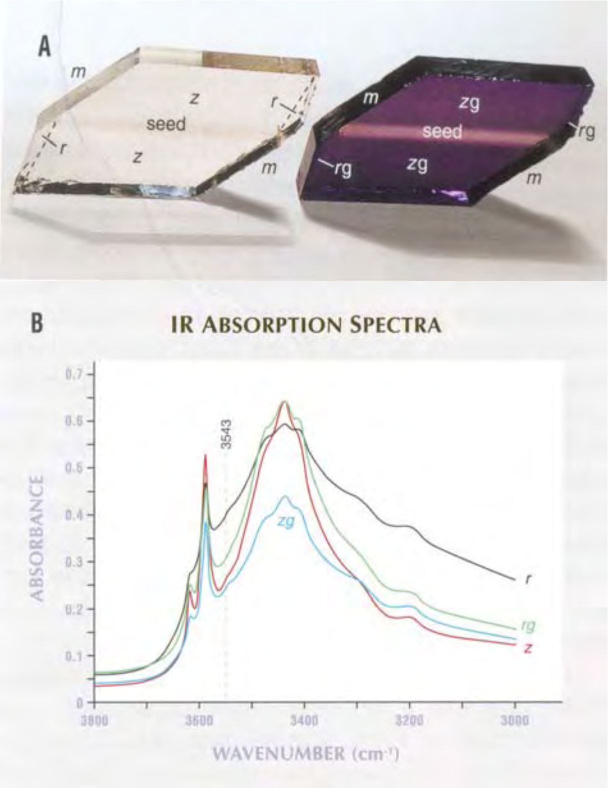


Figure 15. In part A, these plates of synthetic amethyst (10 mm thick and 6.0 cm long, sliced parallel to a*) were grown in alkaline solutions on seed plates cut parallel to* z*. They illustrate Condition 3. As grown, the rhombohedral sectors were pale yellow. With irradiation, the* r *and* z *sectors became purple-violet with a brownish tint, with the* r *sectors being somewhat darker in color. In part B, the 3543 cm^{-1} band is absent (or present as a hardly noticeable shoulder) in the IR spectra of the rhombohedral sectors, both before (*z *and* r*) and after irradiation (*zg *and* rg*). Photo by V. S. Balitsky.*

Condition 4. Also very rarely, the 3543 cm^{-1} band occurs in reverse of the first condition—that is, the band is present in the *r* sectors and absent from the *z* sectors. This situation arises when both amethyst- and citrine-forming impurities are present in the *z* sectors, but the *r* sectors have only the amethyst-forming impurity. In the authors' experience, such conditions are seldom encountered in the commercial growth of synthetic amethyst.

Thus, according to our data, the 3543 cm^{-1} band in the IR spectra of commercially available synthetic amethyst that has been grown in alkaline solutions almost always manifests itself in the *z* sectors and is often absent from the *r* sectors.

From these data and communications with other producers (e.g., in South Korea), we believe that more than 98% of the synthetic amethyst currently produced in Russia and other countries is grown on seeds cut parallel to *z*. This is because such crystals grow much faster than when seeds cut parallel to *r* are used. When grown on the *z*-seeds, the vast majority of such crystals are comprised of *z* sectors (see, e.g., figure 3B). *This is why the 3543 cm^{-1} band is found in the IR spectra of the majority of synthetic amethyst in the international gem trade.*

Effect of Growth Rate, Temperature, and Pressure. Our data show that the presence or absence of the 3543 cm^{-1} band in the IR spectra of synthetic amethyst grown in alkaline solutions mainly depends on the growth rates of the crystals. Growth rates are primarily a function of the pressure/temperature parameters, thermal gradient, composition of the solution, supersaturation, crystallographic orientation of the seed plates, and the position of the seed plates in the autoclave.

Because commercial growth processes maintain the solution at a constant composition, growth-rate variations mainly relate to the seed orientation (e.g., cut parallel to *z* or *r*) and the position of the seed in the autoclave relative to gravity. Depending on the pressure-temperature (P-T) conditions and temperature gradient, growth rates of the *z* face can exceed those of the *r* face by 5–8 times or more. However, the orientation of the seed relative to gravity and the temperature gradient can even affect the growth rates of faces with the *same* crystallographic orientation, especially the *r* faces, by a factor of 10 or more (see, e.g., the crystal in figure 13A). Moreover, slight deviations in the specified P-T conditions, especially the temperature gradient (i.e., solution supersaturation), also can affect the growth rates of both rhombohedra.

Balitsky and Balitskaya (1986) described the distribution of amethyst- and citrine-forming impurities in synthetic quartz according to the growth rates of the *z* and *r* faces. In particular, these faces capture the citrine-forming impurity in addition to the amethyst-forming impurity when they reach their "critical" growth rates. As mentioned above, the presence of the 3543 cm^{-1} band (in natural amethyst, as well as in synthetic amethyst grown in alkaline solutions) correlates to the presence of the amethyst-forming impurity, whereas its absence correlates to the simultaneous presence of both amethyst- and citrine-forming impurities.

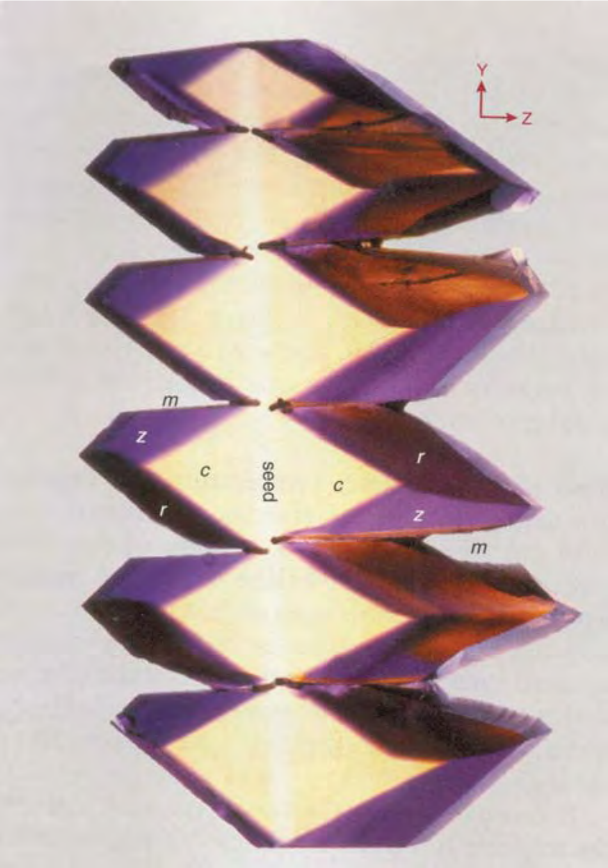


Figure 16. This plate of synthetic ametrine crystals (approximately 6.0 × 11.0 cm) was grown in an alkaline solution on a seed plate cut parallel to c. *The seed was oriented parallel to the vertical axis of the autoclave during crystal growth. In the different crystals, the growth rate of the* z *and, especially, the* r *faces was more rapid on the top than the bottom surfaces, to varying degrees. Faster growth rates caused greater incorporation of the citrine-forming impurities. Photo by V. S. Balitsky.*

This accounts for the fact that when the growth rate is below the critical rate (i.e., under conditions that capture the amethyst-forming impurity almost exclusively), the 3543 cm^{-1} band is present. However, as the critical rate is approached, the intensity of the 3543 cm^{-1} band first decreases and ultimately disappears if the growth rate is increased.

The commercial technology used to grow high-quality synthetic amethyst requires that the seeds be cut parallel to *z*. In this situation, the *z* faces usually do not attain the critical growth rate. We propose that this is the main reason why the 3543 cm^{-1} band is present in the overwhelming majority of synthetic amethyst, which predominantly consists of *z* sectors. However, with this seed orientation the *r* faces reach their own critical rate faster than the *z* faces, and will simultaneously capture both the amethyst- and citrine-forming impurities. This explains why in our samples this band was typically absent from the *r* sectors in the same crystals or in crystals grown on seed plates cut parallel to *r* in the same autoclave. Note that if both *z* and *r* sectors are present in a faceted synthetic amethyst, the 3543 cm^{-1} band will be detected only in certain portions of the sample.

We should emphasize, however, that various technological methods can be used to change the growth rates of the *z* and *r* faces, even within separate crystals in an autoclave (figure 16). Growth rates of these faces will decrease as pressure and, especially, temperature decrease. Thus, manufacturers can predetermine and control the presence or absence of the 3543 cm^{-1} band in synthetic quartz.

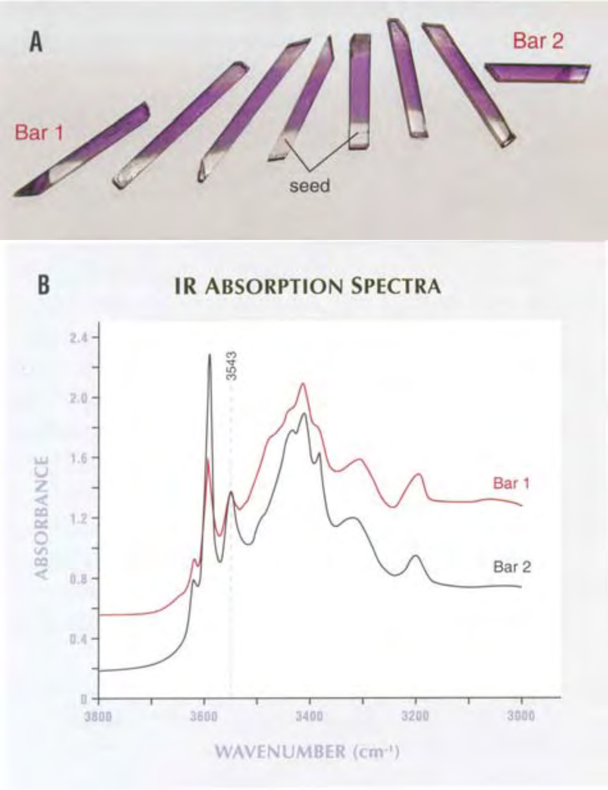
Our observations confirm previous findings on the relationship between these factors and the growth rates of these sectors in natural ametrine (Lemmlein, 1951) and in natural amethyst that develops a near-citrine color after thermal treatment (Nassau, 1981, 1994). This provides strong evidence that growth rate is important for determining the presence or absence of the 3543 cm^{-1} band in the IR spectra of natural, as well as synthetic, amethyst.

Effect of Crystallographic Orientation. To determine the effect of crystallographic orientation on the behavior of the 3543 cm^{-1} band, IR spectra were recorded from oriented cubes and plates cut perpendicular to those described in the preceding section, for both natural and synthetic amethyst. We found that the occurrence of the 3543 cm^{-1} band did not depend on crystallographic orientation (figure 17). However, due to polarization, we observed a change in the intensity of this band.

Effect of Irradiation and Annealing. As noted earlier, the 3543 cm^{-1} band was either completely absent or occurred rarely as a hardly noticeable peak or a shoulder in the colorless as-grown (i.e., non-irradiated) crystals produced in alkaline K_2CO_3 solutions. However, after irradiation to produce the amethyst color, this band appeared distinctly in the IR spectra of the majority of synthetic amethysts (see figures 14 and 18). This band could be eliminated by heat treatment (i.e., at 420°C) to remove the amethyst color, and then be restored by subsequent irradiation to bring back the amethyst color (again, see figure 18).

As a rule, synthetic amethyst grown in alkaline solutions contains Al-alkaline centers in addition to the predominant amethyst color centers (Rossman, 1994). These Al-alkaline centers manifest themselves through irradiation by giving a smoky tint (figure 19). According to our data, the smoky color centers in such crystals can be destroyed by annealing at 300–310°C for one hour. Although the smoky tint disappears, the amethyst color and the 3543 cm^{-1} band remain. However, after further heat treatment at 450°C for two hours, both the amethyst color and the 3543 cm^{-1} band disappear completely. Subsequent gamma irradiation restores the amethyst–smoky quartz color, and the 3543 cm^{-1} band re-appears in the IR spectra.

Figure 17. The bars in image A (each 2 mm thick; bar 2 is 2.0 cm long) were cut in various orientations (differing by approximately 10°) from the same plate of synthetic amethyst, which was sliced parallel to a. *The crystal was grown in an alkaline solution on a seed plate cut parallel to* z. *As shown in part B, the 3543 cm^{-1} band was clearly visible in the IR spectrum of these representative samples, regardless of their orientation. The change in the intensity of this band was due to polarization effects. Photo by D. V. Balitsky.*



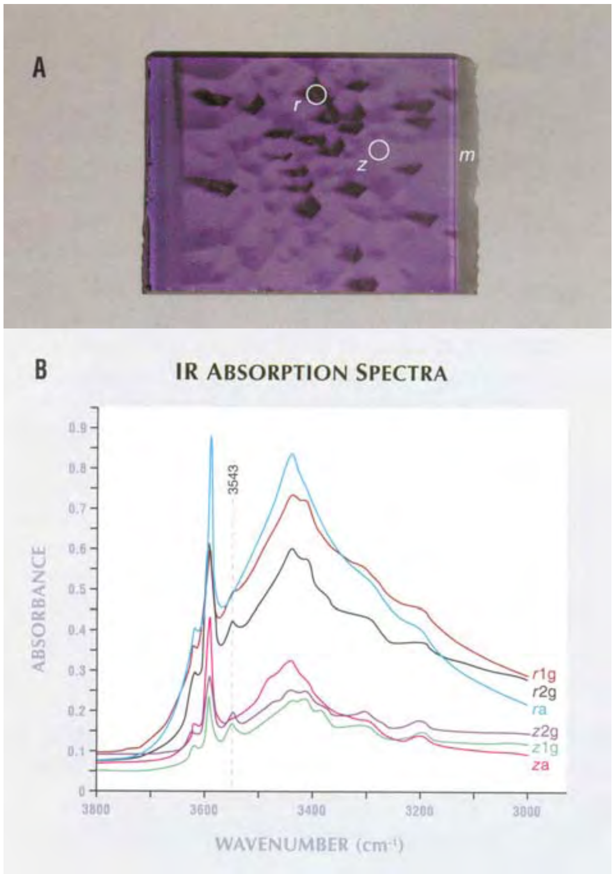


Figure 18. The sample of synthetic amethyst in image A (2.5 mm thick, 5.0 cm wide, sliced parallel to z) *was grown in an alkaline solution on a seed plate cut parallel to* z. *Numerous Brazil* r*-twins (dark areas) are present in this* z *sector. Before irradiation, the plate was colorless and the 3543 cm^{-1} band was absent from both the* z *and* r *sectors. However, as shown in part B, this band appeared in the spectra of these sectors after gamma irradiation (*z1g *and* r1g*). After annealing at 420°C for two hours, this band practically disappeared (*za *and* ra*), but after irradiation it appeared again (*z2g *and* r2g*). The spectra were recorded from the same locations on the sample, as labeled. Photo by D. V. Balitsky.*

Nevertheless, there appears to be no direct relationship between amethyst color and the 3543 cm^{-1} band. Our experiments show that the 3543 cm^{-1} band also occurs in the IR spectra of gamma-irradiated synthetic smoky quartz that was grown in iron-free sodium alkaline solutions on seed plates cut parallel to *z* (Balitsky et al., 2003). In this case, the 3543 cm^{-1} band is present only in synthetic quartz crystals that attain a growth rate on the order of 0.4–0.5 mm/day—that is, close to that of commercially produced synthetic amethyst. By analogy to synthetic amethyst, the 3543 cm^{-1} band in such

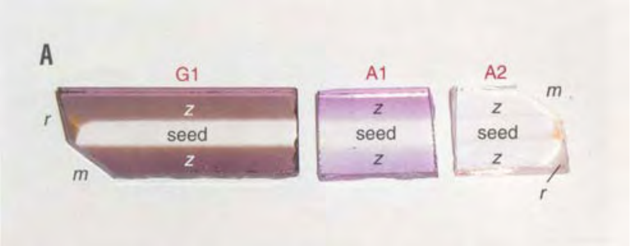
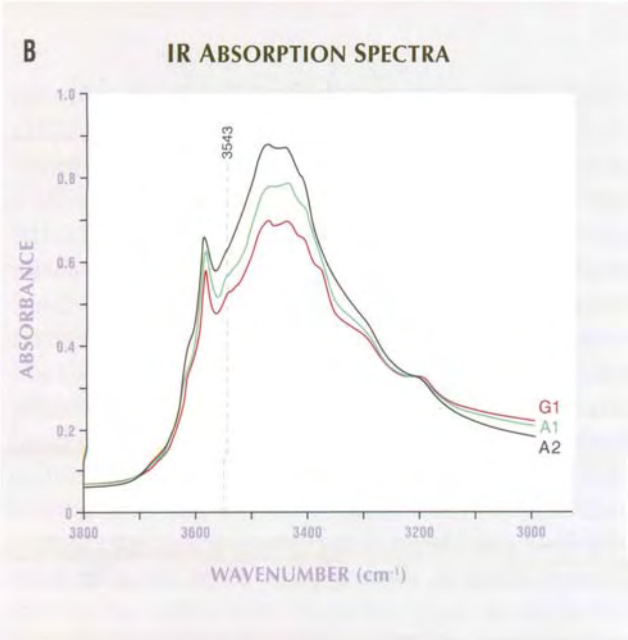
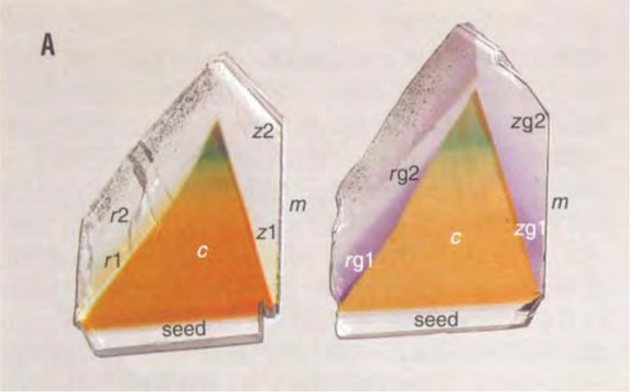


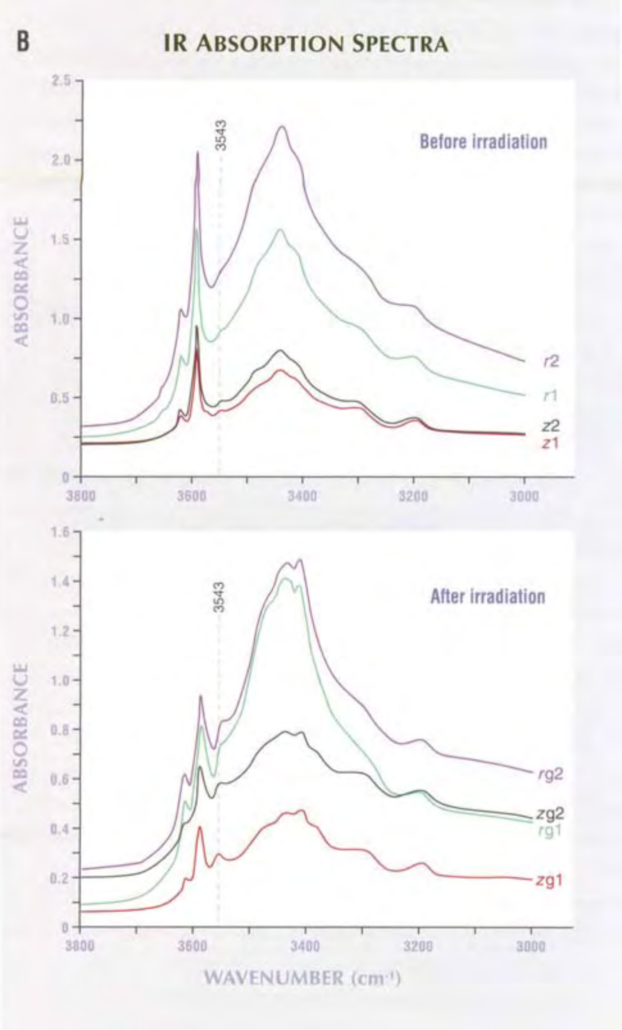
Figure 19. This slice of synthetic quartz (3 mm thick, up to 6.5 cm long, sliced parallel to a) was cut into three pieces for irradiation and heat-treatment experiments (see image A). The original crystal was grown in an alkaline solution on a seed plate cut parallel to z. As grown, the z sectors were colorless, but with irradiation they turned smoky violet (sample G1). Annealing at 310°C for one hour left a pale amethyst color (sample A1). The 3543 cm^{-1} band, though weak, was present in the spectra of both samples (see part B). However, after annealing at 450°C for two hours, the synthetic quartz became completely colorless (sample A2) and the band at 3543 cm^{-1} disappeared. Photo by D. V. Balitsky.



material disappears when it is annealed at 450°C for two hours. This band also is absent from synthetic quartz produced under the same conditions, but with a slower growth rate (0.2 mm/day), although

Figure 20. The plates of multicolored synthetic quartz in image A (2.5 mm thick and 6.0 cm tall, sliced parallel to a) were cut from the same crystal, which was grown in an alkaline solution on a seed plate cut parallel to c. The multicolored nature is related to a decrease of oxygen potential in the solution (Balitsky et al., 1999). Before irradiation (left plate), both the z and r sectors were colorless or pale yellow, and the 3543 cm^{-1} band was present as a very weak peak or shoulder, as seen in part B. After irradiation (right plate), the inner zones of the z and r sectors became purplish violet but their outer zones remained almost colorless. Nevertheless, the 3543 cm^{-1} band was seen in the IR spectra of both the purplish violet and near-colorless zones. Photo by D. V. Balitsky.





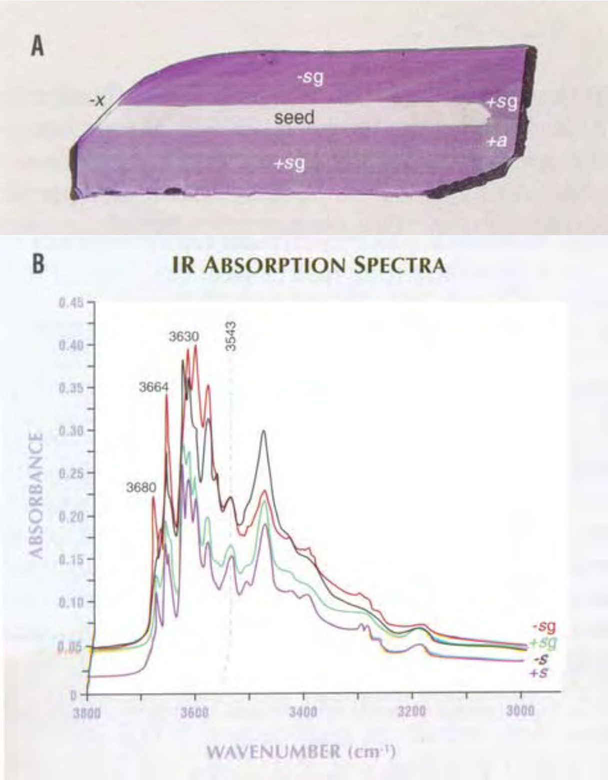


Figure 21. The synthetic amethyst in image A (2.0 mm thick and 2.3 cm long, sliced in ZX-orientation) was grown in an NH_4F solution on a seed plate cut parallel to s. *In part B, typical IR absorption spectra are shown for both the* +s *and* –s *sectors. Several of the peaks (especially at approximately 3680, 3664, and 3630 cm^{-1}) are not found in the spectra of natural or alkaline-solution-grown synthetic amethyst. Note that the 3543 cm^{-1} band was present both before (*+s, –s*) and after irradiation (*+sg, –sg*). Photo by D. V. Balitsky.*

two other characteristic bands at 3612 and 3585 cm^{-1} are present in that case.

Additional evidence for the lack of any correlation between amethyst color and the 3543 cm^{-1} band is found in plates of the multicolored brownish yellow–green–amethyst synthetic quartz before and after irradiation (figure 20).

Thus, our studies show that the 3543 cm^{-1} band in the IR spectra of natural amethyst and of synthetic amethyst grown in alkaline solutions is probably associated with specific OH^- defects that manifest themselves in the quartz structure under the effect of ionizing irradiation.

Effect of Solution Composition. The IR spectra of synthetic amethyst grown in near-neutral NH_4F solutions show unique absorption features (figures 21 and 22). In particular, such crystals show clear

Figure 22. The plate of synthetic amethyst in image A (2 mm thick and 3.0 cm long, sliced parallel to m*) was grown in an NH_4F solution on a seed plate cut parallel to* c. *After irradiation, it was cut into three pieces (image B) that were subjected to heat treatment at 500°C (sample c1), 600°C (sample c2) and 700°C (sample c3). In the IR spectra shown in part C, the unheated sample showed a broad band with a maximum near 3400 cm^{-1} (related to molecular water). This band was not present in the heated samples, although numerous other bands in the 3700–3550 cm^{-1} region—including the 3543 cm^{-1} band—did not undergo any changes. Photo by D. V. Balitsky.*

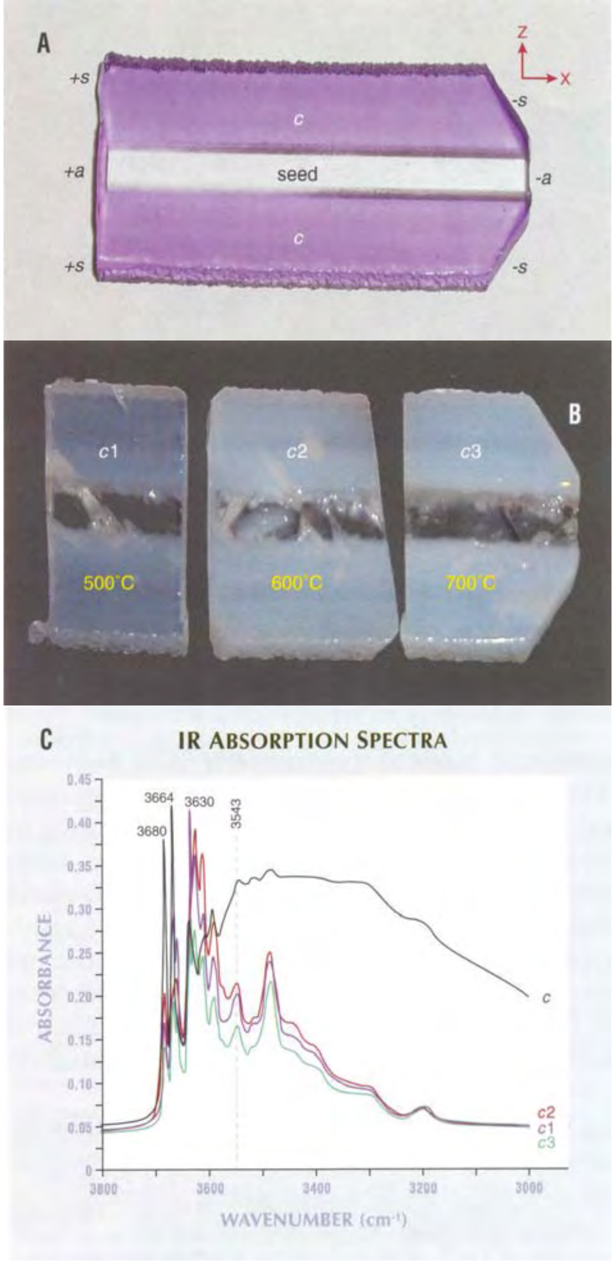


Figure 23. Synthetic amethyst has been produced in large quantities for the gem trade, but it remains challenging to identify. The synthetic amethyst shown here is set in a pendant with pavé diamonds. The unmounted oval brilliant weighs 5.56 ct (GIA Collection no. 13438B). Jewelry courtesy of Gems of La Costa, Carlsbad, California; photo by Maha Tannous.

absorption bands at approximately 3680, 3664, and 3630 cm^{-1} that never manifest themselves in natural amethyst or in synthetic amethyst grown in alkaline solutions (Balitsky, 1980; Balitsky, 1981; Balitsky et al., 2000). Also present are more subtle bands at 3606, 3590, 3543, 3513, and 3483 cm^{-1}. Our experiments indicate that the position and intensity of all eight bands, including the one near 3543 cm^{-1}, are not affected by the irradiation and annealing described above for synthetic amethyst grown in alkaline solutions.

Synthetic amethyst that is grown in NH_4F solutions at low temperature (240–300°C) and low pressure (80 atm) conditions contains a high concentration of molecular water (Balitsky, 1981). The IR spectra of such material show a broad band with a maximum near 3400 cm^{-1} (again, see figure 22). After thermal treatment at 450°C for four hours, the amethyst color disappears, and at higher temperatures (500–700°C) the synthetic quartz becomes milky. This phenomenon, which is related to molecular water, is typical for all varieties of high-water-containing quartz (see, e.g., Kats, 1962; Balakirev et al., 1979; Rossman, 1988).

CONCLUSIONS

Despite its prevalence in the gem and jewelry trade (figure 23), synthetic amethyst remains difficult to separate from its natural counterpart. Infrared spectroscopy has limited usefulness in this distinction. The presence of an absorption band near 3595 cm^{-1} is indicative of natural amethyst (Zecchini, 1999), but not all natural amethyst shows this band. An absorption band at 3543 cm^{-1} can confirm the synthetic origin of amethyst grown in near-neutral NH_4F solutions (together with bands at 3680, 3664, and 3630 cm^{-1}), but it cannot be used to positively distinguish the material grown in alkaline solutions.

Currently, most commercial synthetic amethyst is grown in alkaline solutions, on seeds cut parallel to *z*, at growth rates that usually exclude the capture of the citrine-forming impurity. It is primarily for this reason that the 3543 cm^{-1} band is present in the IR spectra of the overwhelming majority of synthetic amethyst. However, very often this band is absent from the *r* sectors in the same crystals, or from crystals that are grown on seeds cut parallel to *r*. Due to initiatives to increase production by using faster growth rates on seeds cut parallel to *z*, such crystals would be expected to simultaneously capture both amethyst- and citrine-forming impurities. Accordingly, the 3543 cm^{-1} band would not be detected in the IR spectra of material faceted from such crystals.

In addition, the 3543 cm^{-1} band is not as rare in natural amethyst as commonly believed. Its presence in such material is probably also caused by slower growth rates of the rhombohedral faces, resulting in only minor capture of the nonstructural citrine-forming impurities. Nevertheless, natural amethyst is mainly formed by *r* growth sectors that typically capture more nonstructural citrine-forming impurities than the *z* growth sectors. Therefore, the 3543 cm^{-1} band is much less common in natural amethyst than in synthetic material.

On the whole, while the presence of an absorption band at approximately 3543 cm^{-1} may be considered indicative of possible synthetic origin, it cannot be used for the positive identification of synthetic amethyst. Therefore, the unambiguous identification of natural versus synthetic amethyst must be based on a combined examination of the IR spectra, internal growth structures (e.g., characteristics of Dauphiné and Brazil twins, presence of particular growth sectors and zones, as well as a stream-like structure seen in synthetic amethyst), and inclusions (e.g., presence of chlorides, barite, calcite, and multiphase fluid inclusions in natural amethyst).

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2004

LAB NOTES

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Notable Cat's-eye ALEXANDRITE

Through the years, the lab has had the privilege of seeing several beautiful cat's-eye alexandrites. In the Spring 1983 Lab Notes (p. 43), we reported on a 4.02 ct stone that displayed exceptional transparency, as well as a very distinct change of color from red to blue-green. In the Fall issue of the same year (p. 171), we described a much larger one, a 17-mm-diameter cat's-eye alexandrite from Sri Lanka that weighed 32.69 ct. This giant was similar in its spherical shape to the previous stone and also had high diaphaneity, but its color change, though distinct, was not ideal. In 1987, both the East and West Coast laboratories examined a number of faceted alexandrites from Minas Gerais, Brazil (Fall 1987 Lab Notes, p. 164). The color change of these stones was reminiscent of fine Russian alexandrites: green to bluish green in fluorescent light and purple to reddish purple in incandescent light. Several of these stones were cat's-eyes, but—as the needles creating the eyes were not fine enough—their chatoyancy was not exceptional. In addition, the largest was only about 1 ct.

With this history, you can see why we were delighted to examine the cat's-eye alexandrite shown in figure 1. This 16.02 ct oval cabochon was transparent to semitransparent, with a sharp eye due to very fine needles that could only be seen with magnification and fiber-optic illumination. The color change was distinct, from dark bluish green in fluorescent light to very dark reddish purple in incandescent light. The proportions of this oval cabochon were particularly noteworthy. It is a common practice with high-quality chatoyant stones to leave the bottom half very deep, as was the case with the two cat's-eyes mentioned above. This is done to save as much weight as possible from the rough, but it also causes the stones to appear smaller than their weight suggests and makes them difficult to set in jewelry. With measurements of approximately 15.28 × 12.96 × 7.90 mm, this cabochon appeared nearly the same size as the 32.69 ct stone even though it had less than half its weight—a direct result of the better proportions. This also meant that it could be set more easily into a piece of jewelry. Stones like this one, which display such an unusual combination of features (two phenomena and a nice cut), are rare and truly a delight to behold.

Wendi M. Mayerson

Figure 1. This 16.02 ct cat's-eye alexandrite, seen here in fluorescent (left) and incandescent (right) light, not only has fine transparency, a sharp eye, and a distinct color change, but it has good proportions as well.

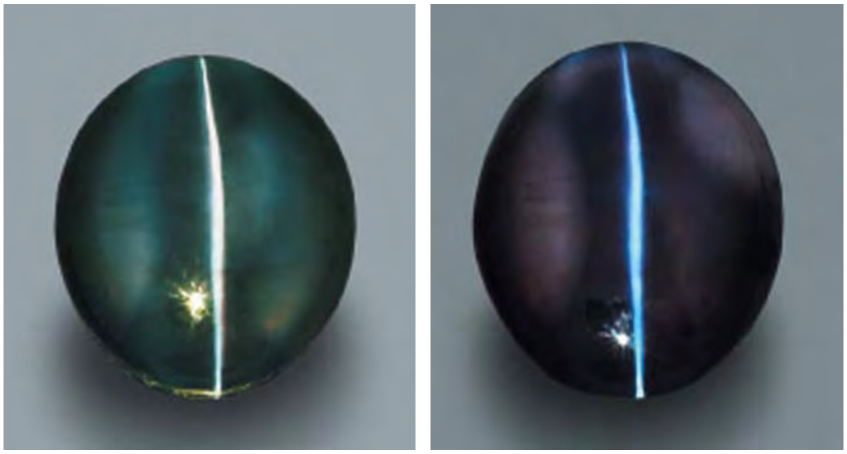

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Figure 2. This 1.02 ct diamond is colored by a pink residue in the large fractures that reach the surface through the crown. The rest of the diamond is near-colorless.

Figure 3. Closer observation shows not only pink in the fractures but also a blue flash-effect color that is typically associated with fracture filling to improve apparent clarity. Magnified 30×.

DIAMOND

Fracture Filled, to Alter Color and Enhance Clarity

While diamonds typically are fracture filled to improve their apparent clarity, we have also seen stones in which a "filler" has been used for other purposes. For example, in the Spring 2003 Lab Notes section (pp. 38–39), the East Coast laboratory reported on a 0.20 ct round brilliant diamond that was filled primarily to produce a pink appearance. This diamond showed an uneven face-up color distribution, with the pink color confined to the eye-visible fractures. No attempt had been made to reduce the visibility of the large fractures, which showed areas of concentrated pink color in a fingerprint pattern when examined with magnification.

Recently, the East Coast lab received the 1.02 ct "pink" round brilliant diamond shown in figure 2 for identification and origin-of-color determination. Like the diamond examined earlier, this stone exhibited uneven coloration, with the pink concentrated in large fractures; magnification of these fractures revealed a dried pink substance in a fingerprint pattern. However, further examination also revealed the flash-effect colors typically associated with the substances used for clarity enhancement (see, e.g., figure 3). These flash-effect colors were visible in the smaller fractures and deeper parts of the large fractures, while the pink color was confined to the largest and most obvious fractures.

Energy-dispersive X-ray fluorescence (EDXRF) spectroscopy indicated the presence of lead and bromine. Both of these elements, which are not found in untreated diamonds, have been identified in diamond fracture-filling materials used for clarity enhancement (see, e.g., R. C. Kammerling et al., "An update on filled diamonds: Identification and durability," Fall 1994 *Gems & Gemology*, pp. 142–177). From this evidence, we concluded that the diamond was indeed fracture filled to improve its clarity. Since the colorless filling was seen deeper in the fractures than the dye, we assume that the diamond was first fracture filled, and then dyed. This is the first diamond we have seen that showed both types of treatment.

Siau Fung Yeung and
Thomas Gelb

Moon-like Surface on a Crystal

Most diamonds are subjected to at least one period of dissolution after their formation and subsequent transport to the surface of the earth. This process results in various surface features, from macro-scale modifications of the crystal morphology to micro-scale etch figures. All of these features are the result of the interaction between corrosive solutions and a diamond's crystal structure (in particular, lattice imperfections in that structure). Common dissolution features include pyramidal trigons produced at dislocation outcrops, flat-bottomed trigons related to dislocations and/or impurities, and etch figures with hexagonal or rhombic forms that are related to twin boundaries on the surfaces (see, e.g., S. Tolansky, *The Microstructures of Diamond Surface*, N.A.G. Press, London, 1955; Yu. L. Orlov, *The Mineralogy of Diamonds*, John Wiley & Sons, New York, 1973). We recently examined a very unusual rough diamond, submitted for origin-of-color determination, with a surface that not only had numerous green radiation stains but also showed a large number of round, crater-like depressions of varying sizes.

The 2.70 ct modified dodecahedron/octahedron (figure 4) measured 8.38 × 7.98 × 5.18 mm. Infrared spectroscopy established that it was a type IaA diamond, with a high concentration of nitrogen. The green

Figure 4. In addition to numerous green radiation stains, the surface of this 2.70 ct diamond crystal was seen to have many unusual round depressions of varying sizes.

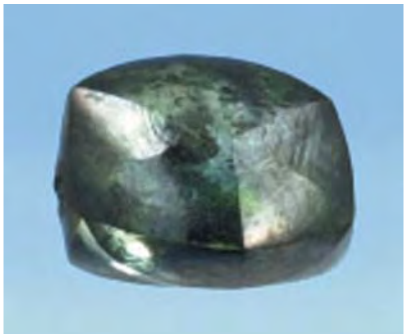


Figure 5. With magnification, the diamond shown in figure 4 revealed an unusual moon-like surface with many round depressions due to etching. The largest "crater" shown here is about 500 µm in diameter.

radiation stains covered the entire surface, forming the typical shallow green "skin" seen on diamonds that have been subjected to natural irradiation. The interior of the stone, as viewed through polished "windows," appeared to be near-colorless. Examination with a microscope revealed that the crater-like depressions (figure 5) occurred randomly over approximately half of the diamond's surface, with no specific relationship to crystal orientation observed. All were almost perfectly round, with the maximum depth estimated at less than 10 µm. Some depressions overlapped one another, and some small "craters" were present within larger ones. They varied significantly in diameter, from ~500 µm to less than 10 µm, with most of them smaller than 100 µm. These features constituted a very interesting phenomenon that called to mind the surface of the moon, with its many round meteorite impact craters. There was no clear corresponding relationship between these depressions and the green radiation stains, although some stains were observed in the flat bottoms of certain depressions.

Judging from the curved corners, faces, and edges of the crystal, it was obvious that it had been subjected to dissolution. The round depressions possibly also formed due to etching. Unlike those etch figures that are seen more commonly, these depressions are most likely discoid sculptures (see Orlov, pp. 93–98), which have been observed on the curved surfaces of rounded crystals from certain diamond deposits. Formation of these discoid sculptures could be related to some special lattice defects in the crystal and selective dissolution processes. The spatial distribution of the green stains and round depressions indicates that the etching process took place before the natural irradiation, which would be expected since such irradiation typically occurs after diamonds have been weathered from their primary deposits.

Detailed investigation of the fine structures of these discoid sculptures and the related green stains could provide a better understanding of the interaction of dissolution and irradiation processes in diamond.

Wuyi Wang, Taijin Lu, and TMM

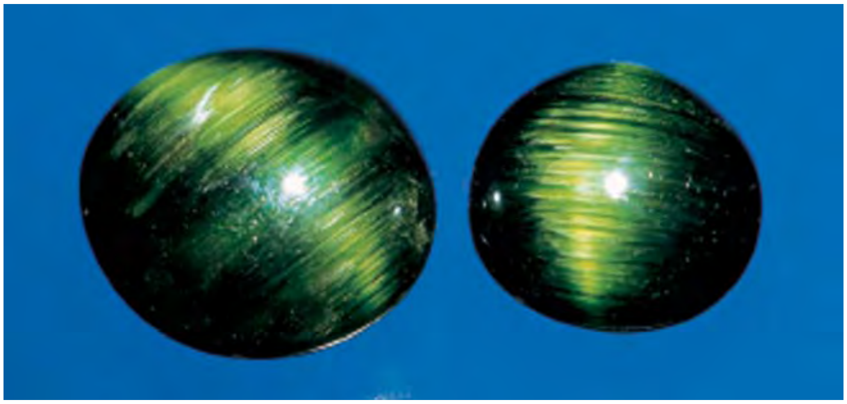
Cat's-eye Demantoid GARNETS

Two translucent to semitranslucent oval cat's-eye cabochons that appeared almost black were submitted to the West Coast laboratory for identification. Each of the cabs, which weighed 4.47 and 6.56 ct, had a broad, intense green chatoyant band (figure 6).

Their refractive indices were over the limits of a standard refractometer, and both had a hydrostatic specific gravity of 3.86. They did not fluoresce to long- or short-wave UV radiation, and they appeared red when viewed through a Chelsea filter. The visible spectrum displayed general absorption to about 510 nm and had lines in the red region at approximately 630, 650, and 680 nm; in most directions, these three lines appeared to converge into a single dark band, which made the individual lines difficult to discern. Neither showed pleochroism, which indicated that the material most likely was singly refractive. Unfortunately, due to the darkness and translucency of the cabochons, we were unable to confirm their optic nature using a polariscope.

Since the results of standard gemological testing were inconclusive, we turned to Raman analysis, which identified both stones as andradite. This was consistent with their gemological properties. Since their visi-

Figure 6. These two cat's-eye demantoid garnets (6.56 and 4.47 ct) are unusually dark with an intense green chatoyant band.



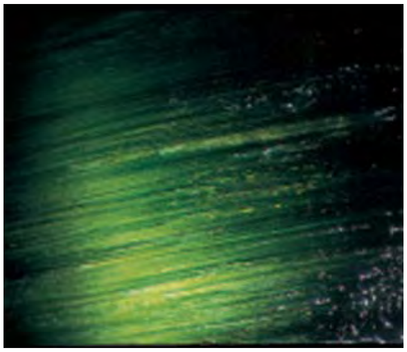
ble spectra and Chelsea filter reactions indicated the presence of chromium, and the "eyes" of both showed an intense green color, we concluded that they were cat's-eye demantoid garnets.

Gems & Gemology has reported on cat's-eye demantoid in the past (see Fall 1985 Lab Notes, p. 174; Winter 1994 Gem News, pp. 272–273). Most recently, a Gem News International item in the Spring 2004 issue (pp. 67–68) described yellowish green to dark "emerald" green demantoid garnets from Iran, some displaying chatoyancy. Two yellowish green cat's-eyes were illustrated in an accompanying photo. However, the two cabochons featured here represent the other end of the color range for cat's-eye demantoid. Except for the eye, these stones appeared virtually black in reflected light. The parallel bundles of fine fibers (most likely a form of asbestos; figure 7) that produced the chatoyancy reflected the intense green bodycolor of the material.

The two stones described here are owned by Robert Petersen of Dublin, California. Reportedly, they are from an undisclosed locality within the U.S., which makes them that much more unusual.

Elizabeth P. Quinn

Figure 7. Parallel bundles of fine fibers are responsible for the chatoyancy in the two cat's-eye demantoids in figure 6. Magnified 20×.



High R.I. GLASS Sold as Peridot

Recently, the East Coast laboratory was asked to identify a large (38.00 × 23.95 × 16.30 mm) dark yellowish green modified shield mixed cut set in a white metal ring that also contained numerous transparent near-colorless and green round brilliants (figure 8). The ring had been purchased at auction with the center stone represented as peridot. The story was that the "peridot" was purchased by the original owner as a loose stone in Africa; on returning to the U.S., the owner had it set in this custom mounting.

Figure 8. The large dark yellowish green modified shield cut in this ring exhibits high dispersion. Although it was purchased as a peridot, advanced testing identified it as glass.

The first thing we noticed when viewing the ring was the extremely high dispersion of the center "gem." To the trained gemologist, this feature made it look more like sphalerite than peridot (see, e.g., Fall 1992 Gem News, p. 204). Standard gemological testing revealed a refractive index above 1.81 (over the limits [OTL] of the refractometer), which conclusively ruled out peridot. As there are several OTL gem materials with similarly high dispersion, such as cubic zirconia, strontium titanate, synthetic rutile, sphene, and sphalerite, the next step was to narrow down the field by optic character. The specimen acted in a singly refractive (SR) manner in the polariscope, and no visible doubling was seen with magnification. This meant it was either SR or amorphous, which ruled out synthetic rutile and sphene. Even though most glass used to imitate gemstones has an R.I. of around 1.40–1.60, it could not be ruled out as a possibility, since we have seen examples of manufactured glass that were OTL (see, e.g., Winter 1993 Gem News, p. 289).

Specific gravity can be a useful property by which to separate gems that are OTL, but such testing was not possible in this case because the specimen was mounted. No reaction was seen to either short- or long-wave ultraviolet radiation. However, with magnification one tiny, high-relief gas bubble was evident through the crown near the girdle. This feature ruled out sphalerite, indicating instead that the specimen was either a melt-process synthetic or a glass.

Advanced testing was required for a final identification. Qualitative chemical analysis by EDXRF spectroscopy revealed that the specimen consisted mostly of zirconium with some titanium and silicon—not consistent with any known gem mineral, natural or synthetic. Infrared spectroscopy revealed two broad peaks associated with glass. The most conclusive information, though, came by taking a minute scraping and performing X-ray diffraction analysis. This test revealed that the specimen did not have a crystal structure and was in fact amorphous. As a result, we concluded that the item in question was a manufactured glass.

This is not the first time we have seen glass sold as peridot. In the Spring 1999 Lab Notes (p. 44), we reported on a 26.28 ct faceted oval we had identified as glass; it had been purchased at the 1998 Tucson gem show as Chinese peridot. Coincidentally, like this most recent piece, that material had an R.I. that was OTL.

Wendi M. Mayerson

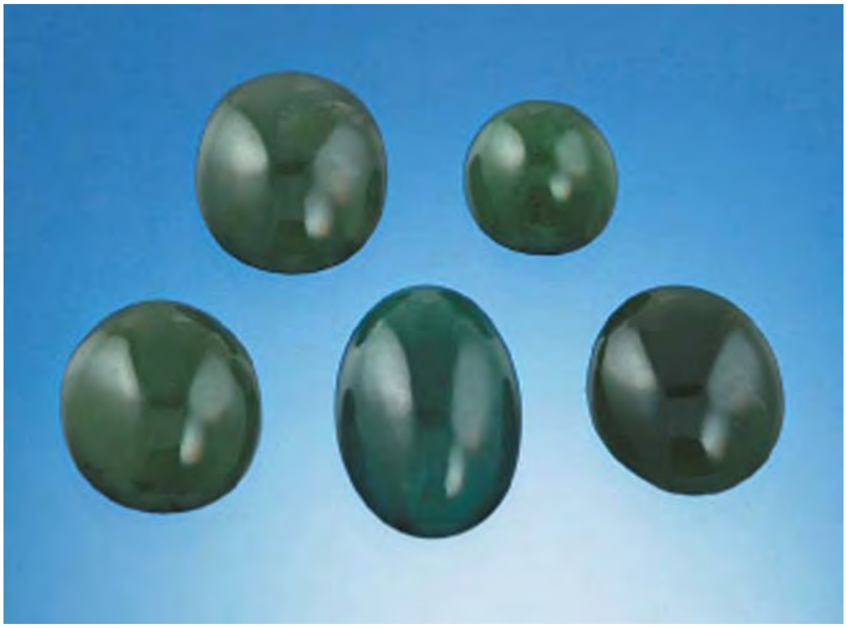


Figure 9. The 17.35 × 9.56 × 3.97 mm dyed jadeite cabochon in the center of the bottom row closely resembles the nephrite cabochons surrounding it.

Dyed JADEITE, Resembling Nephrite

In the spring of 2004, the East Coast laboratory received a 5.65 ct translucent green oval cabochon measuring 17.35 × 9.56 × 3.97 mm. The client believed the cab was nephrite and had submitted it for an identification report. Seen as the bottom-middle cabochon in figure 9, it did resemble the four surrounding nephrites taken from the laboratory research collection. Yet standard gemological testing revealed an R.I. of 1.67 on the base of the cabochon and a volumetric S.G. of 3.31, properties that pointed to jadeite, not nephrite.

Testing with a desk-model spectroscope revealed a dye band at approximately 670 nm, slightly higher than the 650 nm band standard for dye, and there was no reaction to short or long-wave UV radiation. Magnification used in conjunction with transmitted light confirmed the presence of dye (seen in figure 10) as threads of green color in fractures and between individual grains. This visual confirmation is useful even when a dye band is not present, as was the case with the bangle bracelet reported in the Summer 1997 Lab Notes (pp. 138–139). Infrared spectroscopy, a test run as standard procedure on all jadeite, showed no evidence of impregnation.

In 1984, both the East and the West Coast laboratories had the opportunity to study a dyed nephrite cabochon (Spring 1984 Lab Notes, p. 48). That 1.06 ct stone resembled fine green jadeite in color and showed dye concentrations in and around cracks. Notice the shape of the dye concentrations in that dyed nephrite sample (figure 11, left). The grain structure seen in our dyed jadeite, which allows the dye to surround the individual grains, is typical for jadeite (figure 11, right); nephrite is known to have a more fibrous texture (R. Webster, *Gems*, 5th ed., rev. by P.G. Read, Butterworth-Heinemann, London, 1994, p. 272). In fact, it has been suggested that the reason dyed nephrite is not common is because the structure of nephrite resists the dyeing process (Spring 1984 Lab Notes, p. 48).

Figure 10. In transmitted light, the dye concentrations in this 5.65 ct jadeite cabochon could be seen surrounding individual grains, as well as filling surface-reaching cracks and fractures.

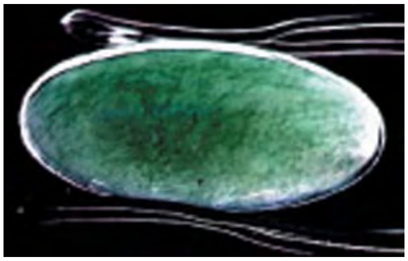
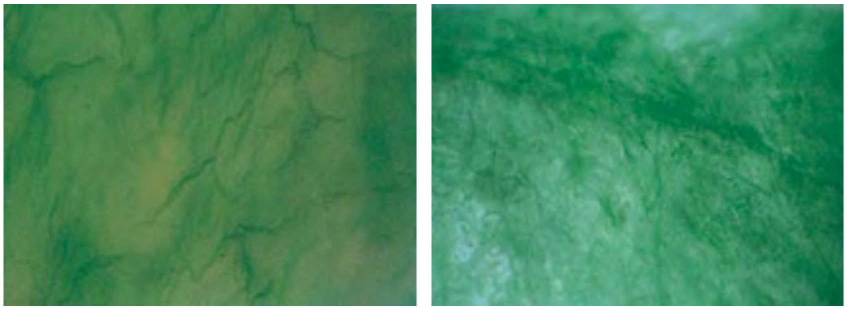


Figure 11. There is a noticeable difference in the way jadeite and nephrite accept dye, due to the differences in their grain structures. The fibrous nephrite grains are more closely interlocked and seem to restrict the absorption of dye to surface cracks and fractures (left, magnified 15×). The more rounded grains of jadeite allow dye to seep in between individual grains and surround them, as well as concentrate in surface cracks and fractures (right, magnified 20×).



Jadeite is often dyed to imitate the finest Imperial jadeite, a bright, vivid green. What makes this piece so unusual is that the color more closely resembles nephrite—typically a darker, less saturated green. It is possible, since there was no polymer impregnation, that this is an old piece in which the dye has degraded over time; it may also just be a poor dye job. It is hard to imagine why this cabochon (or any jadeite) would be dyed specifically to imitate nephrite.

Wendi M. Mayerson

Green QUARTZ with Brazil-law Twinning

Recently, the West Coast laboratory examined a 9.70 ct transparent light grayish yellowish green oval modified brilliant that was readily identified as quartz (figure 12). It displayed a noteworthy example of Brazil-law twinning, which aided us in the identification (figure 13).

Brazil-law twinning is a type of polysynthetic twinning that typically occurs in natural amethyst. Its presence is usually a very good indication that the material is of natural origin. Most synthetic quartz contains no such twinning. While some hydrothermal synthetic quartz grown on twinned natural amethyst seeds may contain Brazil-law twinning (J. I. Koivula and E. Fritsch, "The growth of Brazil-twinned synthetic quartz and the potential for synthetic amethyst twinned on the Brazil law," Fall 1989 *Gems & Gemology*, pp. 159–164), in our experience little if any of this material is available on the market.

Brazil-law twinning is observed when stones are viewed parallel to the optic axis between crossed polarizing filters. Because it may be difficult to see this twinning in some faceted amethysts due to their small size and/or the position of the optic axis, immersion of such stones in water is recommended as a viewing aid. We concluded that the otherwise clean green quartz we examined was of natural origin based on the presence of the well-defined Brazil-law twinning.

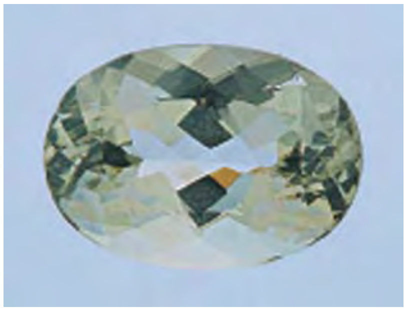


Figure 12. This 9.70 ct light grayish yellowish green modified brilliant proved to be natural quartz.

Figure 13. When the light green quartz in figure 12 was observed parallel to the optic axis between crossed polarizers, it displayed a notable example of Brazil-law twinning. Such twinning is characteristic of natural amethyst.

As with the much more common yellow variety, citrine, green quartz is typically produced by heat treating amethyst, although the green color can occur naturally, as with the green quartz found on the California-Nevada border (T. R. Paradise, "The natural formation and occurrence of green quartz," Spring 1982 *Gems & Gemology*, pp. 39–42). However, there are unsubstantiated reports that the green color of the stone described in this entry was instead produced by an irradiation technique.

Currently there is no way to separate naturally heated from heat-treated green quartz. This material is sometimes referred to as "greened amethyst" or "prasiolite" in the trade.

Elizabeth P. Quinn

SYNTHETIC SAPPHIRE with Unusual Yellowish Green Bodycolor

The light yellowish green emerald cut shown in figure 14 was submitted to the East Coast laboratory last spring for an emerald report. This service indicates whether or not clarity enhancement is present and, if it is, to what degree. Measuring 12.29 × 10.32 × 6.37 mm, the 8.85 ct specimen was eye clean—atypical for emerald, but not uncommon for green beryl. However, standard gemological testing revealed an R.I. of 1.761–1.770, a specific gravity (measured volumetrically) of 4.02, and tiny scattered high-relief gas bubbles seen with magnification and horizontal fiber-optic illumination. These properties indicated the specimen was a synthetic sapphire.

Light yellowish green is an uncommon color for sapphire, whether natural or synthetic. However, we

Figure 14. This 8.85 ct light yellowish green emerald cut submitted for an emerald report was identified as a synthetic sapphire. Its unusual color is attributed to a combination of cobalt and vanadium.

have reported on two similar synthetic sapphires, one even displaying asterism (Lab Notes: Spring 1995, pp. 57–58; Spring 1996, p. 51). As in both previous cases, the current gem did not show any iron-related bands in the desk-model spectroscope (450–470 nm). This absorption contributes to the color in natural green sapphires, which are often dark and inky in appearance. Nor, however, did we see any features around 670 nm, which were observed in the two examples described previously. When tested with EDXRF spectroscopy, both of these earlier samples were found to be colored solely by cobalt (Co^{3+}). This was also the case for some Swiss-manufactured synthetic sapphires in this color range that were examined by GIA Research and the laboratory (again, see the Spring 1995 Lab Note).

For further comparison of this specimen to the two we had reported on previously, we also submitted it to qualitative chemical analysis by EDXRF spectroscopy, which revealed vanadium (V^{3+}) as well as cobalt (Co^{3+}). This combination of elements has been found in non-phenomenal green synthetic sapphires produced in the U.S. (again, see the Spring 1995 Lab Note). To date, cobalt has not been documented as a coloring agent in natural sapphire.

Wendi M. Mayerson

SPINEL

With Interesting Etch Tubes

An 8.88 ct transparent orange-red modified rectangular mixed-cut gem, represented as spinel, was submitted to the West Coast laboratory by Zava Master Cuts of Fallbrook, California, for an identification report (figure 15). The 12.88 × 9.13 × 8.96 mm stone was reportedly from Tanzania's Umba Valley, and contained some interesting internal features.

Figure 15. This attractive 8.88 ct orange-red spinel is reportedly from the Umba Valley of Tanzania.

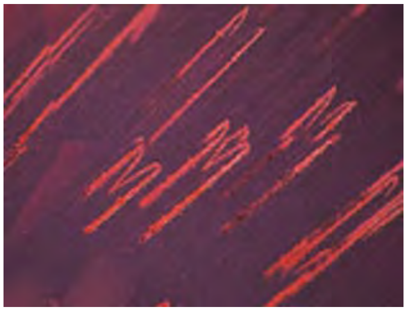


Figure 16. Laboratory staff members had never before observed the unusual "M"-shaped etch tubes seen in the spinel in figure 15. Magnified 10×.

Gemological properties were consistent with those previously recorded for natural spinel. The stone was singly refractive with an R.I. of 1.711 and a hydrostatic S.G. of 3.60. It fluoresced medium to strong red to long-wave UV radiation and extremely weak red to short-wave UV. Using a Beck prism spectroscope, we observed weak chromium lines in the red end of the visible spectrum, along with a band centered at about 560 nm.

Microscopic examination revealed stringers, a plane of fine particles, and some unusual etch tubes that we had never seen before. What was interesting was that several of these etch tubes joined to form the letter "M" (figure 16).

Etch tubes form as a result of chemical dissolution along dislocations in their host. Since such dissolution starts at the host's surface and works inward, the resulting hollow tubes must also extend to the surface unless the host went through a second growth period after the development of the etch tubes. In this spinel, the etch tubes reached the surface and were filled with an orangy yellow limonite-like material, leading us to believe that no secondary growth period occurred. The "M"—or "W"—shapes of these features suggest that they developed in dislocations between octahedral planes, although this could not be precisely determined due to the faceted form of the stone and the isometric nature of spinel.

Elizabeth P. Quinn and John I. Koivula

Natural, Identified with Photoluminescence

An 8.38 ct purple-pink oval modified brilliant was received at the West Coast laboratory for identification (figure 17). The stone was very clean, with just a few pinpoint inclusions and a small feather visible with a standard gemological microscope. Gemological properties included: R.I.—1.714, singly refractive; hydrostatic S.G.—3.59; and fluorescence—weak red to long-wave and inert to short-wave UV radiation. With a desk-model spectroscope, the stone showed Cr^{3+} lines (684 and 685.5 nm) and an Fe^{2+} line (460 nm). These properties, particularly the low R.I., fluorescence reactions, and lack of any anomalous double refraction in the polariscope, were consistent with natural spinel. Additionally, we have not encountered any synthetic spinel with this strong purple color.

However, we still felt that the near-absence of inclusions warranted a more in-depth investigation. Therefore, we performed EDXRF chemical analysis, which revealed a rather high iron content (consistent with the spectroscopic observation) but very little zinc. According to data presented in S. Muhlmeister et al. ("Flux-grown synthetic red and blue spinels from Russia," Summer 1993 *Gems & Gemology*, pp. 81–98), the flux-grown synthetic spinels they studied were consistently low in Zn and Fe, but the natural spinels they examined showed a wide range of Zn and Fe. For comparison, we conducted EDXRF analyses of nine faceted natural spinels and four flux-grown synthetic spinels (three faceted and one rough) from the GIA Museum and Research collections. All the natural samples had colors as similar as possible to the stone in question, whereas the synthetic ones were in different shades of red. All the natural spinels had high Zn, significant Fe, and varying Ga contents. The synthetic samples, however, showed little or no Zn, Fe, or Ga, which is consistent with the Muhlmeister et al. study.

Recently, photoluminescence (PL) spectroscopy has also been applied to study red and blue spinels (F. Notari and C. Grobon, “Spectrométrie de fluorescence du chrome (Cr^{3+}) dans les spinelles,” *Revue de Gemmologie a.f.g.*, No. 147, 2003, pp. 24–30; V. A. Deeva and Y. B. Shelementiev, “Gemological properties of synthetic flux spinel,” *Gemmological Bulletin*, No. 6, 2002, pp. 9–17). Therefore, we recorded PL spectra for the 14 samples mentioned above, using a high-resolution spectrometer with a 514 nm laser. The spectra of two of the natural and two of the synthetic samples are shown in figure 18. All peaks were due to traces of Cr^{3+}; however, the natural samples showed narrow peaks, while the synthetic spinels showed broad “humps.” This is consistent with the spectra shown in Deeva and Shelementiev (2002). We agree with these authors, who suggested that the broader bands in synthetic spinels are due to the presence of irregularity (disorder) and defects in their crystal lattice. The PL spectrum of the client stone was nearly identical to the spectra of the natural spinels (again, see figure 18).

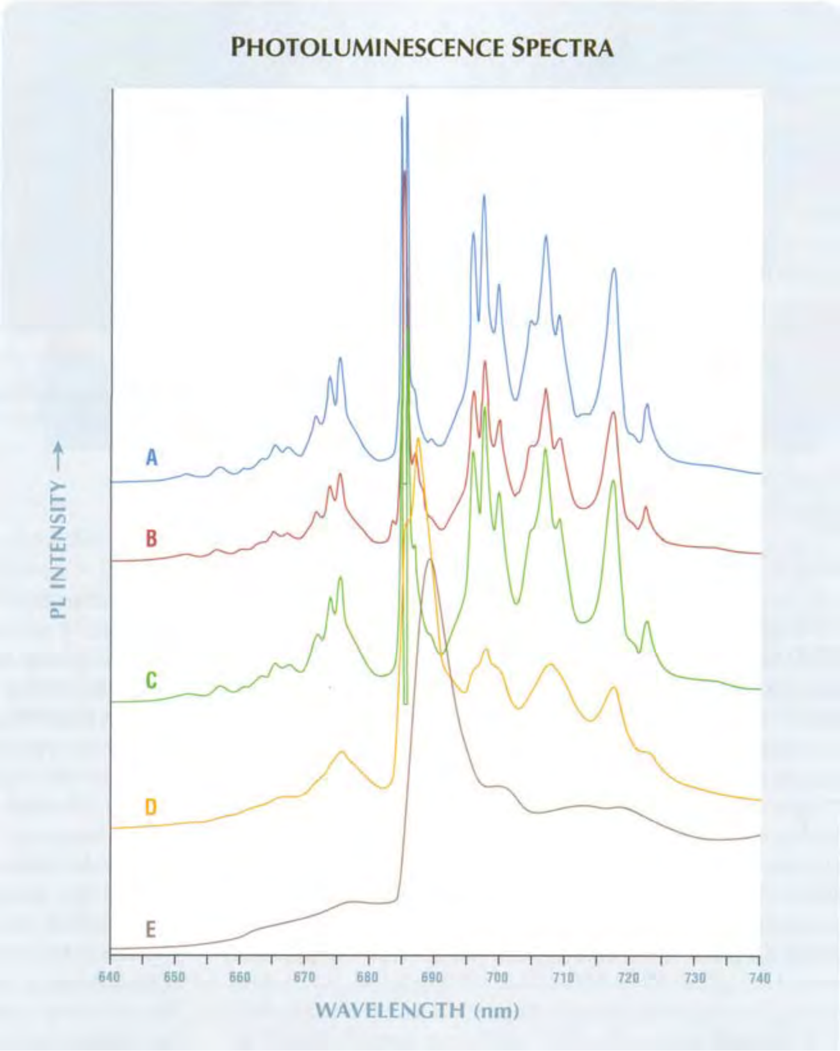


Figure 18. The PL spectra of the stone in figure 17 (A), two natural (B-C), and two flux-grown synthetic (D-E) spinels are given here. The natural spinels show much sharper and narrower peaks than do the synthetics, which have broader “humps.” The sharp peaks in spectrum A clearly show the natural origin of the spinel in figure 17.

Figure 17. This 8.38 ct purple-pink spinel proved to be of natural origin based on its photoluminescence spectra.

Even more so than EDXRF, photoluminescence spectroscopy provides an easy and unambiguous separation of synthetic spinel from its natural counterpart.

Andy Hsi-Tien Shen, Christopher M. Breeding, and Dino DeGhionno

PHOTO CREDITS
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COLORED STONES AND ORGANIC MATERIALS

Amethyst from California. Some notable gem-quality amethyst was found in February 2003 in eastern San Bernardino County, California. Amethyst mineralization has been known in this area for several years (see J. P. Calzia et al., "Mineral resources of the Kingston Range Wilderness Study Area, San Bernardino County, California," *U.S. Geological Survey Bulletin 1709-D*, 1987). The crystals were recovered from the Purple Lily prospect by John Miatech of Sebastopol, California. According to Mr. Miatech, the production consisted of more than 500 loose crystals (up to approximately 9 cm long and 1 cm wide) and small clusters, as well as a large matrix specimen covered with dozens of amethyst crystals. This 43 kg specimen (46 × 67 cm) will be displayed at GIA in Carlsbad until June 2005.

Figure 1. These amethysts (2.44–6.44 ct) were cut from material recovered in eastern San Bernardino County, California. Courtesy of John Miatech; photo by Maha Tannous.

So far, 16 stones have been faceted (0.87–6.44 ct; see, e.g., figure 1) and five crystal "points" have been polished. The cut stones were generally free of inclusions, and commonly showed angular color zoning in rhombohedral directions when viewed in certain orientations. A few of the samples contained primary (figure 2) or secondary fluid inclusions.

Mr. Miatech indicated that the amethyst was produced from a single cavity that measured approximately 0.5 × 1.1 × 1.5 m. The cavity was discovered via systematic prospecting using a satellite ground positioning system instrument to map amethyst-bearing fault zones (trending northwest to southeast) and joints that cross-cut the granitic host rock. Amethyst was also found within local areas of light-colored granite, where the crystals formed in miarolitic cavities. Due to access problems and the rugged terrain, all of the mining done so far has been with hand tools only. Future production of amethyst from this area will likely remain limited. *BML*

Editor's note: The initials at the end of each item identify the editor or contributing editor who provided it. Full names and affiliations are given for other contributors.

Interested contributors should send information and illustrations to Brendan Laurs at blaurs@gia.edu (e-mail), 760-603-4595 (fax), or GIA, 5345 Armada Drive, Carlsbad, CA 92008. Original photos will be returned after consideration or publication.

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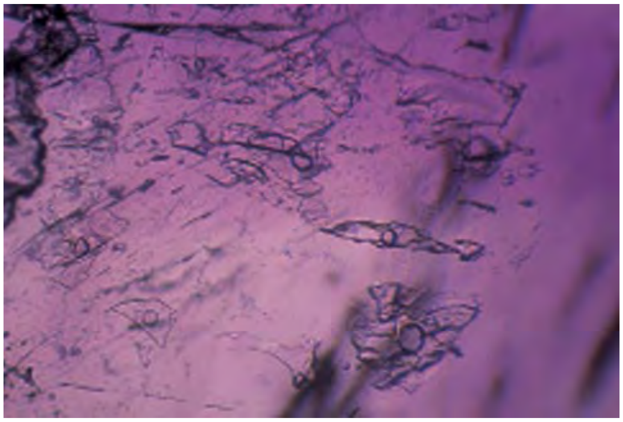

Figure 2. Primary two-phase fluid inclusions of various shapes were present in a few of the California amethyst samples examined. Photomicrograph by John I. Koivula; magnified 20×.

Green petrified wood from Arizona. At the 2004 AGTA show in Tucson, this contributor purchased a 17.81 ct sample of green petrified wood. According to the dealer, William Heher of Rare Earth Mining Co. (Trumbull, Connecticut), this rare material originates from Holbrook, Arizona. He also reported that this green petrified wood was discovered in 1991, but it has only recently become available in limited quantities. A small selection of rough and partially polished pieces were available; in the latter, one side was polished while the other retained the original form of the wood (figure 3).

The following gemological properties were obtained on the sample: color—mottled bluish green and white; diaphaneity—translucent to opaque; R.I.—1.55; S.G.—2.49, determined hydrostatically; Chelsea filter reaction—deep red; fluorescence—inert to both long- and short-wave UV radiation; transmission luminescence—moderate red; and lines in the red end of the spectrum were visible with the desk-model spectroscope. Microscopic examination revealed uneven parallel banding along its length with a somewhat cellular structure seen down the end, in addition to some fractures and cavities.

Raman analysis verified that the material was quartz, as expected for petrified wood. EDXRF spectroscopy performed by GIA Gem Laboratory senior research associate Sam Muhlmeister revealed silicon as a major constituent along with trace amounts of Cr, Ca, Ti, V, Fe, and Sr. Mr. Heher reported that this material is colored by chromium; this is supported by the Chelsea filter reaction, transmission luminescence, visible spectrum, and energy-dispersive X-ray fluorescence (EDXRF) analysis.

It may prove difficult for a novice gemologist to identify this material specifically as petrified wood if the wood-like "skin" has been removed. But the color, along with its subtle structure and gemological properties, should be enough to make a correct identification.

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A unique quartz sculpture from Peru. Quartz has the highest number of identified inclusions of any gem mineral; thus far, more than 150 minerals have been found in quartz (J. Hyrsl and G. Niedermayr, *Geheimnisvolle Welt: Einschlüsse im Quarz/Magic World: Inclusions in Quartz*, Bode Verlag, Haltern, Germany, 2003). Often, attractive inclusions can be employed to special effect in sculpted quartz *objets d'art*; perhaps the most popular example is golden rutile (variety sagenite) in rutilated quartz.

An interesting rock crystal sculpture showing creative use of an inclusion was purchased by this contributor in Lima, Peru, in January 2004. Carved in the shape of an owl with eyes of Indian ruby and a bill of Peruvian pink opal, it was 18 cm tall (figure 4). According to the seller, the sculpture was carved in Lima from a single quartz crystal mined at Pampa Blanca, near Pisco. This Peruvian locality hosts one of the world's most productive deposits of quartz crystals twinned according to the Japan law.

Figure 3. The unpolished side (left) of this 17.81 ct piece of bluish green petrified wood from Arizona retains the structure of the original wood. The polished side (right) displays only a subtle wood grain pattern. Photos by Maha Tannous.

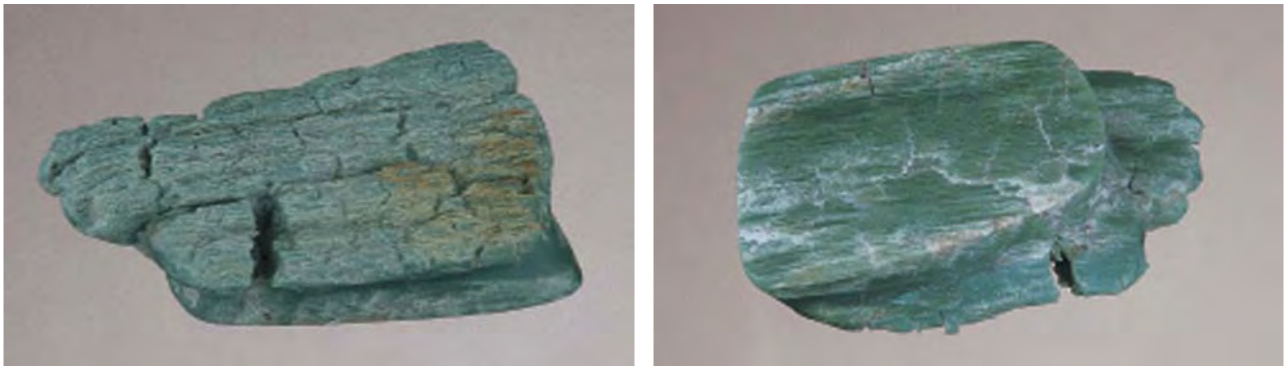

Figure 4. This rock crystal carving in the shape of an owl (18 cm tall) contains a cleverly situated pyrite inclusion, which is visible as the owl's "brain." Photo by J. Hyrsl.

The original crystal was frosted on the surface, making it impossible to view the interior, but a surprise was revealed as the carving progressed. The crystal contained a perfect lustrous pyrite octahedron 1.3 cm across, which through the skill of the artist was positioned within the owl's head to form a well-visible "brain" (again, see figure 4).

Pyrite inclusions of this size are very rare, and almost all of them are found in quartz from Brazil (usually as pyritohedrons) and from the Yuzhnyi deposit in the Ural Mountains of Russia. The combination of such an attractive inclusion with this unusual setting makes this sculpture quite unique.

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Scapolite from Mozambique. At the Tucson gem shows last February, Geofil Ltda. (Cascais, Portugal) had some rough and cut examples of scapolite from a new find in Mozambique. According to Sebastian and Pepe Rodriguez of Geofil, the scapolite was discovered in Nampula Province in October–November 2003. Approximately 2–3 kg of gem-quality rough was recovered, and stones up to 240 ct have been faceted; specimen-quality crystals also formed a significant portion of this production (figure 5).

The geology and mineralogy of the Mozambique scapolite deposits have been examined by one of us (CLG). The best occurrences are known from the northern part of the country, near the border between the Nampula and Zambézia Provinces, in the Malema District. The deposits formed along tectonic boundaries between granulite terranes and greenstone-facies metamorphic rocks, in relatively narrow areas up to several kilometers in length. The scapolite crystals occur in metasomatic stratiform bodies and intrusive veins near the contacts between granite or orthogneiss and compositionally contrasting rocks. These skarn-like rocks and desilicated pegmatites appear to be related to chemical interactions between residual granitic fluids and mafic metavolcanic-to-metacarbonate rocks. The scapolite crystals form in cavities within the coarse-grained veins, together with numerous associated minerals. The main inclusions seen in scapolite crystals are Mn-oxides, lepidocrocite, graphite, and rutile.

Figure 5. Large, transparent crystals of scapolite were recovered from Mozambique's Nampula Province in late 2003. The crystal shown here is 6.2 cm tall, and the oval brilliant weighs 180 ct. Photo © Jeff Scovil.

Since gem scapolite is somewhat resistant to weathering, the most productive deposits are eluvial. Gem-quality cordierite, aquamarine, and spessartine-almandine also are occasionally recovered from the eluvial diggings. To date, the mines have been worked by only a few local people. Recently, a well-organized Mozambique mining company has engaged in an ambitious exploration program in this area, in conjunction with geological research conducted by one of these contributors (CLG).

Gemological properties were obtained by one of us (EPQ) on a partially polished very light yellow-brown striated crystal (figure 6) that was donated to GIA by Geofil Ltda.: R.I.—1.548–1.560 (yielding a birefringence of 0.012); S.G., measured hydrostatically—2.64; fluorescence—weak pink to long-wave UV radiation, and weak red to short-wave UV; and no absorption features when examined with a desk-model spectroscope. Microscopic examination revealed a few inclusions consisting of light or dark opaque crystals with minute tension fractures; most had dislocation bundles extending toward the nearest prism face (figure 7). When the sample was viewed parallel to the c-axis, angular growth lines were evident, particularly near the edges. The properties of this stone are consistent with those listed for scapolite in general by R. Webster (*Gems*, 5th ed., revised by P. G. Read, Butterworth-Heinemann, Oxford, England, 1994, pp. 366–368). Furthermore, the R.I. and birefringence values indicate that this scapolite has a composition close to the marialite end member (see W. A. Deer et al., *Rock-forming Minerals, Vol. 4, Framework Silicates*, Longman Group, London, 1963, pp. 321–337).

Electron-microprobe analyses of two additional scapolite samples (pale yellow and brownish yellow) from this locality were performed by one of us (CLG). The results, in wt.% oxide with the pale yellow sample reported first, were as follows: SiO_2—54.00, 51.12; Al_2O_3—23.31, 24.02; CaO—12.62, 9.12; Na_2O—9.44, 7.82; K_2O—0.10, 0.51; and F—0.10, 0.33. Further chemical analysis and calculations gave Cl—2.21, 2.83; H_2O—0.45, 0.16; and CO_2—1.28, 0.56. In addition, the darker sample contained 0.30 wt.% iron (calculated as Fe_2O_3). The Ca:Na ratio of these two samples (0.84, 0.55) shows that, like the crystal section in figure 6, they have a marialite-dominant composition.

Figure 6. Gemological properties were measured on this partially polished crystal section of scapolite from Nampula Province (6.8 grams). GIA Collection no. 30603; photo by Maha Tannous.

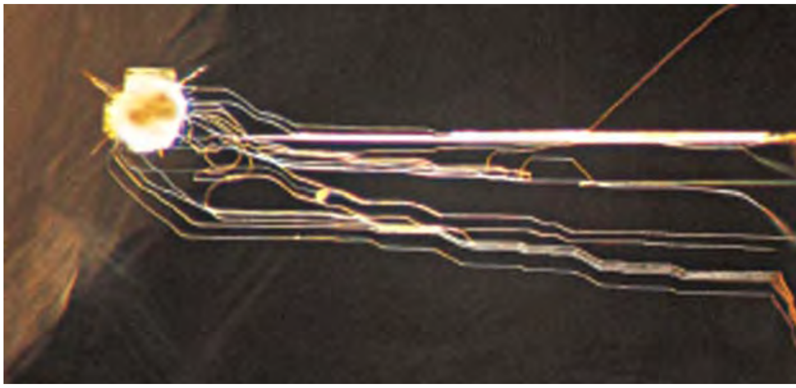

Figure 7. This light-colored inclusion in the Mozambique scapolite shown in figure 6 produced a dislocation bundle that extended toward the surface of the crystal. Subsequent etching from the surface created microscopic channels along the dislocations that are dramatically illustrated here. Photomicrograph by John I. Koivula; magnified 15×.

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BML

Update on tourmaline and other minerals from Warner Springs, California. Since 2001, some notable discoveries of gem tourmaline have occurred at the Cryo-Genie mine in the relatively little-known Warner Springs pegmatite district of San Diego County, California (see Gem News International, Winter 2001, pp. 338–339, and Winter 2002, pp. 355–356). Details on the geology and recent production were reported by A. R. Kampf et al. ("Tourmaline discovery at the Cryo-Genie mine, San Diego County, California," *Rocks & Minerals*, Vol. 78, No. 3, 2003, pp. 156–168). In addition, the Mineralogical Society of America's Pegmatite Interest Group Web site (www.minsocam.org/msa/special/pig) has archived periodic updates on the production that were submitted by mine personnel in August–November 2002, and this site also contains a recent article by J. E. Patterson on a geophysical survey of the pegmatite using ground-penetrating radar.

At last February's Tucson gem show, Dana Gochenour

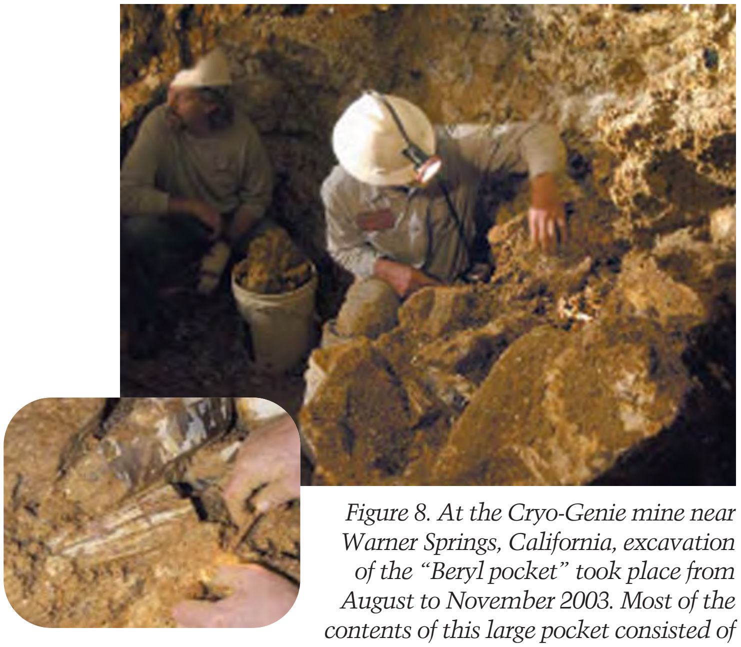


Figure 8. At the Cryo-Genie mine near Warner Springs, California, excavation of the "Beryl pocket" took place from August to November 2003. Most of the contents of this large pocket consisted of broken pieces of pegmatite and fragments of quartz and feldspar (referred to as "pocket rubble"). The inset shows how crystals of pink tourmaline and smoky quartz were carefully excavated from the surrounding sticky brown clay using a chopstick. Photos by Brendan Laurs.

Figure 9. This large beryl crystal (top, approximately 13 cm in diameter) from the Cryo-Genie mine is associated with smoky quartz and bladed aggregates of white cleavelandite feldspar. Courtesy of Gochenour's Minerals; photo by Brendan Laurs.

(Gochenour's Minerals, Tustin, California) had some cut stones and mineral specimens from these finds as well as more recent pockets. This report provides an update on these later developments—particularly the August 2003 discovery of the "Beryl pocket." This large clay-filled cavity was found on the same trend in the pegmatite as two other significant pockets (described in the previous GNI entries) that are referred to by the miners as the Big Monday and BAT pockets.

The top of the Beryl pocket was initially encountered in the floor of the underground workings, so to provide better access the mining crew drove a new tunnel around the mineralized area to intersect it from below. A smaller cavity found along the way (the New Drift pocket) contained several pink tourmaline crystals up to 15 cm long and 7.5 cm in diameter. Unfortunately, the tourmalines were extensively fractured and came out in numerous fragments. Nevertheless, many of the pieces were facetable, yielding stones up to 4.5 ct of an attractive "pure" pink color with no brown modifier.

The new tunnel reached the bottom portion of the large cavity in late August, and the miners proceeded to work the host pegmatite from around the sides so that large portions of the clay-encrusted pocket contents could be removed (figure 8). On August 29, they found a large specimen consisting of pale greenish blue beryl (approximately 13 cm in diameter), smoky quartz, and cleavelandite feldspar (figure 9). Several additional specimens containing smaller beryl crystals also were recovered. Some of the

Figure 10. The Cryo-Genie beryl (left) fluoresces greenish yellow to short-wave UV radiation (right, with a blue overtone from the lamp). Sample (3.7 cm long) donated by Gochenour's Minerals; photos by Maha Tannous.

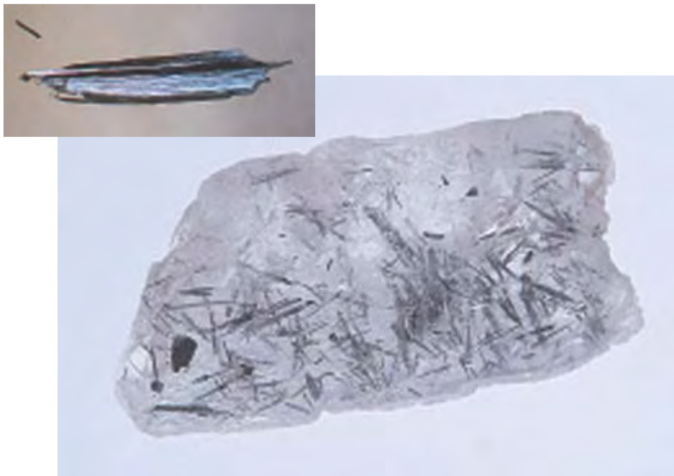


Figure 11. Metallic gray inclusions of pääkkönenite in quartz have been recovered from the Cryo-Genie mine, as shown by this sample (1.8 cm long; GIA Collection no. 30485) donated by Gochenour's Minerals; photo by Maha Tannous. The inset shows one of the inclusions in more detail; photomicrograph by John I. Koivula, magnified 10×.

specimens had small prisms of pink tourmaline that formed inclusions in—and overgrowths on—the beryl; this association of pink tourmaline with blue beryl is quite unusual. Due to its pale color and numerous inclusions, only one sample of the beryl has been faceted so far, into an 8 mm round brilliant.

A sample of beryl from this pocket was studied by Dr. George Rossman (California Institute of Technology, Pasadena), who reported that the pale blue color was caused by iron (as is typical for aquamarine) and the sample contained significant cesium. A most unusual characteristic of this beryl was its fluorescence. Although inert to long-wave UV radiation, the beryl fluoresced a moderate greenish yellow to short-wave UV (figure 10). Luminescence spectroscopy by Shane Elen of the GIA Gem Laboratory showed a predominant broad band in the green-to-yellow spectral region corresponding to the blue fluorescence, with a weaker blue-green component and a small emission band in the green region at 540 nm.

Figure 12. Tourmaline from the recent finds at the Cryo-Genie mine typically has an attractive pink color with no brown modifier. The rectangular tourmaline weighs 9.01 ct, and the stone in the ring is 2.5 ct. Courtesy of Gochenour's Minerals; photo by C. D. Mengason.

The large pocket (2.9 × 2.3 × 1.2 m) also contained a few significant crystals of pink tourmaline, as well as several matrix specimens of quartz and cleavelandite. The crystals were carefully removed from the sticky clay in the pocket using hand tools and soft digging implements such as chopsticks (see figure 8, inset). Nevertheless, most of the tourmalines had been previously fractured by natural forces, and fell apart when removed from the pocket or during cleaning.

Further mining uncovered additional pockets with pink and dark blue-violet tourmaline, as well as morganite beryl. The largest of these cavities (1.8 × 1.2 × 0.9 m), excavated in March 2004, contained a significant amount of pink tourmaline gem rough.

For inclusion enthusiasts, the Cryo-Genie mine has yielded an unusual mineral—dark gray metallic needles of pääkkönenite (Sb_2AsS_2) in quartz (figure 11). According to Kampf et al. (2003; cited above), prior to being found at the Cryo-Genie mine in two of the recent pockets, this mineral was known from just four other localities worldwide (none of them pegmatites).

As of April 2004, approximately 1,000 carats of pink tourmaline had been faceted in mostly calibrated sizes, consisting of about 500 stones of 0.5 to 5 ct, and another 500 that weighed less than 0.5 ct (mostly 3–6 mm round brilliants). The largest stone cut to date is a 25.25 ct rectangular modified brilliant. In addition, about 100 bluish green melee (3–5 mm) were faceted, and some of the pink tourmaline has been set into attractive gold jewelry (see, e.g., figure 12). *BML*

INSTRUMENTS AND TECHNIQUES

Recent U.S. patents for diamond fingerprinting methods. Ever since concerns about the use of diamonds to support armed conflicts, terrorism, and other illicit activities arose in the early 2000s, the industry has been in search of methods that would allow the tracking of individual diamonds from source to market (see, e.g., A. A. Levinson and J. E. Shigley, "White House Conference on 'conflict diamonds,'" Spring 2001 Gem News International, pp. 64–66). These typically have included marking techniques and means of recording unique internal properties or chemical characteristics. Given the potential value of a practical and reliable method of diamond "fingerprinting," it is not surprising that various individuals and groups have recently sought patents in this area.

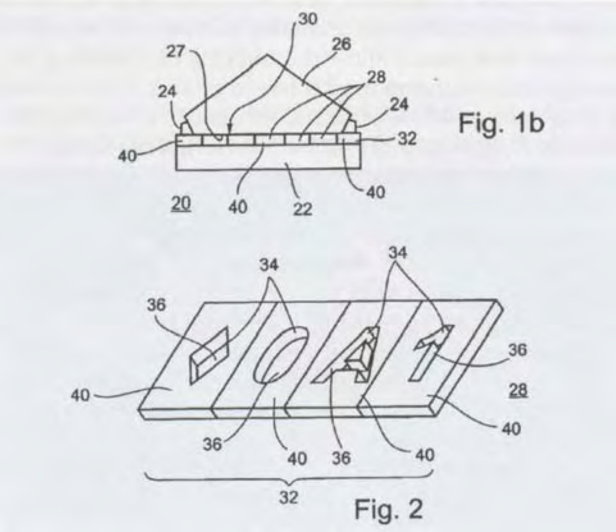
However, of the possible methods discussed at the 2001 White House Conference, U.S. patents have been issued only for those that record internal characteristics via optical examination (see, e.g., S. Redfearn, "Optics may hold key to derailing contraband diamond trade," *Optics and Photonics News*, Vol. 13, No. 2, 2002, pp. 20–22), or that mark a diamond using a laser or radioactive isotopes. No methods appear to have been patented recently in the U.S. for fingerprinting by X-ray topography (see, e.g., R. Diehl and N. Herres, "X-ray fingerprinting routine for cut diamonds," Spring 2004 *Gems & Gemology*, pp. 40–57; the technique discussed in that article has been patented in Germany), by ion implantation (see Winter 2002 Lab Notes, pp. 344–345), or by spectroscopic or chemical analysis of inclusions or coatings. Despite the attention devoted to LA-ICP-MS for diamond fingerprinting (see N. Lubick, "Fingerprinting a diamond's source," *Geotimes*, Vol. 48, No. 12, 2003, pp. 38–39; M. Resano et al., "Possibilities of laser ablation–inductively coupled plasma–mass spectrometry for diamond fingerprinting," *Journal of Analytical Atomic Spectrometry*, Vol. 18, No. 10, 2003, pp. 1238–1242), no such U.S. patents appear to have been issued.

Following is a summary of U.S. patents and patent applications for methods of diamond fingerprinting that have been awarded or published since the White House Conference in January 2001, in chronological order.

Lalit K. Aggarwal of Philadelphia, Pennsylvania, received a patent for an "automated" diamond grading device (L. Aggarwal, *Apparatus and Method for Grading, Testing, and Identifying Gemstones*, U.S. patent 6,239,867, filed December 7, 1999, issued May 29, 2001). The device records several attributes of a diamond within a computer-controlled imaging apparatus. Although intended primarily for the grading of diamonds for clarity, color, and cut, the inventors claim that the device also gathers sufficient information to fingerprint a specific gemstone based on its internal and external characteristics. The grading device, known as ImaGem, is expected to be marketed in 2004 by ImaGem Inc., also of Philadelphia, and has been the subject of several articles in the trade press (see, e.g., V. Gomelsky, "New instrument automates diamond grading," *National Jeweler*, Vol. 98, No. 2, 2004, p. 32; I. Solotaroff, "A new diamond age," *Modern Jeweler*, Vol. 102, No. 10, pp. 48–56). Once a diamond has been scanned by the ImaGem device, another instrument, known as VeriGem, can be used to identify it later by matching it to stored information. Grading a diamond with ImaGem takes about five minutes; identification with VeriGem takes approximately 20 seconds. VeriGem is currently being beta tested; ImaGem plans to release it in 2005.


Figure 14. This confocal microscope system is being used to fingerprint a diamond by recording the relative positions of its inclusions. The blue light in the center is a sample diamond being illuminated by the microscope's laser. Courtesy of University of British Columbia Bioimaging Facility.

Figure 13. This drawing taken from a recent patent by Aharon Zidon of Givatayim, Israel, demonstrates how a diamond can be marked with a unique pattern by exposure to a radioactive isotope. A mask (lower drawing) is placed between the diamond and a small amount of radium so that as the radium decays, it implants daughter isotopes in the desired pattern.



Aharon Zidon of Givatayim, Israel, has received a patent for a method of marking diamonds (and other objects) with radioactive isotopes in a specific pattern (A. Zidon, *Apparatus for and Method for Marking Objects, Objects Marked Thereby and Apparatus and Method of Reading Marked Objects*, U.S. patent 6,616,051, filed June

28, 2000, issued September 9, 2003). The pattern is applied by masking the diamond in front of a small quantity of radium such that, as it releases radioactive "daughter" isotopes (radon, lead, bismuth, and polonium) through radioactive decay, these are implanted in a precise pattern in the diamond (figure 13). The pattern is invisible except to the proper type of radiation detector, and the amount of radioactive material implanted is designed to be below regulatory limits for release of radioactivity.

A team from Lazare Kaplan International, New York, has received a patent on a new method of laser inscribing gemstones (G. R. Kaplan et al., *Microinscribed Gemstone*, U.S. patent 6,684,663, filed September 6, 2002, issued February 3, 2004). This is a patent from a "divisional application" of an earlier application for a similar method, now patented as well (an inventor files a divisional application when the patent examiner finds that the original application describes more than one invention; the divisional application extracts the extra invention into a new application). This patent describes several methods of encrypting and authenticating laser inscriptions that could be useful for diamond fingerprinting.

Recently, Malcolm Warwick of Vancouver, Canada, submitted a patent application for a method that uses confocal laser interferometry to determine the relative positions of inclusions in a diamond (M. R. Warwick, *Method and Apparatus for Identifying Gemstones*, U.S. patent application 20030223054, filed May 29, 2002, published December 4, 2003). With this method, shown in figure 14, the diamond is scanned by a laser beam and the position and orientation of inclusions are recorded in a unique profile, which can be encoded in a laser inscription on the stone's girdle (another pending patent, not yet published, covers the coding method). The process is currently being developed by Canadian Gem ID Systems, with assistance from Sirius Diamonds and the use of technical staff and facilities at the University of British Columbia, all in Vancouver.

For those interested in searching the U.S. Patent and Trademark Database (www.uspto.gov/patft/index) for future patents on this subject, some classifications that may include fingerprinting methods are given in table 1.

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TABLE 1. U.S. patent classes that may include diamond fingerprinting methods.

Fingerprinting method	Patent class
Laser inscription	63/32
Implantation of radioisotopes	235/487, 235/491
ICP-MS	250/281–282, 250/288
Ion implantation	315/111.81
Optical examination	356/30
X-ray topography	378/74

SYNTHETICS AND SIMULANTS

Colored cubic zirconia Buddha carvings. For the past few years, several types of near-colorless, yellow, and orange-to-red Buddha statues have been offered to tourists in Thailand as amber carvings (see, e.g., figure 15). Four of these statues (ranging from about 2.5 to 7 cm tall) were loaned to this contributor for examination. The carvings had rounded corners that suggested a worn appearance, as well as areas that appeared to show relics of gold foil. The indentations and depressions contained an unidentified dust-like brown material. All of these factors helped make the carvings look antique and authentic.

Although they were too large for measuring hydrostatic S.G. values with the equipment available, their heft indicated that they were probably all made of the same material, which was far too dense for amber. A detailed examination with magnification revealed no inclusions, high transparency, and homogeneous color, properties that are unlikely to be found at the same time in amber.

However, these properties were consistent with cubic zirconia. To verify this hypothesis, we analyzed two carvings (one yellow and one red) using a PGT energy-dispersive detector coupled with a Jeol 5800 scanning electron microscope in the low vacuum mode. The main elements present in both statuettes were Zr and Y, with smaller amounts of Hf, which confirmed that the material was yttrium-stabilized cubic zirconia. The red sample also contained K, Ca, and Mn.

Although such CZ Buddha carvings are not new (see Winter 1993 Lab Notes, p. 278), their representation as amber was previously unknown to this contributor.

EF

Figure 15. Buddha statues such as this one (2.5 cm tall) are being sold as amber carvings in Thailand. However, they are manufactured from cubic zirconia. Photo by Anne-Claude Couturier.

Figure 16. This strand of imitation pearls, sold as "shell pearls," proved to be Tridacna *clam shell beads with a lacquer coating. Photo by H. A. Hänni, © SSEF.*

"Shell pearls" with *Tridacna* clam shell beads. Recently, a client donated a strand of approximately 8-mm-diameter white "shell pearls" (figure 16), so that these imitation pearls could be characterized at the SSEF Swiss Gemmological Institute. "Shell pearls" typically are composed of a shell bead that is coated to resemble pearls (see, e.g., Summer 2001 Lab Notes, pp. 135–136).

Examination of the drill holes of the "shell pearls" revealed a silvery coating and a transparent top layer with radiating microcracks (figure 17). When the coating was peeled away, it was evident that the beads were composed of very white shell material showing coarse layers (figure 18). Identification of the bead material as aragonite was made by Raman analysis (peaks at 1085, 705, 207, and 153 cm^{-1}); the S.G. was measured hydrostatically as 2.83. At 10× magnification, a fine flame structure was visible (again, see figure 18). This structure differs from that of shell beads traditionally used as cultured pearl nuclei, such as those from North American freshwater mussels. However, the beads were very similar to shell material of the *Tridacna* giant clam. Scanning electron microscopy of a reference sample of *Tridacna* shell revealed an array of aragonite tiles, similar to those seen in conch shell. This fibrous structure makes the substance relatively tough and solid, a necessity for the build-up of shell material in the larger mollusks. The similarity in the microstructure to that of the beads in the imitation pearls provided additional evidence that these beads were made from *Tridacna* shell.

Tridacna shell beads reportedly have been used as nuclei in Australian cultured pearls (see Summer 2002 Gem News International, p. 179), and we also have heard rumors about their use in black Tahitian cultured pearls and Chinese Akoya cultured pearls. Since *Tridacna* clams can grow quite large, they could be a good source of white shell material for large beads. However, they are already scarce in some areas due to overharvesting, and therefore wild *Tridacna* clams should not be harvested for shell beads. Since the source of the beads used for imitation pearls is not important as long as the material approximates the weight of genuine pearls, it is really unnecessary to use *Tridacna* shell when common marble could provide usable beads with far less impact on the environment.

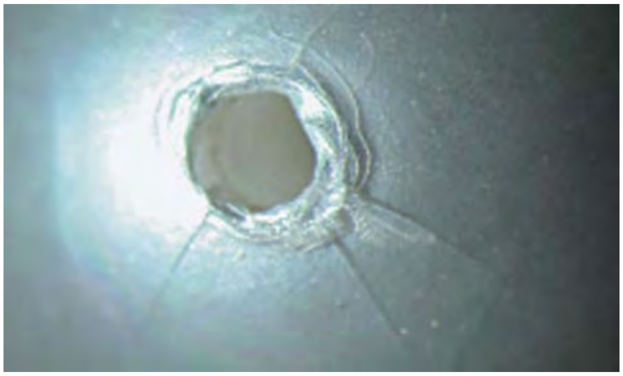

Figure 17. Around the drill hole of one of the "shell pearls," the silvery coating and a transparent top layer (with cracks) are visible. Typical for a pearl imitation are the folded layers around the hole. Photomicrograph by H. A. Hänni, © SSEF.

Regardless of the material used for the beads, we feel that the trade name "Shell Pearls" is incorrect and misleading for these imitation pearls. *HAH*

Fake tanzanite mineral specimens. As the demand increases for gem and mineral specimens, miners are often saving attractive crystals and matrix specimens, hoping for the premium that collectors might pay. However, the number of salable items is limited, because few specimens survive the rigors of blasting and transportation from remote source areas. This constricted supply, coupled with increasing demand, has fostered a thriving business in repaired specimens and also assembled fakes.

Figure 18. The "shell pearls" contained beads that consisted of coarse layers (right side) and, in some areas, showed a flame structure (left side). These features are typical of non-nacreous shell material. Photomicrograph by H. A. Hänni, © SSEF.

Figure 19. This cleverly assembled imitation of a tanzanite mineral specimen (5.5 × 3.0 × 1.0 cm) contains pieces of grayish purple tanzanite, light green diopside, and smoky quartz glued onto a matrix of calcite and graphite (left). With exposure to long-wave UV radiation (right), the glue mixture fluoresced bright white (the orangy pink areas are calcite). Photos by Maha Tannous.

On a recent buying trip to Tanzania, this contributor was presented with several assemblages that were constructed to resemble naturally occurring mineral specimens. One of these (figure 19) was created by combining many of the minerals that are naturally associated in the Merelani tanzanite deposits. This cleverly assembled imitation measured 5.5 × 3.0 × 1.0 cm, and had three grayish purple tanzanite crystals, a light green diopside crystal, and three smoky quartz fragments mounted on a base consisting of calcite and graphite. The largest tanzanite crystal was dusted with minute pyrite crystals that grew naturally on its surface. All of the crystals were attached to the matrix with a white chalky material mixed with glue. The glue was easily visible using 20× magnification, and fluoresced strongly to long-wave UV radiation (again, see figure 19).

For comparison, figure 20 shows a genuine specimen of tanzanite, with a white calcite matrix, light green diopside, and a small area of graphite. The calcite has grown naturally around the tanzanite crystal, and there was no evidence of any glue or chalky paste mixture with either magnification or exposure to long-wave UV.

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CONFERENCE REPORTS

ICNDST-9. The 9th International Conference on New Diamond Science and Technology was held March 26–29, 2004, at Waseda University in Tokyo, Japan. The conference brought together an international audience of more than 200 scientists and engineers who study the growth and physical properties of diamond and related carbon materials, as well as the potential uses of these materials for numerous electronic and other high-technology applications. Several presentations focused on topics of gemological interest.

Dr. Alan Collins of King's College, London, discussed the annealing behavior of interstitial-related optical centers in electron-irradiated type Ib synthetic diamonds. He described particular changes in visible and infrared spectral features after the synthetic diamonds were annealed at up to 500°C. The annealing behavior in nitrogen-containing synthetic diamonds was found to be more complicated

Figure 20. This genuine specimen of tanzanite (4.0 × 2.2 × 1.4 cm) showed no evidence of glue or paste material, either with magnification or when exposed to long-wave UV radiation. The associated minerals are calcite, diopside, and graphite. Photo by Maha Tannous.

Figure 21. These sapphires (the largest ones weigh 0.59 and 0.19 ct) are from a recently discovered deposit on Baffin Island in northern Canada. Courtesy of True North Gems; photo © Stephen Krasemann.

than previously thought in terms of the optical defects and how they react to heat treatment. **This contributor** discussed the gemological identification of natural, treated, and synthetic diamonds, and highlighted current challenges to this effort, such as the detection of HPHT treatment. At present, the identification of gem diamonds requires not only documentation of visual features and other aspects obtained from conventional gemological testing, but characterization using a variety of spectroscopic techniques as well. **Branko Deljanin** of EGL USA, Vancouver, Canada, discussed the diagnostic features (e.g., luminescence reactions and spectroscopic features recorded with infrared and photoluminescence techniques) of several CVD-grown synthetic diamonds produced by Apollo Diamond in Boston, Massachusetts; a subsequent presentation by **Dr. Robert Linares** of Apollo Diamond reviewed his company's efforts to produce high-quality single-crystal synthetic diamonds by a CVD process. The growth of the ICNDST conference since its inception in 1988 illustrates the greater interest in diamond as a material for use in an expanding range of products. *JES*

GAC–MAC 2004. The 49th annual joint meeting of the Geological Association of Canada and Mineralogical Association of Canada was held May 12–14, 2004, at Brock University in St. Catherines, Ontario. Although focused on the geology of the Lake Erie and Lake Ontario regions, the meeting covered a wide range of other topics. Several presentations in sessions devoted to rare-element deposits and kimberlites may be of interest to gemologists.

Dr. David London of the University of Oklahoma, Norman, discussed how increasing concentrations of "fluxing elements" (Li, F, B, and P), along with rapid crystallization rates, contribute to producing the observed vertical zonation of Na and K in feldspars and other minerals in pegmatites and mineralized granites. **Matthew Taylor** of Masaryk University, Brno, Czech Republic, and coauthors proposed a new theory on the crystallization of granitic pegmatites from sol-gel processes in magmatic melts or fluids. The gel theory provides an alternate explanation for problematic aspects of pegmatites, such as the suspension of large crystals and the formation of massive quartz cores. **Dr. Petr Černý** of the University of Manitoba, Winnipeg, and coauthors calculated the overall bulk composition of the famous Tanco rare-element pegmatite in southeastern Manitoba. These data support the derivation of this pegmatite and similar ones elsewhere by igneous fractionation from a leucogranitic magma. **Heather Neufeld** of the University of British Columbia (UBC), Vancouver, and colleagues described the geology of the Regal Ridge emerald deposit in the Finlayson Lake District of southeastern Yukon, Canada. Emeralds occur within quartz veins that intrude mid-Paleozoic metavolcanic and metaplutonic rocks. Efforts are currently under way to determine the extent of emerald mineralization at the deposit. **Dr. Lee Groat**, also of UBC, and coauthors described the deposit of green-to-blue beryl at the True Blue property in the Ketza-Seagull District, also in the southern Yukon. Beryl crystals up to 5 cm long occur in quartz veins that fill tension gashes in syenite. In a poster presentation, **Andrea Cade** of UBC and coauthors described the geology of the recently discovered occurrence of gem-quality blue sapphire (figure 21) near the community of Kimmirut on Baffin Island in northern Canada. The sapphire (along with other gem minerals such as apatite, spinel, and sphene) is found in a paleo-Proterozoic marble host rock.

In the session on kimberlites, **Christian Böhm** and colleagues from the Manitoba Geological Survey, Winnipeg, described current efforts to discover diamondiferous kimberlites in Manitoba. Although no occurrences have been reported to date, a number of geological components essential for such occurrences are present in the province, as are promising results from indicator mineral surveys. **Dale Sutherland** and coauthors from Activation Laboratories, Ancaster, Ontario, described a new exploration method that measures gas hydrocarbon compounds in soils to indicate buried kimberlites. **Shannon Hay** of the University of Alberta, Edmonton, and colleagues reported on the recent discovery of diamond-bearing kimberlite pipes on the Churchill property in the Kivalliq region of Nunavut. Evaluation is currently under way to determine their potential. **Christine Vaillancourt** of the Ontario Geological Survey, Sudbury, and coauthors discussed the discovery of millimeter-size gem diamonds in volcaniclastic breccias from northern Ontario. This is a potentially new type of commercial diamond occurrence, different from Phanerozoic kimberlites and lamproites, and hence it provides a new exploration target for diamonds in Archean greenstone belts. *JES*

ANNOUNCEMENTS

Exhibits

Pearls at the Royal Ontario Museum. "Pearls: A Natural History," a traveling exhibition tracing the natural and cultural history of pearls organized by the American Museum of Natural History (New York) in collaboration with the Field Museum (Chicago), will be on display at the Royal Ontario Museum in Toronto from September 18, 2004 to January 9, 2005. Included will be displays on pearl formation and culturing, as well as historical pearl jewelry that once belonged to Queen Victoria and Marie Antoinette. Visit www.rom.on.ca/exhibits/pearls.

Carnegie Gem & Mineral Show. On November 19–21, 2004, at the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania, this show will feature sapphires in special exhibits and invited museum displays. Visit www.carnegiemuseums.org/cmnh/minerals/gemshow.

Conferences

5th European Conference on Mineralogy and Spectroscopy. On September 4–8, 2004, at the University of Vienna, Austria, this meeting will be held in conjunction with the *6th European Mineralogical Union School on Spectroscopic Methods in Mineralogy*, which takes place from August 30 to September 8. Students will gain exposure to optical (UV-Vis-NIR) and luminescence spectroscopy, vibrational spectroscopy (Raman and infrared), Mössbauer spectroscopy, nuclear magnetic resonance spectroscopy (NMR), and X-ray absorption spectroscopy (XANES and EXAFS). Visit www.univie.ac.at/Mineralogie/ECMS2004 and www.univie.ac.at/Mineralogie/EMU_School.

Gems of Pacific continental margins. The International Association on the Genesis of Ore Deposits will host a symposium titled "Gemstone Deposits on Continental Margins" at the Interim IAGOD Conference on Metallogeny of the Pacific Northwest: Tectonics, Magmatism & Metallogeny of Active Continental Margins. The conference will take place September 11–19, 2004, in Vladivostok, Russia. Visit www.fegi.ru/IAGOD.

Diamond 2004. A review of the latest scientific and technological aspects of natural and synthetic diamond (as well as related materials) will take place at the 15th European Conference on Diamond, Diamond-like Materials, Carbon Nanotubes, Nitrides & Silicon Carbide, September 12–17, in Riva del Garda, Italy. Visit www.diamond-conference.com.

ICAM 2004 in Brazil. The 2004 International Congress on Applied Mineralogy will be held in Águas de Lindóa, Brazil, September 19–22, and will include a special session on gem materials. Pre- and post-conference field trips will tour colored stone and diamond deposits in the Ouro Preto and Diamantina areas, as well as agate and amethyst mines in Rio Grande do Sul State. Visit www.icam2004.org.

Hong Kong Jewellery & Watch Fair. Held at the Hong Kong Convention and Exhibition Centre on September 19–22, this show will host GIA GemFest Asia 2004 on September 20. This free educational event, titled "Update on GIA's Diamond Cut Research," will take place from 9:30 to 11:30 am in Room 301B of the Hong Kong Convention and Exhibition Centre; RSVP to events@gia.edu or giahk@netvigator.com, or call 760-603-4205 in the U.S. or 852-2303-0075 in Hong Kong. The Fair will also host an educational seminar given by the Gemmological Association of Hong Kong on September 21, in addition to several jewelry design competitions. Visit www.jewellerynetasia.com/exhibitions.

Rapaport International Diamond Conference 2004. On October 12, 2004, this conference will take place in New York and feature an insider's look at the international diamond and jewelry industry. Visit www.diamonds.net/conference.

CGA Gemmology Conference 2004. The Canadian Gemmological Association is holding its annual conference at the Terminal City Club in Vancouver on October 22–24. The theme of the conference will be "Seasons over Time." Visit www.gemconference2004.com.

Pegmatites at GSA. A topical session titled "Granitic Pegmatites: Recent Advances in Mineralogy, Petrology, and Understanding" will be held at the annual meeting of the Geological Society of America in Denver, Colorado, November 7–10, 2004. The meeting will also feature a session covering advanced mineral characterization methods. Visit www.geosociety.org/meetings/2004.

Antwerp Diamond Conference. The 3rd Antwerp Diamond Conference, presented by the Antwerp Diamond High Council (HRD), will take place in Antwerp on November 15–16, 2004. The conference will focus on synthetic diamonds, as well as strategies to promote consumer confidence in natural diamonds. Visit www.hrd.be/newscenter/newscenter/hrd_news/article.aspx?iNewsItemID=47.

ERRATUM

The herderite entry in the Spring 2004 Lab Notes (pp. 61–62) contained an error in one of the references. The reference for Leavens et al. (1978) should have been:

P. B. Leavens et al., "Compositional and refractive index variations of the herderite–hydroxyl-herderite series," *American Mineralogist*, Vol. 63, No. 9–10, 1978, pp. 913–917.

We thank John S. White for bringing this to our attention.

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Book **REVIEWS**

2004

Secrets of the Gem Trade: The Connoisseur's Guide to Precious Gemstones

*By Richard W. Wise, 274 pp., illus., publ. by Brunswick House Press, Lenox, MA, 2003. US$79.95**

Capturing the essence of what it takes to be a gem trader in today's world of ubiquitous gem treatments, synthetics, and new sources is a formidable task. Richard Wise has "lifted the veil" to uncover many aspects of gem trading, while holding back just enough to leave the reader yearning for more. Mr. Wise's enthusiasm for gemology, extensive travel to gem localities, and numerous publications have given him the expertise to share and explain many secrets of this venerable profession.

Part I (Chapters 1–7) introduces various elements of becoming a gem connoisseur, while Part II (Chapters 8–43) provides an overview of commonly traded gems. Each of the gems covered in Part II is given a brief history and introduction followed by detailed information on color, clarity, and cut, as well as a special section on the gem's rarity factor. When applicable, "crystal" (the author's preferred term for transparency), texture, and even heat-enhancement information is included.

The first chapter offers a historical look at the instinctual human attraction to gems for adornment, as religious and status symbols, and for their medicinal and talismanic properties. This perspective creates a logical basis for understanding the reverence for gems that persists today. Mr. Wise shows how gem connoisseurs can combine modern scientific knowledge with historical facts and lore. He discounts today's irreverent use of the term *semiprecious* by suggesting that the real connoisseur should focus on beauty and rarity. Also, the factors of supply and demand vs. apparent and actual rarity are clearly explained and supported with well-chosen examples.

In a chapter titled "Rethinking the Four C's," the author introduces his view that the fourth C (carat weight) should be replaced with "crystal." Though Mr. Wise makes a valid point, he provides no clear parameters for how this term could be applied to various degrees of "crystal quality." It would seem to be more useful as a subcategory of clarity and transparency.

Mr. Wise does, however, do an exceptional job of addressing cut, clarity, and color. He explains the evolution of cutting styles and how modern gemological research has established that there can be more than one "ideal" cut. By clearly defining the color language terms of *hue*, *tone*, and *saturation*, Mr. Wise successfully communicates how these terms, along with their modifiers, can be applied to describe subtle differences in colored gems. In Chapter 4, he presents a clear explanation of color science and the need for proper viewing conditions. Throughout the book, Mr. Wise provides his ideal hue, tone, and saturation percentages for each of the gems featured. This information can be extremely useful when communicating the quality of a particular gem variety.

In Chapter 5, Mr. Wise focuses on the unique grading skills required for judging phenomenal stones, fancy-color diamonds, and pearls. The next chapter briefly covers gem enhancements, while Chapter 7 focuses on new sources from Africa, Brazil, North America, and Australia.

The detailed information in Part II is provided for gems ranging from alexandrite to tanzanite to spinel. Beryl, garnet, pearls, and corundum are particularly well covered. Though a well-deserved tribute because of its historical significance and recent popularity, the agate chapter, placed after alexandrite and amethyst, seems out of place. Later, Mr. Wise skillfully recreates the feeling of actually being present when a pearl farmer inserts the nucleus into a mollusk or when a miner's efforts are rewarded with a colorful gem crystal. This entire section is filled with fascinating anecdotes and additional information on the relative value of gems based on quality, size, color, clarity, and rarity.

The excellent choice and placement of photos is a visual delight, although I was disappointed that carat weight was not included for many of the images. Also, there are some typos and misspellings, such as "Moguk" throughout the chapter on ruby. However, footnotes at the bottom of almost every page provide additional pertinent information for those interested in learning more.

I highly recommend this book to students wishing to supplement their gemological studies with practical gem value and trade knowledge. Collectors and other gem enthusiasts will find many helpful bits of information to assist in their gem purchases while navigating the path to becoming a true gem connoisseur.

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**This book is available for purchase through the GIA Bookstore, 5345 Armada Drive, Carlsbad, CA 92008. Telephone: (800) 421-7250, ext. 4200; outside the U.S. (760) 603-4200. Fax: (760) 603-4266.*

The Gem Hunter: True Adventures of an American in Afghanistan

*By Gary W. Bowersox, 505 pp., illus., publ. by Geovision, Inc., Honolulu, HI, 2004. US$29.95**

Written as a companion book to the author's 2002 video travelogue (reviewed in the Spring 2002 *G&G*, p. 113), *The Gem Hunter* chronicles Gary Bowersox's life as a gem merchant, starting with his youth in Michigan and his military experience in Vietnam, continuing into his beginnings in business and his eventual path to Afghanistan.

But this is more than just the exciting memoirs of an intrepid wanderer. Throughout the book, he returns to the concept of "*The Great Game*—the complex geo-political scramble among the powerful and the developing countries . . ." Mr. Bowersox does not mince words in his criticism of U.S. foreign policy in central Asia in the 1980s through September 11, 2001, and he writes passionately from his sneakers-on-the-ground perspective of what was happening vs. what he believes should have been happening.

Each of the author's many journeys over the mountains and passes between Pakistan and Afghanistan seems to be more harrowing than the last, as he relates his encounters with the many dangers in that harsh, unforgiving part of the world. With the help and guidance of loyal and resourceful Pakistani and Afghan friends, he somehow overcomes one obstacle after another. Upon arriving in Afghanistan at the midpoint of each trip, dodging bullets, bombs, and missiles becomes a constant routine.

In 1976, the Afghan government granted Mr. Bowersox exclusive rights to export lapis lazuli to the United States. Drawing on these early contacts, from 1980 through 2002 he held a series of eight gemological symposia at various sites in the U.S. and Pakistan in an effort to open the world's eyes to the full gemological potential of Afghanistan.

With future business in mind, but not without some altruism for this war-torn nation and its people, Bowersox's *raison d'être* has become the training of gem miners and the exploration and mapping of Afghan gem deposits—emeralds of the Panjshir Valley; rubies of Jegdalek; tourmaline, aquamarine, and kunzite of Nuristan; lapis lazuli of Sar-e-Sang; and spinels of Kuh-i-Lal. Sadly, the book's last entry, from April of 2003, speaks of this proposal being lost in the bureaucracy of the newly forming government.

Illustrated with over 200 black-and-white photographs and 50 maps and drawings, this work is a singular reference on Afghan gems. Extensive appendices include a glossary of proper names, a bibliography, a chronology of Afghan historical and political information, and GPS coordinates for over 1,200 gem and mineral localities.

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Gem and Ornamental Materials of Organic Origin

*By Maggie Campbell Pedersen, 268 pp., illus., publ. by Elsevier Butterworth-Heinemann, 2004. US$54.95**

Organic materials were undoubtedly the first to be used for personal adornment in prehistoric times. Forty-one tiny shells with holes for stringing, dating to more than 75,000 years ago, were recently found in South Africa. However, very little information on the properties and identification methods for organic materials has been published. This new book is the most comprehensive, in-depth, and scientific examination of these materials to date.

Organic gem materials cannot be positively identified with the usual gemological equipment, which is perhaps why these materials are given short shrift in gemology classes. As the author writes in her introductory notes, "'Observation' is the key to identifying organics. . . . Occasionally feel and even smell can help with their identification." Having taught hands-on seminars on the subject since 1990, I can attest to the accuracy of Ms. Pedersen's statements about sensory tests. She goes on to describe—and give warnings about—some potentially destructive tests, such as the hot-point (which can be very destructive indeed) and UV radiation (which is more destructive to the tester than the material). She also mentions the importance of testing several different specimens and then comparing the results.

Overall, the book is very well organized. A chapter is devoted to each material or related materials (such as amber and copal), including jet, ivory, bone, antler, horn, tortoiseshell, pearl, shell, and coral, as well as some lesser-known "miscellaneous organics." A separate chapter covers organic imitations made with a variety of plastics. Each chapter is divided into subtopics: structure and properties; species (for animal products) or varieties; treatments and uses; simulants; tests and identification; conservation status (and availability); and past and present uses. Strict attention to this format leads to some redundancy, but the structure does make it easier to find specific information. The appendices of "Quick Reference Charts" for look-alike materials and the Glossary are also helpful.

I commend Ms. Pedersen for accurately distinguishing between vulcanite (hard vulcanized rubber) and gutta percha (a different type of tree resin), but I am mystified by her omission of the simplest and least destructive test for vulcanite: simply rubbing it with the thumb. The friction will cause the material to give off the unmistakable sulfuric odor of vulcanized rubber.

The book is well illustrated by the author, who is a professional photographer, although some photos are better than others at illustrating a material's properties. The limitations of two-dimensional photos and verbal descriptions, however detailed, are a reminder that there is really no substitute for hands-on examination and sensory experience. Nevertheless, gemologists and jewelry historians should find this book informative and useful.

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Gemological **ABSTRACTS**

2004

COLORED STONES AND ORGANIC MATERIALS

Culturing abalone half-pearls: The story of the New Zealand Eyris Blue Pearl. P. Hutchins, *Australian Gemmologist*, Vol. 22, No. 1, 2004, pp. 10–20.

The Eyris Blue Pearl Co. is producing cultured abalone half-pearls from the New Zealand paua (*Haliotis iris*) which, Ms. Hutchins states, possesses the most brilliant coloration of any of the world's 130 abalone species. The company has farms in five different localities in isolated areas around New Zealand to guard against the decimation of any one year's harvest by natural disasters.

Wild paua that grow naturally in New Zealand waters are ideal for culturing pearls and have a healthy genetic diversity. Sea-Right Investments Ltd., the parent company of Eyris Blue Pearl, collects an annual quota of 23 tons of wild paua and a portion of this is designated for pearl culture. The paua selected for this purpose must be healthy and at least 125–135 mm in shell length (~4–5 years old).

From one to four beads are implanted in each abalone, depending on its size. A minimum of 36 months is needed to culture half-pearls 9–15 mm in diameter. During captivity, the abalone are kept in specially designed black polyethylene barrels that help regulate their diet and protect against predators. Fluctuations in water temperature will affect the ultimate color of the cultured pearl. Once harvested, several manufacturing steps are necessary to transform the cultured blister pearls within the abalone shell into a saleable product. Each Eyris pearl is accompanied by a certificate stating the name of the diver, the date and area where the abalone was harvested, and the size and quality of the cultured pearl.

JEC

Recent studies on inky black omphacite jade, a new variety of pyroxene jade. C. M. Ou Yang, J. Q. Li, H. Li, and B. Kwok, *Journal of Gemmology*, Vol. 28, No. 6, 2003, pp. 337–344.

A dark green to black "jade" has recently become common in the Hong Kong and Chinese gem markets, where it is sold (and misrepresented) under the name "inky jadeite jade." It is usually cut in saddle-shaped cabochons or carved into Guanyin or Buddha figures. The rough can be bought at jade auctions in Yangon, Myanmar, typically as smooth pebbles, which suggests an alluvial source; the exact geographic origin is not reported. Although this material has been available for about 20 years, it has not previously been characterized gemologically.

In general, the material has a fibroblastic texture, a relatively good transparency, and consists of >85% omphacite (like jadeite, a member of the pyroxene group) with minor amounts of jadeite, kosmochlor, opaque metal oxides, and specks of either graphite or a black organic material. The R.I. and S.G. values of this omphacite are slightly higher than those of jadeite. Two similar materials, black amphibole "jade" and black serpentine, can easily be separated by their S.G. and R.I. values. Although small amounts of omphacite are commonly found near the rims of jadeite grains in jadeite jade, this is the first description of an almost monomineralic decorative rock composed of omphacite.

WMM

Tourmaline discovery at the Cryo-Genie mine, San Diego County, California. A. R. Kampf, K. Gochenour, and J. Clanin, *Rocks & Minerals*, Vol. 78, No. 3, 2003, pp. 156–168.

The Cryo-Genie mine is located in north-central San Diego County, ~3.5 km north-northwest of the town of Warner Springs. This is the southernmost mine in what is called the Chihuahua Valley pegmatite district. As is the case with most other gem pegmatites in San Diego and neighboring Riverside County, this occurrence was first worked for tourmaline and other pegmatite minerals in the early 1900s. Limited mining has continued at the site on an intermittent basis since that time. This article describes the results over the past three years of exploiting the deposit on a more extensive basis.

The Cryo-Genie dike is a complex, internally zoned granitic pegmatite that averages 2 m in thickness and can be traced along strike for more than 200 m. Principal minerals include albite, microcline, quartz, biotite, muscovite, lepidolite, almandine-spessartine, amblygonite-montebrasite, beryl (mainly morganite), and tourmaline (both schorl and elbaite). Accessory phases include apatite, cookeite, and ferrocolumbite, plus other less common minerals. The authors provide a well-illustrated chronicle of recent discoveries, which in October 2001 included a gem pocket measuring 1.8 × 1.5 × 0.9 m. This cavity yielded pink tourmaline crystals ranging up to 25 cm long and 10 cm wide. Mining has continued since that time with discoveries of additional gem pockets.

JES

Trace elements in quartz—A combined electron microprobe, secondary ion mass spectrometry, laser-ablation ICP-MS, and cathodoluminescence study. A. Müller, M. Wiedenbeck, A. M. Van den Kerkhof, A. Kronz, and K. Simon, *European Journal of Mineralogy*, Vol. 15, 2003, pp. 747–763.

Detailed analyses of quartz samples from several petrologic environments (magmatic and hydrothermal), using various techniques, provided data on certain trace elements (Li, Al, Ti, Na, K, and Fe) commonly found in this mineral. The highest precision for a wide range of elements at low parts per million (ppm) levels was obtained by SIMS analysis, but this was offset by the lack of a high-quality quartz reference sample for calibrating the technique. LA-ICP-MS gave only average trace-element values for zoned quartz samples due to the relatively large sampling volume required. Because of the better spatial resolution in conjunction with the ability to combine spot analyses with cathodoluminescence images, the authors suggested that the electron microprobe provides the most reliable *in situ* method for obtaining quantitative data for trace-element concentrations above a few tens of ppm and from a small sampling volume (<10 μm).

The authors found a positive correlation of higher Ti contents with stronger blue cathodoluminescence in the samples they examined, although no suggestion was made that this luminescence was caused by Ti. There was a correlation in the abundances of Li, K, and Na. There was a clear but weaker correlation between Li and K, and both Al and Fe; these observations fit with the general assumption that Li^+ and K^+ act as charge compensators for Al^{3+} and Fe^{3+}. The correlation of Na and Al was less pronounced. Ti showed little correlation with Al, and no correlation with the other trace elements. The authors discussed the locations in the quartz atomic structure where these trace elements could be accommodated.

JES

DIAMONDS

Alluvial diamond—The start of an industry. G. Boxer, *Rough Diamond Review*, No. 2, September 2003, pp. 23–27.

On all continents, the first discoveries of diamonds were in alluvial deposits, usually as a result of prospecting for gold. Until kimberlites were found in South Africa in the late 1860s, alluvial diamond deposits were the only known source of this gem. Currently, alluvial diamonds account for 20% of the world's production by weight and 30% by value. Diamonds become concentrated in alluvial deposits after weathering from a primary host rock. As diamond has a relatively high specific gravity (S.G. = 3.5) compared to most other minerals, it and other heavy minerals (e.g., gold) preferentially settle, and become concentrated, in river beds while the lighter minerals are removed by flowing water. The main factors governing the concentration of diamonds and other heavy minerals into economic alluvial deposits are water velocity and turbulence, river bed morphology, degree of particle sorting, and reworking.

Alluvial diamonds may be found hundreds of miles downstream from their primary source. Although there is a reduction in average size with increasing distance from the source, the diamond value invariably increases as poor-quality stones disintegrate with distance. Diamond grades (typically 0.01–0.1 carat per tonne) encountered in alluvial deposits are low compared to those in primary deposits, but they still can be economic because of the relatively high value of the diamonds. *MWF*

Epochs of diamond placer formation in the Precambrian and Phanerozoic. A. A. Konstantinovskii, *Lithology and Mineral Resources*, Vol. 38, No. 6, 2003, pp. 530–546.

Alluvial placer deposits represent important sources of gem diamonds in various parts of the world. In most cases they are *paleoplacers*, or mineral deposits formed in sedimentary environments in the distant geologic past. Based on a survey of world occurrences, the author identifies seven main epochs of diamond placer formation, including three in the Early Precambrian, two in the Late Precambrian, one in the Middle-Late Paleozoic, and one in the Early Mesozoic. The geologic settings of the main diamond placer deposits for each of these epochs are then briefly discussed. Since kimberlites are the major source of diamonds, the author suggests that these epochs of placer formation followed periods of more intense kimberlite volcanism through geologic history.

JES

Etching of diamond crystals in the system silicate melt—C–O–H–S fluid under a high pressure. V. M. Sonin, E. I. Zhimulev, A. I. Chepurov, V. P. Afanas'ev, and A. A. Tomilenko, *Geochemistry International*, Vol. 41, No. 7, 2003, pp. 688–693.

The common occurrence of various geometric features on the surfaces of natural diamond crystals (e.g., trigons and other markings) has led to the widely held idea that their formation is the result of crystal growth and/or chemical etching. This article reports on experiments to study the etching of diamond crystals in a silicate melt in the presence of a C-O-H-S fluid at a pressure of 3.0 GPa and a temperature of 1,300°C for up to 30 minutes. A variety of macro- and micro-morphological features (e.g., pits, striations, and rounded crystal surfaces and edges) were produced on the partially dissolved crystals; they corresponded to etch features observed on natural diamonds recovered from kimberlites. The authors conclude by speculating on the role of sulfur in the etching fluid to create some of the morphological features. *JES*

Invisible coatings affect diamond recovery. S. Cooper, *Rough Diamond Review*, No. 2, September 2003, p. 47.

Although grease tables are used around the world to separate diamonds from kimberlite heavy-mineral concentrates, they have recently been shown to be ineffective in recovering diamonds that are encapsulated in a hard, thin coating. This came to light when a South African kimberlite was being sampled, and the recovered diamond grade was much lower than expected. During this recovery, a large diamond fell into the waste chute, bypassing the grease table. Scanning electron microscopy showed the presence of a thin coating that was invisible to the naked eye. The coating, ranging from 50 to 300 microns thick and totally enveloping the diamond, was found to contain Fe, Ca, Al, Si, Ti, and P. The Ca content was particularly high and unrelated to the other elements, suggesting the presence of calcium carbonate. The coating evidently remained intact during the scrubbing process that liberates diamonds from the ore.

While rough diamonds normally have a high aversion to being wetted, and a strong attraction to grease tables, coated diamonds can be wetted easily. If such coatings are common on diamonds within a kimberlite, and grease tables are the sole means of recovery, then an apparent low diamond grade within that kimberlite may simply be the result of unsuitable recovery techniques.

MT

As luzes secretas dos diamantes [The secret lights of diamonds]. R. Schultz-Güttler and J. L. Brusa, *Diamond News*, No. 16, 2003, pp. 5–9 [in Portuguese].

This article briefly describes the mechanisms behind luminescence, fluorescence, and phosphorescence in diamonds. It explains the role of trace elements, valence transfer, crystal lattice defects, and color centers. A list of properties that cause fluorescence colors is presented. Several photographs illustrate the coloration of diamonds in daylight and when exposed to UV radiation. As only basic knowledge of physics is required, the article provides a good introduction to this topic for the nontechnical reader. *RT*

One hundred years of digging. E. Blauer, *New York Diamonds*, Vol. 76, May 2003, pp. 61–66.

The illustrious Premier diamond mine in South Africa has just celebrated its centennial year of operation with special events and memorabilia (e.g., colorful coffee-table books). The mine was purchased by Thomas Cullinan in 1902 for £52,000, and production began in 1903. In its first year, it produced more than 100,000 carats of rough. In a little less than two years, the 3,106 ct Cullinan diamond was discovered. De Beers began buying shares in the Premier mine shortly after production started, ultimately gaining complete control, and operated it as an open-pit mine until its closure in 1932. After World War II, the Premier was reopened as an underground mine.

The Premier mine's fame comes from its production of at least 300 diamonds weighing more than 100 ct, as well as a quarter of all the diamonds in the world weighing over 400 ct; further, it is the primary source of type IIb blue diamonds. Since 1903, it has produced ~120 million carats (Mct) of all colors. Although a very old mine, the Premier still produces 1.7 Mct annually. Modernization (including a new recovery plant) is expected to extend the mine life until 2020. A cutting factory that employs 125 cutters from the Sotho, Zulu, and Tswana tribes operates at the Premier site, working with rough up to 3 ct. [*Editor's note:* To commemorate the mine's 100th anniversary, in November 2003 De Beers renamed the Premier mine the Cullinan Diamond mine.]

MT

Spectroscopic 2D-tomography: Residual pressure and strain around mineral inclusions in diamonds. L. Nasdala, F. E. Brenker, J. Glinnemann, W. Hofmeister, T. Gasparik, J. W. Harris, T. Stachel, and I. Reese, *European Journal of Mineralogy*, Vol. 15, No. 6, 2003, pp. 931–935.

High-pressure mineral inclusions in three diamonds (one from the Kankan district, Guinea, and two from the Panda kimberlite, Ekati diamond mines, Canada) have been studied using an *in situ* point-by-point mapping technique with a confocal Raman system. The mineralogy of the inclusions (Ca-silicates, coesite, and graphite), their distribution patterns (e.g., of the various Ca-silicate phases), and their order-disorder distribution patterns (e.g., for graphite/disordered carbon) were determined. Raman mapping of the host diamonds yielded 2D-tomographic pressure and strain distribution patterns and gave information on the residual pressures of specific inclusions (~2.3 GPa for coesite and ~2.6 GPa for graphite). The inclusions were surrounded by haloes of significantly enhanced pressure that were several hundred microns across. These haloes exhibited complex pressure-relaxation patterns consisting of micro-areas affected by both compressive and dilative strain, the latter being intensive enough to result in apparent "negative pressures."

RAH

The timing of kimberlite magmatism in North America: Implications for global kimberlite genesis and diamond exploration. L. M. Heaman, B. A. Kjarsgaard, and R. A. Creaser, *Lithos*, Vol. 71, 2003, pp. 153–184.

Four broad kimberlite emplacement patterns have been recognized in North America, based on age determinations using U-Pb (in perovskite and zircon) and Rb-Sr (in phlogopite) data gathered from the existing literature. These provinces run roughly north-south and include: (1) a northeast Eocambrian/Cambrian Labrador Sea province; (2) an eastern Jurassic province; (3) a Cretaceous central corridor; and (4) a western mixed kimberlite province. Ten new age determinations were obtained from the western mixed province to better constrain emplacement histories for the Slave and Wyoming cratons. Four periods of kimberlitic activity have been found to exist in the Slave craton of Canada, and two periods of activity have been identified in the State Line field of Colorado/Wyoming.

The kimberlite age data from the literature, along with the new North American age data, were used to better associate kimberlite emplacement with global tectonic activity. The majority of the world's kimberlite pipes were generated during increased mantle-plume activity associated with the rifting and break up of the supercontinent Gondwana. One of the surprises in the timing of kimberlite magmatism is the absence of activity between about 250 and 360 million years ago. This approximately 110 My period of quiescence is linked to the relative crustal and mantle stability that occurred during the existence of Gondwana.

Several clearly discrete periods of economic diamond-bearing kimberlite activity have taken place worldwide. For both North America and southern Africa, the two most prominent periods are the Cambrian and Tertiary. The important diamond-bearing kimberlites in Yakutia, Russia, were emplaced during the Devonian period.

Eric Fritz

Vacancy-type defects in brown diamonds investigated by positron annihilation. V. Avalos and S. Dannefaer, *Physica B*, Vol. 340–342, 2003, pp. 76–79.

Brown coloration is common in diamonds. Optical measurements have linked it to a broad, featureless absorption band centered at 477 nm in type Ia/Ib diamond, and to a gradually decreasing absorption extending from less than 400 to about 600 nm in type IIa diamond. Regions of high dislocation density are believed to be the origin of the brown color on the basis of an observed spatial correlation between this coloration and dislocation slip bands.

Five natural type IIa diamonds, ranging from light to darkish brown, were HPHT-treated to colorless in order to investigate the cause of the brown coloration using the positron annihilation technique. Before treatment, the diamonds were found to contain a significant number of trapped monovacancy-type defects, as well as clusters of approximately 20 monovacancies. HPHT processing removed the brown color and reduced the number of vacancies in the clusters by half. These vacancy clusters are associated with regions of strong plastic deformation in type IIa diamond, which in turn indicates that these regions give rise to the brown color.

JES

WHALES and RAVENS to recover diamonds. *SA Mining*, August 2003, p. 21.

De Beers Technical Support Services, based in Johannesburg, provides research and development for the company's mining operations. It is currently developing WHALE and RAVEN, two new methods to improve the efficiency of diamond recovery.

WHALE (Wet, Heavy, And Large Extraction) is a diamond sorting machine designed to recover large (25–75 mm) diamonds following the primary crushing stage. The stones are recovered in free fall after an X-ray luminescence signal activates a high-pressure air ejector. RAVEN (Raman, Value Engineered), a machine utilizing laser technology based on Raman principles, is used for the final recovery of diamonds (8 mm or less) from the X-ray concentrate. This technology is highly selective in identifying diamonds by their unique molecular structure. As with WHALE, diamonds recovered by RAVEN are ejected by pulses of air.

Technical Support Services, in collaboration with De Beers Marine, is also conducting research on methods to improve the efficiency of diamond extraction from the seabed. Tools that suck up diamondiferous gravel are being optimized, and new methods for mapping the seabed topography and geology are being developed.

MT

GEM LOCALITIES

Age of pegmatites from eastern Brazil and implications of mica intergrowths on cooling rates and age calculations. R. R. Viana, I. Mänttäri, H. Kunst, and H. Jordt-Evangelista, *Journal of South American Earth Sciences*, Vol. 16, No. 6, 2003, pp. 493–501.

The Eastern Brazilian Pegmatite Province (EBPP) is one of the largest producers of colored gem minerals such as alexandrite, aquamarine, kunzite, tourmaline, and topaz. It covers an area of approximately 800 × 150 km in eastern Minas Gerais State, and extends into portions of the neighboring states of Bahia, Espírito Santo, and Rio de Janeiro. The authors report U-Pb and K-Ar age dating of selected minerals from different types of granitic pegmatites in the northern region of the EBPP.

Dating of monazite and zircon from a non-gem pegmatite with simple mineralogy gave U-Pb ages of about 498 My, which is interpreted as the time of pegmatite crystallization during the post-tectonic late magmatic stage of the Brasiliano–Pan-African orogeny (650–480 My). Dating of zoned mica crystals from beryl-bearing pegmatites gave K-Ar ages of about 498 My for muscovite rims and about 485 My for biotite cores; these post-crystallization ages are interpreted as the time of cooling to 400 and 350°C, respectively. From this age difference of 13 My, a mean cooling rate of 3.3°C/My was calculated. This suggests that it took 60 My for the beryl-bearing pegmatites and surrounding country rock to cool from 600°C (the approximate crystallization temperature of the pegmatite) to 400°C (the K-Ar "closure temperature" of muscovite). The crystallization age of the beryl pegmatites was therefore about 560 My, which corresponds to the late-tectonic main stage of granitic magmatism of the Brasiliano–Pan-African orogeny.

JES

Al-rich diopside in alluvial ruby and corundum-bearing xenoliths, Australian and SE Asian basalt fields. F. L. Sutherland, R. R. Coenraads, D. Schwarz, L. R. Raynor, B. J. Barron, and G. B. Webb, *Mineralogical Magazine*, Vol. 67, No. 4, 2003, pp. 717–732.

This study was undertaken to get a better understanding of the conditions under which rubies found in palaeodrainage deposits along the Cudgegong-Macquarie river system in central eastern New South Wales, Australia, originally formed. Sixty gem samples collected along the two drainages were investigated to document their mineralogical and chemical properties, as well as their inclusions. The rubies had up to 0.6 wt.% Cr_2O_3 and up to 0.5 wt.% Fe_2O_3, and contained syngenetic inclusions such as Al-rich diopside (with up to 21 wt.% Al_2O_3), scapolite (meionite), and anatase. Associated sapphires had up to 0.8 wt.% Fe_2O_3, with one sample containing an unusual nepheline-anorthoclase inclusion.

The chemical composition of the rubies contrasts with that of other Mesozoic-Cenozoic basalt-associated corundum deposits in Australia, suggesting they originated from a different eruptive source. However, their composition is similar to that of rubies from the eastern Thailand basalt fields (but not from other occurrences in southeast Asia), which are thought to have a metamorphic origin deep within the earth. It is suggested that the rubies formed at temperatures between 1,000 and 1,300°C, which are high equilibration temperatures for proposed lithospheric granulite sources. Further work will be required to definitively establish the geologic source for the Cudgegong-Macquarie ruby suite.

JES

Chemical fingerprinting of some East African gem rubies by laser ablation ICP-MS. A. H. Rankin, J. Greenwood, and D. Hargreaves, *Journal of Gemmology*, Vol. 28, No. 8, 2003, pp. 473–482.

Laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS) is a sensitive technique that enables simultaneous multi-element analyses to be performed on a sample essentially nondestructively. Trace and minor elements of gem materials, determined by this and other methods, have been used successfully as indicators of both provenance and genesis. In this study, LA-ICP-MS was used to analyze rubies from two East African deposits—Chimwadzulu Hill, Malawi, and Longido, Tanzania—and to compare the results with data from other localities worldwide.

Distinctive differences were found in the Fe, Cr, and Ga contents of rubies from Chimwadzulu Hill and Longido. When plotted as Fe vs. Cr, the characteristic compositions of rubies from each deposit are particularly evident and can be used to determine geographic origin. Combined with published data from Kenyan and Madagascan rubies, the Chimwadzulu Hill and Longido samples define a broad "East African Trend" that probably reflects their similar geologic setting. When Fe_2O_3/Cr_2O_3 vs. Cr_2O_3/Ga_2O_3 plots of rubies from East Africa are compared to those obtained from other localities (e.g., Myanmar, Thailand/Cambodia), there are significant areas of overlap. In such cases, additional criteria, notably types of inclusions, would be needed to confirm any distinction between deposits that was suggested by the trace-element data.

WMM

The coloured gem potential of Baffin Island and Nunavut. P. Gertzbein, *Canadian Gemmologist*, Vol. 25, No. 1, 2004, pp. 10–17.

Nunavut, the newest (since 1999) territory in Canada, is a very large (one-fifth of the entire country), under-explored region with the potential for many types of colored stones. In recent years, exploration for colored gems has languished in favor of diamonds. However, this is changing as several companies are now actively engaged in colored stone exploration. Baffin Island, with geologic similarities to Mogok (Myanmar) and Hunza (Pakistan), is particularly favorable for the formation and preservation of gems in metamorphic rocks (i.e., marbles and schists). Gems reported to have been found there include sapphire, garnet, spinel, diopside, chrome diopside, oligoclase, tourmaline, and quartz-group minerals. In other parts of Nunavut, amber is found in coal seams on Ellesmere Island, while beryl, tourmaline, and quartz-group minerals occur in pegmatites at several locations.

The colored stone potential of Nunavut has not been thoroughly investigated, primarily because of the new territory's remoteness, lack of infrastructure, harsh climate, and short field season. Several government agencies are encouraging the development of a colored stone industry because, if done properly, it could provide great benefits to small communities. Also, the territory has a relatively large population of artistically talented people who could provide value-added activities.

AAL

The Dusi (Garba Tula) sapphire deposit, central Kenya—A unique Pan-African corundum-bearing monzonite. C. Simonet, J. L. Paquette, C. Pin, B. Lasnier, and E. Fritsch, *Journal of African Earth Sciences*, Vol. 38, No. 4, 2004, pp. 401–410.

Dusi in central Kenya is the largest and most productive primary sapphire deposit in the world. This unique deposit consists of a monzonite dike, 4–5 m thick and at least several kilometers long, composed of plagioclase and orthoclase feldspars, corundum, zircon, and Fe-mica. Gem-quality corundum occurs as euhedral, barrel-shaped crystals up to 20 cm in width that vary from dark blue to golden yellow. The transparency of the crystals is commonly compromised by cracks, polysynthetic twin planes, fluid inclusions, and two types of mineral inclusions (rutile "silk" and hexagonal platelets of an Fe-Ti-oxide mineral).

Geochemical (trace element and Sr-Nd isotope) data suggest that the monzonite is of mantle origin. Geologic data and U-Pb geochronology of zircon crystals (the only early-crystallizing inclusions found in the sapphires) show that the dike crystallized at 579±6 My and is linked to the Barsaloian episode, a major tectonothermal event in the Mozambique Belt. Similarities (e.g., in range of colors, crystal habit) exist between Dusi sapphires and corundum commonly associated with alkali basalt fields. However, there are significant differences in their inclusions; basalt-hosted sapphires contain inclusions of Nb-Ta-Ti oxides, but these have not been found in the Dusi sapphires.

Paul Johnson

Gemstone mineralization in the Palghat-Cauvery shear zone system (Karur-Kangayam belt), southern India. M. Santosh and A. S. Collins, *Gondwana Research*, Vol. 6, No. 4, 2003, pp. 911–918.

The Karur-Kangayam belt is an important gem region covering about 70 × 70 km in south-central India. Gems found in this region include beryl (aquamarine and emerald), chrysoberyl (alexandrite), corundum (ruby and sapphire), feldspar (sunstone and moonstone), garnet, iolite, quartz (rock crystal, amethyst), topaz, tourmaline, and others that occur in several different geologic settings (e.g., pegmatites, gneisses). This gem belt is situated along the southern edge of the Palghat-Cauvery shear zone system that separates several large crustal blocks of high-grade metamorphic rocks.

Many geologists believe that these crystal blocks were brought together during the final assembly of the Gondwana supercontinent in Neoproterozoic–early Cambrian times (about 750–520 My ago). They have also recognized a correlation between these Indian gem and other mineral deposits with those of similar geologic age and occurrence in Sri Lanka, Madagascar, and East Africa. During Precambrian times, these land masses all formed central terrains in Gondwana, and various geologic models have been proposed for their juxtaposition based primarily on the correlation of intracontinental shear zones. The authors suggest the existence of a Neoproterozoic–early Cambrian gem province in central Gondwana, and based on similarities between ruby deposits, they suggest a connection between the Palghat-Cauvery shear zone system in southern India and the Betsimisaraka suture zone in Madagascar.

JES

Granitic pegmatites of the O'Grady batholith, N.W.T., Canada: A case study of the evolution of the elbaite subtype of rare-element granitic pegmatite. T. S. Ercit, L. A. Groat, and R. A. Gault, *Canadian Mineralogist*, Vol. 41, 2003, pp. 117–137.

Tourmaline of pegmatite origin is an uncommon gem mineral from localities in Canada. This article describes the first find of lithium tourmaline–bearing, rare-element granitic pegmatites in the Sapper Range of the Selwyn Mountains. This site is located approximately 100 km north-northwest of the town of Tungsten in the western Northwest Territories. The article results from a study undertaken to understand the evolutionary history of these pegmatites, which occur in hornblende granites of the 94-million-year-old O'Grady batholith.

The pegmatites outcrop along a 10-km-long belt that is up to 1 km wide, with the lithium-mineralized bodies occurring along a 1-km-long section of the belt. In the vicinity of the Li mineralized zones, the thickness of the pegmatites is ~20 m (maximum 80 m). Most show simple, vertical asymmetrical zoning of feldspar, mica, quartz, and other accessory minerals (such as tourmaline, zircon, danburite, lepidolite, axinite, and rare-earth minerals). Crystal-lined miarolitic cavities in some of the pegmatites contain well-formed crystals of elbaite tourmaline. The chemical compositions of the main and accessory minerals indicate that the hornblende granites are direct precursors of the pegmatites. The article concludes with an inferred geologic history of the pegmatites as crystallization products of the O'Grady batholith.

JES

Maw-sit-sit jade from Burma: A particular jade formed by dynamic metamorphism and metasomatism. L. Qi, X. Lu, W. Liu, and Q. Ouyang, *Journal of Gems and Gemmology*, Vol. 5, No. 4, 2003, pp. 1–7 [in Chinese with English abstract].

Twenty-one representative samples of the ornamental rock maw-sit-sit from Hpakan, Myanmar, were studied using a variety of classical (e.g., petrographic microscope) and more advanced instruments and techniques (e.g., X-ray diffraction, electron microprobe, and Raman and IR spectroscopy). The main minerals identified were: chrome-jadeite (with 15–18 mol% kosmochlor), chromian eckermannite (with ~4 wt.% Cr_2O_3), albite, chromiferous albite (with ~1 wt.% Cr_2O_3), kosmochlor, and chromite. Maw-sit-sit is characterized by mylonitic, fibroblastic, pseudomorphous, and network-like textures. This jadeite-like rock probably formed by the superposition of multistage regional metamorphism and metasomatic reactions at a relatively low temperature. These results both confirm and update mineralogical and geologic data on this material in the literature. *TL*

Mineralization characteristics of gems in [the] Ailaoshan structural belt, Yunnan province. J. Zhang, C. Zhou, and C. Hu, *Journal of Gems and Gemmology*, Vol. 5, No. 3, 2003, pp. 27–30 [in Chinese with English abstract].

Yunnan Province, in southern China adjacent to Myanmar, Vietnam, Laos, and India, contains China's most important colored stone resources. Ruby, spinel, "red" beryl (actually morganite), aquamarine, topaz, and quartz occur in the 450-km-long Ailaoshan structural belt. Notable is the marble-hosted ruby and spinel mine at Xiaoyangjie, Yuanjiang County, which produces the best rubies in China. Irregularly shaped ruby crystals generally range from 2 to 10 mm, with the largest reported at >50 mm (121.6 grams). Their color varies: pinkish red (24–28%), light "rose" red (15–21%), "rose" red (46%), and dark "rose" red (10–12.5%). Cr_2O_3 contents range from 0.1 to 3% and are proportional to the intensity of the red color. Trace amounts of Fe, Ti, and Mn also are found in the rubies.

Topaz, beryl, and quartz crystals occur in pegmatites within the belt. Aquamarine and topaz come from Heishitou, while beryl and topaz are mined at Gaofengbei; both deposits are in Yuanyang County.

TL

Multi-star quartzes from Sri Lanka. K. Schmetzer and M. Glas, *Journal of Gemmology*, Vol. 28, No. 6, 2003, pp. 321–332.

Asterism, including multi-star networks, observed in 32 samples of polished quartz from Sri Lanka is described. Samples cut as cabochons or as complete spheres, in general, revealed a single six-rayed star. This asterism was caused by three sets of needle-like inclusions, at 60° to one another, that were oriented parallel to the basal plane (perpendicular to the c-axis). Multi-star quartz was observed only rarely. The most common type of multi-star network was caused by two groups (six plus three) of symmetrically equivalent sets of inclusions forming nine intersecting light bands.

On the basis of the trigonal symmetry of quartz, up to five different groups of inclusions forming 18 intersecting light bands may be present in the most complex multi-star networks. Rutile is the most common needle-like inclusion found in quartz, but sillimanite and dumortierite needles also have been identified in certain asteriated quartz. Each mineral will have a specific orientation in the host quartz and will form characteristic star networks.

The five groups of inclusions (needles) recognized by the authors were characterized in terms of (1) their crystallographic orientation with respect to the host quartz, (2) the inclination of the needle axis to the quartz c-axis, (3) the angle of light bands relative to the c-axis, and (4) the number of symmetrically equivalent sets of needles. The presence of such needles in various orientations, alone or in combination, is the ultimate cause of the numerous multi-star combinations that have been found in quartz. *MWF*

Optical spectroscopy study of variously colored gem-quality topazes from Ouro Preto, Minas Gerais, Brazil. M. N. Taran, A. N. Tarashchan, H. Rager, S. Schott, K. Schürmann, and W. Iwanuch, *Physics and Chemistry of Minerals*, Vol. 30, No. 9, 2003, pp. 546–555.

Five gem topaz samples from Brazil were studied by IR and UV-Vis spectroscopy and photoluminescence methods to better understand the causes of their coloration. Oriented, polarized absorption spectra were collected for light violet, yellowish pink, orange-red, and colorless samples from mines near Ouro Preto (and, for comparison, a deep violet Cr-bearing topaz from the Ural Mountains in Russia). The samples also were chemically analyzed by electron microprobe. Features observed in the near-infrared spectra (~750–2500 nm) appeared identical for all the samples examined, and were not related to topaz coloration.

The colors of the samples could be explained by various combinations of three sets of absorption bands in the visible and near-UV range. The first set was a pair of broad bands, centered at about 400 and 555 nm, that varied in strength according to color and were due to Cr^{3+}. The second set was the edge of a broad absorption band (centered in the UV region) that extended to various degrees into the visible region of the spectrum. Two color centers are believed to contribute to this broad band: a thermally stable center due to a charge-transfer mechanism, and a thermally unstable center of unknown structure. The third set was a pair of broad absorption bands, centered at about 417 and 525 nm, that also varied in their relative strength; they were attributed to Cr^{4+}. Thus, chromium ions participate in the coloration of all the Brazilian topaz samples studied here: pink to violet colors—Cr^{3+}, and red-orange—Cr^{4+}. The valence state of chromium can change following irradiation and thermal annealing, and therefore the authors suggest that various other ions (O^{2-}, F^-, OH^-) likely also play a role in topaz coloration and the changes in this coloration brought about by laboratory treatment. *JES*

Spectroscopic study of natural gem quality "Imperial"-topazes from Ouro Preto, Brazil. S. Schott, H. Rager, K. Schürmann, and M. Taran, *European Journal of Mineralogy*, Vol. 15, No. 4, 2003, pp. 701–706.

Gem-quality colorless, "rose," yellow, pink, and violet topaz crystals from various localities in Brazil and Russia were studied to determine the cause of color in orange-red topaz from the Capão do Lana deposit, Ouro Preto, Brazil. Different colors in topaz can be caused by color centers, color-inducing ions (chromophores), or a combination of both. Electron microprobe analyses, optical absorption spectra, and electron paramagnetic resonance (EPR) measurements were obtained. It was found that the orange-red color is related to two electron centers, since the EPR signals of the transition elements in the topaz were unaffected by annealing to 600°C, and the red color, upon annealing to 450°C, became light "rose" to nearly colorless. These color centers can be generated by irradiation, which suggests the occurrence of radiogenic elements in the Ouro Preto deposits containing orange-red topaz. *AI*

Oxygen isotope composition of the Denchai sapphire, Thailand: A clue to its enigmatic origin. T.-F. Yui, K. Zaw, and P. Limtrakun, *Lithos*, Vol. 67, 2003, pp. 153–161.

Basalts cover an area of about 70 km^2 in the Denchai region of northern Thailand. Gem sapphires are recovered from several alluvial placers and paleochannel deposits in this area. In such occurrences, the sapphires are often assumed to have originated from the basalts. In this study, the oxygen-isotope compositions of 15 sapphires ranged from +4.7 to +6.1‰ $\delta^{18}O$, as determined by a CO_2 laser-fluorination method. The authors suggest that these sapphires are not in oxygen isotopic equilibrium with the nearby alkali basalts; rather, they represent xenocrysts from the basalts (which contain olivine phenocrysts with lower $\delta^{18}O$ values of +4.9 to +5.1‰). Within individual sapphire crystals there are relatively homogeneous $\delta^{18}O$ values, suggesting that there was little interaction with carrier magmas during transport of the sapphires to the surface. Crustal rocks with values greater than +5.5‰ $\delta^{18}O$ may have been involved with sapphire formation. The authors postulate a hybrid-origin model for the Denchai sapphires, which involves different degrees of interactions between a fractionated partial melt from metasomatized mantle material and a lower- or mid-crust aluminum-rich rock. *JES*

Photoluminescence spectra of Tahitian cultured black pearls. W. Liu, *Journal of Gems and Gemmology*, Vol. 5, No. 2, 2003, pp. 7–10 [in Chinese with English abstract].

The photoluminescence (PL) spectra of 20 Tahitian cultured black pearls were obtained using a Raman spectrometer and then compared to the PL spectra of treated samples. Four PL bands were detected in the natural-color Tahitian samples, at 597, 619, 653, and 676 nm, together with a broad band from 700 to 890 nm. The 597 nm band is attributed to aragonite. The intensities of the bands at 619, 653, and 676 nm were proportional to the intensity of the black color, indicating that these bands are related to black pigments. Gamma-irradiated cultured black pearls, as well as dyed Chinese freshwater cultured black or gray pearls, displayed irregular PL bands depending on the dye materials and irradiation conditions, but they did not contain the three bands at 619, 653, and 676 nm. Therefore, the author concludes that these three bands are characteristic of Tahitian cultured black pearls and can be used for identification purposes. *TL*

A study on the characteristics of some opals from Turkey. F. Esenli, I. Kumbasar, V. Esenli, and S. Kirikoğlu, *Neues Jahrbuch für Mineralogie, Monatshefte*, No. 4, 2003, pp. 177–192.

The mineralogical, physical, and structural characteristics of 16 opals from eight localities in eastern Turkey were investigated. All were derived from Tertiary-age (Upper Miocene to Eocene) volcanic-sedimentary formations. Powder X-ray diffraction (XRD) data showed that seven samples consisted of opal-CT (i.e., with cristobalite and tridymite) and nine consisted of opal-CT with quartz. The tridymite content of these samples is notable.

Differences in the amount of cristobalite-tridymite, and the amount of structural disorder in the opal structures, could be estimated from the spacing and width of the 4Å band in the XRD patterns. Water content and density increased with greater amounts of opal-CT; this relationship did not hold for those samples containing quartz. The structures in the older (Eocene) samples were the most ordered. Structural differences between opals consisting solely of opal-CT and those consisting of opal-CT and quartz were attributed to diagenetic processes.

AI

Tracing the emerald origin by oxygen isotope data: The case of Sandawana, Zimbabwe. J. C. Zwann, A. Cheilletz, and B. E. Taylor, *Comptes Rendus Geoscience*, Vol. 336, No. 1, 2004, pp. 41–48.

For economic and other reasons, the geographic origin of emeralds is of interest. Given the wide range of oxygen isotopic composition found in emeralds worldwide ($\delta^{18}O$ varies between +6.2 and +24.7‰), the authors tested the hypothesis that oxygen isotopic analysis can help determine an emerald's geographic origin. They found that the $\delta^{18}O$ content of emeralds from Sandawana is relatively constant—between +6.6 and +8.0‰—and compared these results with $\delta^{18}O$ values obtained from emeralds elsewhere that are reported in the literature.

Although the $\delta^{18}O$ values of the Sandawana emeralds were among the lowest measured, they overlapped those of emeralds from deposits in Brazil, Austria, Australia, and Madagascar. Thus, oxygen isotopes alone are not sufficient to unequivocally determine the geographic origin of commercially available emeralds. However, the authors suggest that in combination with other characteristics (e.g., physical properties, inclusions, chemical composition), oxygen isotope data could be a deciding factor in determining geographic origin.

KAM

INSTRUMENTS AND TECHNIQUES

Application of synchrotron radiation X-ray topography in gemmology. X. Wu, Z. Wu, and Y. Tian, *Journal of Gems and Gemmology*, Vol. 5, No. 3, 2003, pp. 15–18 [in Chinese with English abstract].

X-ray topography is a nondestructive technique that has been used to study lattice defects (e.g., dislocations) in gem materials. However, it has the disadvantage of requiring rather long exposure times. This article presents the advantages and applications of synchrotron radiation X-ray topography, based on research done at the Beijing Synchrotron Radiation Facility of the Chinese Academy of Sciences. At this 43-m-long facility, X-ray topographs can be obtained under various diffraction conditions with high resolution (up to a few microns), using exposure times of 1–2 seconds. The rapid exposures are made possible by an intense X-ray source (about 10,000 times stronger than in X-ray diffraction instruments), the large spot size of the beam (43 × 13 mm), and special computer software.

By way of example, a diamond crystal from Liaoning, China, was shown to display radiating dislocation bundles within which the individual dislocations could not be resolved. However, based on a comparison of two topographs taken under different diffraction conditions, the space orientations of the dislocation bundles were determined. Sectional topographs of a diamond were obtained by irradiation in specific orientations. A three-dimensional topograph showing the distribution of all the defects in the specimen was constructed by combining several sectional topographs with appropriate software. "Tatami"-like structures consisting of two systems of deformation bands were also observed. Although synchrotron radiation X-ray topography has potential application to gemology, particularly for studying crystal imperfections, only a few facilities have this instrumentation and analyses are very costly. *TL*

ESR behavior and ^{13}C NMR representation of treated amber and resin. L. Qi, X. Yuan, M. Chen, and S. Lin, *Journal of Gems and Gemmology*, Vol. 5, No. 2, 2003, pp. 1–6 [in Chinese with English abstract].

Using traditional gemological methods, it is sometimes difficult to identify amber and resin that have been treated; however, this can be accomplished with techniques such as IR spectroscopy, electron spin resonance (ESR), and nuclear magnetic resonance (NMR). Using these techniques, spectra were obtained from 32 samples, including amber (from Liaoning, China), copal resin (the Netherlands), hard resin (Vietnam), heat-treated amber, pressed amber, and synthetic resins.

Natural copal resin showed three characteristic weak IR absorption bands at 3083 cm^{-1}, 1637 cm^{-1}, and 889 cm^{-1}. The C=O stretching vibration band at 1702 cm^{-1} in natural amber was shifted to 1727 cm^{-1} in treated amber. ESR spectra provide information on the spin concentration of the stable free-radical carbon functional groups in various ambers and resins. This spin concentration in hard resin was about 20 times higher than in copal resin, and about 10 times higher than in treated amber. The ^{13}C NMR spectra showed the relative contents of functional groups in the ambers and resins. The treated resins had sharper carbonyl carbon functional-group peaks than in natural amber. In certain cases, the spectra obtained by these techniques were influenced by the ages of the material as well as by post-formation environmental conditions.

TL

Optic fibre: Benefits and advanced use of fibre illumination. T. Linton, *Australia's Own Metal, Stone and Glass*, Vol. 25, Summer 2003, pp. 18–23, 44.

Examination of internal and external features in gems always presents a challenge, whether performed with a 10× loupe or a microscope. Proper lighting is crucial for such examinations, and it is now recognized that fiber-optic illumination is far superior to, and has replaced, high-intensity incandescent light sources. Fiber-optic illumination delivers bright light from a concentrated light source, through a sheathed, flexible fiber, to a point where the illumination can be used in a multitude of ways. The introduction of polymer fibers has made this type of illumination affordable, and the standard for gemologists in quality determination and grading.

Fiber-optic illumination provides distinct advantages. For example, it is very helpful for examining gems mounted in jewelry. In addition, one light source can supply many fiber extensions, so that several areas can be illuminated simultaneously. Two flexible arms placed in opposite horizontal directions can provide quasi-darkfield illumination, thus highlighting inclusions. Thin fiber lights can be inserted into the drill holes of black cultured pearls to help distinguish irradiated or dyed specimens. This equipment is also useful for detecting synthetic gems and fracture-filled diamonds, as well as for determining the best orientation to cut sapphire rough. *MT*

Pocket LED light sources for gemmologists. S. Gumpesberger, *Canadian Gemmologist*, **Part I.** Vol. 24, No. 3, 2003, pp. 94–101; **Part II.** Vol. 24, No. 4, 2003, pp. 119–126.

A light emitting diode (LED) is a semiconductor device that emits light when an electric current passes through it. LEDs are starting to replace incandescent light sources in many applications, including gemological instruments. Cool, energy efficient, long lived (~100,000 hours), and now reasonably priced, LEDs come in a variety of near-monochromatic colors, as well as white, infrared, and long-wave UV. They may be used for a variety of simple gemological observations, such as immersion/dispersion testing, crossed-filter applications, refractometry, pearl "candling," and as a portable long-wave UV source (fluorescence). This two-part article offers do-it-yourself tips (e.g., how to construct a kaleidoscope, based on a laser pointer and a translucent 35 mm film canister, to observe differences in refractive indices of transparent gemstones), product sources, and Web resources. Proper handling to avoid damage to eyesight and skin is emphasized. *DMK*

JEWELRY MANUFACTURING

Von der Steinschneidekunst. Ein Bericht über Kugeln, Ketten und Schalen [The art of gemstone carving. A report about balls, chains and dishes]. P. Prüfer, *Lapis*, Vol. 28, No. 12, 2003, pp. 33–37 [in German].

For centuries, China has produced ivory carvings containing up to 20 freely moving, nested, hollow balls. This article illustrates and describes the sophisticated carving procedure and explains the differences between these masterpieces and similar carved objects with balls of lesser artistic quality made of jade and other stones. The methods of carving chains out of a single piece of stone, as well as sets of dishes from agates and of balls within agate cubes, also are demonstrated. *RT*

JEWELRY HISTORY

Imperial coup. B. L. Scherer, *Art+Auction*, Vol. 26, No. 10, 2004, pp. 65–68.

Publisher Malcolm Forbes assembled the world's foremost private collection of Fabergé eggs—precious *objets d'art* created for the Russian imperial family during the final three decades of its reign. Early in 2004, the Forbes family announced it would sell the collection that its patriarch had assembled between 1960 and 1990. The entire collection, which included nine imperial eggs and 180 additional works of jeweler Carl Fabergé, was expected to bring over $90 million through Sotheby's New York auction house.

Then two things happened. First, a decades-long mystery of a missing "surprise" in the Renaissance Egg was solved. Family member Christopher Forbes, in reviewing the collection, found that one egg, the Resurrection Egg, was not catalogued in the imperial collection. However, he found photographic evidence that it had belonged to Empress Maria Feodorovna. Then he discovered that a description of the Renaissance Egg, given in a book of Fabergé, actually fit the Resurrection Egg. The Renaissance Egg, according to histories, had contained a "surprise"—an *objet d'art* inside—that had since disappeared. Upon reading this "mistaken" description, Forbes found that the Resurrection Egg fit neatly inside the Renaissance Egg and was, thus, the missing surprise.

Second, on February 4, Sotheby's announced that the collection would not go up for auction after all, but would be sold *in toto* to a Russian industrialist named Viktor Vekselberg (the fourth-richest man in Russia). He had approached a Russian art specialist living in Palo Alto, California, André Ruznikov, who contacted Sotheby's about selling the collection outright. Vekselberg's offer, believed to be ~$110 million, was subsequently accepted by Sotheby's and the Forbes family. *RS*

Mysteries of the Amber Room. R. Nalley, *Forbes*, Vol. 173, No. 6, March 29, 2004, pp. 48–54.

One of the enduring mysteries to emerge from World War

II is: What became of the legendary Amber Room in the Catherine Palace Museum outside St. Petersburg, Russia? The Russian government last year reopened the room, fully restored with genuine amber materials, but the event rekindled questions and speculation about the fate of the original room, constructed in 1716. The Amber Room was the third of the chambers along the Catharine Palace's Golden Corridor. The walls of the room were lined with thin sheets of amber inset with gem mosaics and topped by gilded woodwork.

In 1941, after Nazi Germany invaded the Soviet Union, museum officials packed up a number of the Catherine Palace Museum's treasures for safekeeping, but they could not dismantle the Amber Room. They attempted to disguise the treasure by covering the amber walls with wallpaper, but the room was too famous for such a ruse to work. When the Nazi armies overran the palace grounds in November 1941, they dispatched six men who worked 36 hours to dismantle the entire room, pack the contents into two dozen large wooden crates, and ship them to Germany via military freight train. The contents were reassembled in the castle museum in the German city of Knigsberg (Konigsburg; currently Kalingrad) and displayed there for over two years, until the war began turning against Hitler's troops. Although Allied bombs destroyed the Knigsberg castle in 1944, notes from its curator, Alfred Rohde, said the room's contents had been packed up again and stored. Rohde and his wife died from typhus shortly after being interrogated by Russian officials, and they never revealed the location of the Amber Room treasures. Since then, no one has been able to locate the contents of the room, though numerous theories—ranging from plausible to absurd—have been floated over the years. *RS*

JEWELRY RETAILING

Sparkler on the other hand. S. O'Laughlin, *Brandweek*, Vol. 45, No. 16, April 19, 2004, pp. 18–19.

In early 2003, the De Beers Diamond Trading Company launched a new diamond jewelry advertising campaign through its advertising agency, J. Walter Thompson (JWT). This campaign, called the "Right Hand Ring," was the first in the U.S. aimed at women's self-purchase, and was introduced after two years of study. However, in positioning the product, JWT wanted to avoid confusion with diamond jewelry products currently on the market, including cluster and cocktail rings. Thus, they developed a set of design criteria, including use of open space and "vertical" orientation (aligned parallel to the wearers' finger) that would set them apart from other pieces. Participating designers could choose from four motifs: contemporary, floral, romantic, and vintage.

JWT then worked to draw attention to the right hand rings by placing them on celebrities and the popular TV show *Sex and the City*. The agency followed this with a $5.6 million advertising campaign in upscale magazines such as *Elle*, *Condé Nast Traveler*, *Vogue*, and *Vanity Fair*. While a number of manufacturers and retailers have embraced the program, Richard Lennox, executive vice president of JWT New York, said the full success will not be evident for the next year or two because "the purchase cycle is long at every level. Many will think about it for 2–3 years." *RS*

SYNTHETICS AND SIMULANTS

First synthesis of olivine single crystal as large as 250 carats. K. Ito et al., *Journal of Crystal Growth*, Vol. 253, 2003, pp. 557–561.

A 250 ct crystal of synthetic olivine was grown using the Czochralski-pulling method, at ~1,900°C in a pure iridium crucible to minimize contamination. Natural olivine from San Carlos, Arizona, was used as a source material, in conjunction with a synthetic forsterite (Mg_2SiO_4) seed crystal. The 250 ct crystal was uniform in color, with no inclusions, voids, or zoning visible in the optical microscope. Electron-microprobe analyses showed that the crystal had a uniform composition of 97.1% forsterite and 2.9% fayalite (Fe_2SiO_4). *AI*

Identification of an impregnated quartz imitation of jade. T. L. Tan, T. S. Tay, B. L. Tan, and W. H. Tan, *Journal of Gemmology*, Vol. 28, No. 7, 2003, pp. 392–398.

Dyed and impregnated quartz is becoming increasingly prevalent as an imitation of Imperial jadeite. In some cases, identification of the quartz simulant may be difficult, especially when it has a good color or is mounted. This article reports on the study of two cabochons each of natural jadeite (A-jade), polymer-impregnated jadeite (B-jade), and dyed and impregnated quartz, to determine methods by which the simulants and the impregnated jadeites can be distinguished from Imperial jadeite.

Standard gemological testing is frequently not sufficient for identifying jade imitations. (In this study, S.G. and UV fluorescence were determined, but surprisingly no R.I. values were reported.) Energy-dispersive spectroscopy is particularly useful for testing stones set in jewelry, and could separate the impregnated quartz from the jadeites since the latter contains elements such as Na, Al, and Fe that are not major constituents of quartz. Also, ratios of C/Si and O/Si calculated using this technique were characteristic for each of the three materials. FTIR spectroscopy not only enabled the quartz to be separated from the jadeites but also provided the identification of the green polymers used for impregnation of the B-jade. *WMM*

A peek into the history of sapphire crystal growth. D. C. Harris, *Proceedings of SPIE*, Vol. 5078, 2003, pp. 1–11.

The growth of gem-quality synthetic sapphire has been achieved by the flame-fusion (Verneuil), flux, Czochralski, and floating-zone methods. However, additional techniques of growing such crystals were introduced in the 1960s, stimulated by demand from the electronics and optical industries, as well as by the need for special sizes and shapes. These are Edge-defined Film-fed Growth (EFG), the Heat Exchanger Method (HEM), and the Gradient Solidification Method (GSM).

EFG was initially developed in the U.S. (and concurrently in the Soviet Union) to produce reinforcement fibers for metal matrix composites. In this process, a molybdenum die acts as a wick to deliver molten alumina to a growing sapphire seed crystal. This crystal is suspended above the surface of a molten interface that exists between the crystal and the die. As the seed is withdrawn, liquid crystallizes near the interface, forming a crystal in the shape of the die. Dies can be of different shapes, and thus fibers, rods, tubes, sheets, and plates of synthetic sapphire can be produced.

HEM was invented in the U.S. In this method, a seed crystal is placed at the bottom of a crucible that is loaded with alumina "crackle." The furnace is evacuated and heated, melting the crackle but leaving the seed partially solid. With the rest of the furnace held at constant temperature, the flow of helium coolant to the vicinity of the seed is increased, allowing crystallization to proceed outward in three dimensions. *In situ* annealing completes production of the highest-quality synthetic sapphire boules, routinely 34 cm in diameter and weighing 65 kg.

GSM was developed in Israel. A sapphire seed crystal is placed at the bottom of an evacuated hemispheric molybdenum crucible filled with alumina. A thermal gradient is then introduced with the highest temperature at the top. The temperature is carefully lowered so that crystallization proceeds outward from the seed. This method is used to produce high-quality domes for heat-seeking missiles. *DMK*

Ultrahard diamond single crystals from chemical vapor deposition. C. Yan, H. Mao, W. Li, J. Qian, Y. Zhao, and R. J. Hemley, *Physica Status Solidi A*, Vol. 201, No. 4, 2004, pp. R25–R27.

Single-crystal synthetic diamonds up to 4.5 mm thick have been grown homoepitaxially (in the same crystallographic orientation) on a type Ib synthetic diamond substrate. A fast growth rate (50–150 μm/hour) is attained by using a microwave-plasma chemical vapor deposition (CVD) technique. Cutting and polishing of the as-grown CVD material revealed that it has higher fracture toughness than type Ib synthetic yellow and type Ia or IIa colorless natural diamonds. Annealing at high temperatures (2,000°C) and pressures (5–7 GPa) for 10 minutes produced transparent colorless material. The latter was found to be ultrahard (Vickers hardness of ~160 GPa or more) as compared to either unannealed type Ib, Ia, or IIa diamond (~90–110 GPa) or annealed type IIa diamond (~140 GPa). The authors suggest that further theoretical and experimental work is needed to understand these unprecedented mechanical properties. *JES*

Ultraviolet cathodoluminescence spectra of Chatham synthetic diamond. Y. Yang, L. Qi, and X. Yuan, *Spectroscopy and Spectral Analysis*, Vol. 23, No. 5, 2003, pp. 913–916 [in Chinese with English abstract].

A specially designed spectrometer (range 190–850 nm) was installed on an electron microprobe to enable simultaneous chemical analysis, cathodoluminescence (CL) imaging, and CL spectra to be obtained from a very small area of a specimen. With this equipment, four Chatham synthetic diamonds (two colorless and two light blue) and 30 natural diamonds from Hunan and Liaoning, China, including some that had been irradiated, were investigated. All of the Chatham samples displayed weak blue fluorescence, as well as growth-sector structures and seed crystals, characteristic of synthetic diamonds. They also showed CL peaks in the UV region at 234 and 268 nm, although with shapes and intensities (but not positions) that varied between the samples; such peaks were not found in the spectra of any of the natural or irradiated diamonds. The authors suggest that the ultraviolet CL spectra of Chatham synthetic diamonds appear characteristic and may possibly be used not only for distinguishing natural diamonds from Chatham synthetic diamonds, but also for distinguishing the Chatham product from those of other producers. *TL*

TREATMENTS

Some effects of extreme heat treatment on zircon inclusions in corundum. A. H. Rankin and W. Edwards, *Journal of Gemmology*, Vol. 28, No. 5, 2003, pp. 257–264.

Well-formed zircon inclusions in pale blue/green sapphires from Chimwadzulu Hill, Malawi, show major changes after exposure to extreme heat treatment, most notably mottling, darkening, and the development of distinctive textures. This article reports on the changes that occur and the temperature controls on their formation.

The thermal decomposition of the zircons at high temperature results in their replacement by an intergrowth of two phases. Bright blebs are composed of the monoclinic form of ZrO_2 (m-ZrO_2; baddeleyite), while dark areas consist of glasses with variable compositions within the SiO_2-Al_2O_3-ZrO_2 system. The intergrowths are due to the melting and interaction of zircon with the surrounding sapphire. They are interpreted as quench melt textures, in which case heating occurred above the eutectic (i.e., minimum melting) temperature of ~1,750°C. Identification of these quench phases and textures in zircon pseudomorphs can be useful for recognizing instances of extreme heat treatment in gem corundum. *WMM*